UNIVERSIDAD
DE MÁLAGA

DEPARTMENT OF ECONOMICS AND BUSINESS ADMINISTRATION
School of Industrial Engineering

Doctoral Thesis

PREVENTION THROUGH DESIGN (PtD) AS A MANAGEMENT TOOL IN OCCUPATIONAL RISK PREVENTION

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Málaga, 2014

Publicaciones y
Divulgación Científica
UNIVERSIDAD
DE MÁLAGA

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HACEN CONSTAR:
Que la tesis doctoral presentada por D. Antonio López Arquillos, con el título de:

"Prevention through Design (PtD) as a management tool in occupational risk prevention"

se ha desarrollado bajo nuestra dirección y reúne los requisitos necesarios para optar al grado de Doctor, por lo que autorizamos iniciar el trámite de su depósito, lectura y defensa.

Y para que así conste a los efectos oportunos, expedimos y firmamos el presente documento en Málaga, a tres de marzo de dos mil catorce.

JUAN CARLOS RUBIO ROMERO   ALISTAIR GIBB

A las tres MC de mi vida y a mi padre.
Gracias a todos por vuestro ejemplo,
paciencia y comprensión.

“La inspiración existe pero
tiene que encontrarte trabajando”

Pablo Ruiz Picasso

SECTIONS

SECTIONS

ACKNOWLEDGEMENTS

ACKNOWLEDGEMENTS

Resulta imposible expresar todo mi agradecimiento a todas las personas que me han ayudado, a lo largo de esta empresa denominada tesis doctoral, en tan solo unas líneas. Aún siendo imposible, siempre merecerá la pena intentarlo.

En primer lugar, quisiera transmitirles mi más sincero agradecimiento a mis directores de tesis.

Por un lado, a la persona que me dio la oportunidad de intentarlo, el Dr.D. Juan Carlos Rubio Romero. Sin esa oportunidad que me brindó mostrando fe en mí, este trabajo no habría sido posible. No seré yo quien descubra la valía y las capacidades de mi director, a su admirable curriculum y trayectoria profesional me remito. Gracias por compartir tus conocimientos y espíritu de perseverancia conmigo, y con todos tus colaboradores. Sin tu aliento este proyecto habría fracasado.

Por otro lado, al Professor Alistair Gibb, que me ofreció la oportunidad de trabajar bajo su tutela y me acogió como a un británico más durante mi estancia en Loughborugh (U.K). Ha sido un honor poder contar con una persona de su valía humana y profesional. Dear Alistair, it is a privilege to be your pupil. Please accept my sincere gratitude for your reviews, suggestions, and your patience.

En segundo lugar, agradecer a todos los profesionales y expertos del sector de la construcción, pertenecientes tanto a empresas constructoras como a empresas fabricantes de encofrados, por su colaboración y sus valiosas aportaciones a las distintas partes de la tesis. Sin su ayuda este trabajo no habría sido posible.

No quisiera olvidarme de compañeros como Carmen, Ana y Mario que me dieron su apoyo en labores del día a día, ni de amigos como Guillermo, Francisco, y Vicente que aún viéndolos poco siempre están ahí.

De un modo especial quisiera dar las gracias a mi familia: mis padres Antonio y Mari Carmen, mi hermana Concha y mi cuñado Jose, mis abuelos Concha, Joaquín, Esperanza y Pepe, así como mis tíos Antonio y Ángeles. Quisiera agradecer también la calidez y el cariño recibido por parte de la familia Rey-Merchán.

Por último, pero no menos importante, expresar mi más profundo agradecimiento a mi esposa Mari Carmen, cuya extraordinaria tenacidad y capacidad tanto humana como intelectual constituyen una fuente inagotable de inspiración, de la que aprender todos los días de mi vida. Gracias por todo.

A todos los que de una manera u otra han contribuido al trabajo que contiene esta Tesis, gracias de corazón.

Antonio López Arquillos

Universidad de Málaga

Málaga, 2014

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PUBLICATIONS AS GUARANTEE OF QUALITY

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The current Doctoral Thesis is based on several different scientific publications. In addition, part of the research was financed by Spanish Government [Ministry of Science and Technology] through the project named:

"Seguridad desde el diseño en las actividades de ejecución de estructuras mediante encofrados en obra"

and referenced like BIA2011-27338 in the list of approved projects in the National Plan of Research and Development. The Project is linked to the development of the thesis, because they share the majority of their objectives, methodologies, results and conclusions.

The reasons for the elaboration of the publications are the following:

- Although construction sector is especially dangerous and there are many scientific studies about the topic of construction occupational safety, updated publications such as those included in this work were not found.
- Scientific paper format spreads the main results and conclusions of the research in the scientific community without any delay. It is a guarantee of originality and novel of the discoveries when they are published.
- Papers and communications included in the thesis have been accepted or they are in a review process by journals included in the Journal Citation Report (JCR), and International Conferences. Before their acceptance and publication, they have been evaluated by different expert reviewers in several peer blind review process

The PhD candidate contributed to each scientific paper in the following ways:

- Reviewing the existing literature
- Establishing the aims of the papers
- Determining the adequate methodologies according to the researches' objectives
- Obtaining results according to the proposed methodologies
- Analyzing results from accident data or from professional surveyed
- Plotting results in tables and figures
- Discussing the results obtained
- Extracting conclusions
- Writing manuscripts in their first version

Additionally, in the case of publications based on accident analysis:

- Searching for accident data
- Changing data according to the statistics software's requirements

While in the case of publications based on professional opinion and stakeholder perception:

- Addressing the experts requirements
- Contacting with experts proposed by the supervisors, according to the requirements established
- Developing scientific questionnaires

The supervisors contributed with the design of the research, the planification and control, and the continuous reviews of all task developed during the elaboration of each publication.

Publications included in the thesis:

PAPERS PUBLISHED IN JOURNAL CITATION REPORT (JCR) JOURNALS

I. López-Arquillos, A., Rubio-Romero. JC.,& Gibb, A. (2012). Analysis of construction accidents in Spain, 2003-2008*. Journal of Safety Research*, 43(5-6), 381. http://dx.doi.org/10.1016/j.jsr.2012.07.005

II. López-Arquillos, A., Rubio-Romero. JC., Gibb, A., & Gambatese J.A. Safety risk assessment for vertical concrete formwork activities in civil engineering construction. *WORK: A Journal of Prevention, Assessment & Rehabilitation*. In press. http://dx.doi.org/10.3233/WOR-131724

COMUNICATIONS IN INTERNATIONAL CONFERENCES

III. López-Arquillos, A., Rubio-Romero, JC., Suarez-Cebador, M., & Carrillo, J. A. (2013). How safe is the civil construction sector in Spain?. Contractor´s perspective through an expert panel. *Occupational Safety and Hygiene. SHO Conference 2013.* Published in: Proceedings book of the International Symposium on Occupational Safety and Hygiene-SHO 2013. ISSN:2182-8482.

IV. López-Arquillos, A., Rubio-Romero, JC.,& Carrillo, J. A. Occupational Health and Safety (OHS) at construction projects. A perspective from formworks & falseworks companies. *Occupational Safety and Hygiene.SHO Conference 2014.*

Accepted to be published in: Proceedings book of the International Symposium on Occupational Safety and Hygiene-SHO 2014

V. López-Arquillos, A., Rubio-Romero, JC.,& Martínez-Aires, M.D. Prevention through Design (PtD) concept at university. Engineering & Architecture students´ perspective. *Occupational Safety and Hygiene.SHO Conference 2014.*
Accepted to be published in: Proceedings book of the International Symposium on Occupational Safety and Hygiene-SHO 2014

PAPERS IN A REVIEW PROCESS:

VI. Lopez-Arquillos, A., Rubio-Romero. JC.,& Gibb, A. Accident data study of concrete construction companies similarities and differences between qualified and non qualified workers in Spain. *International journal of occupational safety and ergonomics: JOSE.* Under review

VII. Lopez-Arquillos, A.,Rubio-Romero, J.C., Martinez-Aires,M.D., Prevention through Design (PtD). Performance of the concept at Engineering & Architecture university courses. *Safety Science*. Under review.

INTRODUCTION

1. INTRODUCTION.

This chapter provides a description of the motives behind the development of the present thesis dissertation in order to obtain an International PhD from the Universidad de Málaga. It also outlines the objectives and methodologies implemented.

1.1 MOTIVATION.

According to International Labour Organization data (ILO, 2013), 321,000 people die every year around the world as a consequence of a fatal occupational accident. In addition, 317 million non-fatal occupational accidents occur each year. In other words, every 15 seconds, 115 workers have an accident somewhere in the world. These alarming figures provide clear evidence that accidents at work are a serious problem worldwide.

Occupational accidents are linked to many different costs (economic, human, organisational, financial, etc). The majority of these costs are not easily quantifiable as they are indirect or hidden by other factors (Betastren-Belloví, 2001). Nonetheless, their negative impact on companies, the workforce and on society as a whole cannot be denied (Heinrich, 1959, Bird, 1975).

Occupational accidents affect all productive sectors in all countries, but construction accident rates continue to be an international cause of particular concern. This concern is justified in that in many countries the highest casualty rates are recorded in the construction sector (Eurostat, 2011, BLS, 2010, Camino *et al*., 2008).

The United States of America (USA) are a case in point, since in 2009 workers in the construction industry incurred the largest number of fatal injuries (816) of any industry in the country's private sector (Bureau of Labor Statistics, 2010). These accidents represented approximately 19% of the "all occupation" deaths from injuries in the USA.

In the original 15 EU Member States alone, about 1,300 construction workers die every year, a further 800,000 are injured, and countless more suffer work-related ill health (Eurostat, 2011).

In countries such as Spain and the United Kingdom, the rates are no better than in the US, as both countries have a higher percentage of such accidents than the US in the construction sector (Eurostat, 2011). However, there are significant differences in the submission of reports and work accident registration procedures in different countries, such as the definition of a workplace accident and the consideration of road traffic accidents (Aires, Rubio & Gibb, 2010). An example was provided by Eurostat data (Eurostat, 2010) showing accident rates in construction across the European Union in recent years reveal that incidence rates in Spain are around twice the European average, possibly partly as a result of the above-mentioned differences in procedures and definitions.

These data are a clear indication of the continuing occurrence of construction accidents and the need to find and implement efficient solutions. In order to identify such solutions, many researchers have studied the different factors that make up the problem. Contributing factors in construction accidents can be classified in three categories (Haslam *et al* 2005): immediate accident circumstances and shaping factors (worker, workteam, workplace, materials and equipment, etc) and originating influences (construction design and process, project management, risk management, etc). Originating influences, especially inadequacies with risk management, were considered to have been present in almost all (94%) of the accidents.

Prevention through Design (PtD) constitutes one of the most important tools for risk management in construction projects from the outset. The influence of the PtD concept in improving occupational health and safety levels in the construction sector has been studied by authors such as Gambatese (1997), Behm (2005) or Fadier (2006). If PtD is adequately implemented, safety risks can be designed-out during the design phase of the construction project. Theoretically, if the design were perfect, no hazards and risks would exist during the construction. However, at present the design for safety techniques in the construction sector are not sufficiently developed, and construction sites tend to employ other safety management techniques. Despite the proven worth of the PtD concept, it is all too often implemented incorrectly in construction projects.

In addition to the cited reasons for developing the current research, the author has a particular interest in issues related to occupational health and safety. During his engineering degree he designed his academic curriculum selecting subjects related to occupational health and safety, such as Industrial Safety or Quality Management. On completion of his degree he enrolled in a training program to become a qualified “Occupational Health & Safety Consultant” in the three fields of prevention: Safety, Hygiene and Psychosocial Ergonomics. After the positive experience of all his OHS training, in 2010 he was accepted to undertake an Occupational Risk Prevention Masters Degree. During the Masters he was recruited by the “Catedra de Prevención y Responsabilidad Social Corporativa”. In his professional activity in the Cátedra de Prevención, he has participated in many OHS studies, projects and training activities. His participation in the project “Seguridad desde el diseño en las actividades de ejecución de estructuras mediante encofrados en obra" is particularly noteworthy, as this project was included in the Spanish government's National Plan of Research and Development.

It is clear that the candidate's interest and experience were two central reasons to undertake the current research.

To sum up, the motivations for the research are the following:

- The importance of occupational accidents to the economy, workforce, and quality of life in any country. Any improvement in the management of occupational health and safety issues will be considered a positive contribution.
- Accident rates are especially significant in the construction sector in Spain. In addition, this sector plays a major role in the country's development.
- Preventive measures are key factors in the improvement of workers' occupational health and safety and in their working conditions.
- The Prevention through Design (PtD) concept is often inadequately implemented in the construction sector.
- The author's interest and experience in occupational health and safety issues, especially with regard to construction topics.

1.2 RESEARCH OBJECTIVES AND METHODOLOGIES.

The above motivations provide a clear illustration of the importance of this topic. Several stakeholders are affected by OHS management of prevention: project designers, contractors, subcontractors, trade unions, etc. Statistical analysis of accidents in the workplace linked to the expert opinion of different stakeholders could therefore be most useful in identifying the main causes of such accidents and contributing to their prevention.

Having established the general research topic as the management of occupational health and safety in construction and the importance of Prevention through Design (PtD), it was proceed to explain the approach by answering the following questions:

- What are the current causes of construction accidents in Spain?
- In these accidents, which workers are more likely to suffer fatalities?
- Are there any differences between workers involved in concrete structures and other construction workers?

- What are the similarities and differences in accidents involving qualified and non-qualified workers in the construction of concrete structures?
- What are the construction companies' opinions regarding occupational safety problems in the civil construction sector in Spain?
- What are the risk levels in construction activities?
- Are construction safety risks properly assessed?
- Are hazards identified correctly during the construction of concrete structures?
- What are the main safety risks in the construction of concrete structures?
- Is the PtD concept implemented adequately in civil construction?
- Is the importance of PtD in concrete structures construction projects similar to the importance it is afforded by experts on the topic?
- How adequate is the professionals' training in PtD?
- How important is the PtD concept in university syllabi?

In line with the above questions, a global objective was defined for the thesis. Based on this global objective, certain partial aims were also defined. These partial aims were then further divided into specific goals, which together are intended to achieve the global objective.

The aims of the thesis are divided as follows:

❖ GLOBAL OBJECTIVE

To obtain an extended and updated insight into likely risks in the construction of vertical structures and the management of Occupational Health and Safety using the PtD concept.

- PARTIAL AIM
  a) To analyse construction accidents recorded in official data.
  SPECIFIC AIMS
  a.1) To assess the importance of different factors in construction accidents.
  a.2) To compare findings from an analysis of accidents in concrete construction companies in Spain and to compare the accident rates of qualified and non-qualified workers.

- PARTIAL AIM
  b) To assess the safety risk in construction activities with formworks in civil construction.

SPECIFIC AIM

b.1) To evaluate the safety risk for vertical concrete formwork activities in civil engineering construction.

- PARTIAL AIM

  c) To ascertain how design in safety during the performance of civil construction projects, including formwork activities, is perceived.

  SPECIFIC AIMS

  c.1) To determine the opinion of construction stakeholders regarding occupational safety in civil construction projects.

  c.2) To investigate the perception of safety needs in the design and use of formworks, compiling the opinions of different stakeholders in the construction sector.

- PARTIAL AIM

  d) To quantify the presence of the Prevention through Design concept in the education and training of the professionals.

  SPECIFIC AIMS

  d.1) To evaluate the integration of PtD in university syllabi.

Once these objectives have been defined, the next step is to specify the methodologies to be employed in achieving them. Current research methodologies can be classified as either quantitative objective methodologies (e.g. statistical analysis and descriptive techniques) or qualitative subjective methodologies (e.g. opinion surveys and expert panels).

The following methodologies were implemented in order to achieve each objective:

QUANTITATIVE METHODOLOGIES

A preliminary literature review was carried out into issues of occupational health and safety in civil construction. Bibliographic searches focused on topics such as accidents in construction, risks in the construction of concrete structures, PtD in the construction sector, construction research methods or integration of PtD in university courses.

Secondly, a descriptive analysis was developed based on a total of 1,163,178 accidents. The analysis design for this part of the study was based on previous research by Camino *et al*. (2008). The study variables were chosen and then categorised in groups to assess the relationship between all the variables and the severity of the outcomes of each accident. In a preliminary approach, contingency tables were elaborated by analysing all 57 variables included in the accident notification form. For some variables the majority of the values in the contingency tables did not reach a statistical significance of 95%, which would confirm their independence, and it could not be confirmed the existence of more than a random influence for severity-variable. Accordingly, the majority of the 57 variables were rejected. Finally, ten variables were chosen and the influence of each variable was evaluated with respect to the severity of the accident. Their contingency tables were drawn up and chi-square values were calculated to test the independence of each variable with respect to severity. The statistical analysis package SPSS (Statistical Package for the Social Sciences) was used to analyse the data.

Thirdly, a descriptive analysis was developed based on a total of 125,021 accidents in concrete structures construction companies. The accident rates of cited companies were compared with general rates in the construction sector. In addition, a comparison was made between qualified (white-collar) workers and non-qualified (blue-collar) workers. Again, a preliminary analysis was carried out of all variables included in the anonymous Official Workplace Incident Notification Forms and their contingency tables were elaborated. Variables were rejected whenever the majority of their values in their contingency tables did not reach statistical significance. Finally, the most statistically sound variables were selected. Contingency tables were drawn up and chi-square values were calculated to test the independence of each variable with respect to severity. The SPSS statistical analysis package was again used to analyse the data.

QUALITATIVE METHODOLOGIES

Fourthly, the methodology of staticized groups was implemented analysing twelve activities and ten safety risks which were identified and validated by experts. Every safety risk identified in this manner was quantified for each activity using binary methodology according to the frequency and severity scales developed in prior research. A panel of experts was selected according to the relevant literature on staticized groups (Hallowell and Gambatese, 2009). The authors contacted 15 construction companies and 10 universities. After a review of the background and availability of the possible candidates, 12 experts were selected from 7 large high-profile companies from the engineering construction sector and from 5 Schools of Engineering. In addition to the flexible point system requirements proposed by Hallowell and Gambatese (2009), only one expert was selected per company or per University in order to ensure diversity. As a guarantee of expertise in Safety at Work and Occupational Risk, all members of the panel had obtained a Masters Degree in Occupational Risk Prevention. Between them, the panellists have 94 years of experience in the construction sector.

Fifthly, another group of experts from eight international construction companies with activity in Spain was selected to be interviewed. A total of 25 experts were selected according to specific requirements such as experience in civil construction or academic background. These requirements were established following some of the guidelines included in the “Flexible Point System for the Qualification of Expert Panelists” proposed by Hallowell and Gambatese (2009) in their study about qualitative research in construction engineering and management. All panellists exceeded the minimum level required by this system, and can therefore be deemed experts in civil construction, safety at work and occupational risk.

Sixthly a Likert-scale survey was distributed to project designers, construction companies and manufacturing formwork companies in order to identify needs in the design phase, the construction phase and in legal issues. Since the Likert scale questionnaire has been demonstrated as a very useful tool in previous papers on occupational health and safety in construction (Ismail *et al*., 2011, Gittleman *et al*., 2011, Melia *et al*., 2008) it was considered appropriate for the present work. A total of 206 questionnaires were delivered to the selected groups of interest. Finally 160 were collected. Respondent professionals accumulate a total number of 2,122 years of experience with an average of 13.26 years of experience per professional. Of these respondents 88.1% were male and 11.9% female. It is noteworthy that 90% of the professionals had training in Health and Safety (H&S), and only 10% had no background in Health and Safety training. The questionnaires were designed to be simple and brief. They were checked previously by eight different experts on Occupational Health and Safety in Construction for suitability and quality of the questions. Suggestions of the experts about the language level, comprehensiveness or item content were included in the final version of the questionnaire. In addition, statistical tools such as median test, kruskall-wallis test, and Mann-Whitney-U were used in order to test specific hypotheses about the items.

Seventhly, a Likert-scale survey was distributed to students and lecturers from different engineering and architecture degrees in several universities in order to evaluate the integration of the PtD concept in their syllabi. With a view to obtaining the opinion of future construction professionals, 12 courses related to the design or construction of concrete structures from 8 different under/degrees at three different universities were selected (6 courses from four different Old degrees, and 6 courses from four different Bologna degrees). The selection criteria used were that the course be part of a civil or building construction under/degree and that the syllabus includes the design or construction of structures. From the selected construction courses 454 students were surveyed in-situ using a questionnaire during a lecture on theory. A total of 432 students completed correctly all of the items on the questionnaire and thus the response rate was 95%.

All methodologies briefly explained in this subsection are described in full in their relative publications included in section 5 of the current study.

1.3 RESEARCH DATA AND SOURCES.

Research data and information sources have been classified according to the UNESCO classification.

FORMAL SOURCES.

Scientific research was developed in the following data bases:

- *Bases de Datos del Consejo de Universidades.*
- *BNE (Bibliografía Nacional Española, recoge referencias de los libros*
- *CICA (Bussiness elite).*
- *Ciencia y Tecnología del CSIC.*
- *CINDOC, Catálogo de revistas.*
- *CIRBIC-Libro. Catálogo colectivo de libros del CSIC.*
- *CIRBIC-Revistas. Catálogo colectivo de revistas del CSIC.*
- *depositados en la Biblioteca Nacional. De temática multidisciplinar).*
- *EBSCOHOST.*
- *Google Scholar.*
- *ISBN. Información bibliográfica de libros editados en España.*
- *ISI web of Knowledge.*
- *ISOC. Base de datos del Instituto de Información y Documentación en Ciencias Sociales y Humanidades del CSIC. Cubre las áreas temáticas de Economía, Sociología, Ciencias Políticas, Ciencias Jurídicas, etc.*
- *PUBMED.*
- *REBIUN. Catálogo colectivo de libros y revistas de bibliotecas universitarias. − Etc.*
- *ScienceDirect.*
- *SCOPUS.*

- *TESEO. Base de datos del Ministerio de Educación y Cultura donde se encuentran todas las tesis doctorales leídas en España.*

The following journals were especially important most contain information about the current research topic:

- *Accident Analysis & Prevention.*
- *Applied Ergonomics.*
- *Capital Humano.*
- *Dyna Ingenieria e Industria.*
- *Ergonomics.*
- *Health and Safety Executive Bulletin.*
- *Health Promotion International.*
- *Human Factors.*
- *Industrial Relations Journal.*
- *Informes de la construcción.*
- *International Journal of Health Services.*
- *International Journal of occupational Safety and Ergonomics.*
- *International Labour Review.*
- *Journal of Cleaner Production.*
- *Journal of Construction Engineering and Management.*
- *Journal of Occupational Rehabilitation.*
- *Journal of Safety Research.*
- *Journal of the Institute Occupational Safety and Health.*
- *NOHSAC Technical Report.*
- *NZ Centre for SME Research.*
- *Occupational Safety and Health.*
- *Prevención.*
- *Prevención Express.*
- *Prevención, Trabajo y Salud.*
- *Professional Safety.*
- *Revista de la economía pública, social y cooperativa.*
- *Revista de la construcción.*
- *Safety Science.*
- *Work: A journal of prevention, assessment &rehabilitation, etc*

Other web sites related to occupational health and safety were of interest:

- *Instituto Andaluz de Tecnología (IAT).*

- *Instituto Nacional Americano de Normalización (ANSI).*
- *Instituto Nacional de Riesgo y Seguridad (INRS).*
- *Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT).*
- *Instituto Nacional de Salud y Seguridad Ocupacional (NIOSH).*
- *Instituto de Seguridad y Salud Británico (HSE).*
- *Observatorio Estatal de Condiciones de Trabajo (OECT).*
- *Organización Mundial de la Salud (OMS-WHO).*
- *Organización Internacional del Trabajo (OIT).*
- *Administración Americana de Seguridad y Salud (OSHA).*
- *Agencia Europea para la Seguridad y Salud en el Trabajo.*
- *Asociación Española para la Calidad (AEC).*
- *Asociación Internacional de la Seguridad Social.*
- *CIB. International Council of building.*
- *NSC. National Safety Council.*

The information obtained at the following events or conferences should also be mentioned:

- International Symposium on Occupational Safety and Hygiene-SHO2014. Guimaraes, Portugal, February 2014.
- 5ª Jornada Anual de Prevención de Riesgos Laborales y Responsabilidad Social Corporativa. Seguridad Vial y Movilidad Sostenible. April 2013.
- International Symposium on Occupational Safety and Hygiene-SHO2013. Guimaraes, Portugal, February 2013.
- 6th International Conference on Industrial Engineering and Industrial Management. Vigo. June 2012.
- 11 International Conference Occupational Risk Prevention ORP 2012. Bilbao, May 2012.
- International Symposium on Occupational Safety and Hygiene-SHO2012. Guimaraes, Portugal, February 2012.
- Tertulia-taller sobre “Investigación sobre soluciones preventivas ante el riesgo de vuelco de maquinaria”. Cátedra de Prevención y Responsabilidad Social Corporativa de la Universidad de Málaga. February 2012.
- Tertulia-taller sobre “Principales cambios en el Reglamento de los Servicios de Prevención”. Cátedra de Prevención y Responsabilidad Social Corporativa de la Universidad de Málaga. February 2010.
- Tertulia-taller sobre “Claves de la coordinación de actividades empresariales en grandes organizaciones donde se produce la concurrencia de numerosas empresas”. Cátedra de Prevención y Responsabilidad Social Corporativa de la Universidad de Málaga. February 2010.

Last but not least, the candidate's different research stays must be highlighted as important sources of information:

- Research stay at Loughborough University. June-September 2012.
- Research stay at University of Granada. April-June 2013.

STATISTICAL DATA

For this study, the Ministry of Labour and Immigration supplied the anonymous data of all workplace accidents in the Spanish construction sector as defined by the National Classification of Economic Activities in Spain (CNAE 93.Rev 1) during the period 2003-2008. A total number of 1,163,178 Notification Forms were supplied and analysed. In addition, complementary questionnaires were developed for experts in the research topic.

1.4 BACKGROUND.

From the analysis of the literature reviewed during the development of the current research, it is important to highlight the most noteworthy and significant previous research into similar topics.

Many authors have found that successful management of Occupational Health and Safety (OHS), is based on complete knowledge of the causes of accidents and incidents. (Williamson and Feyer 1998). It follows that only with a correct analysis of the causes of occupational accidents and incidents will it be possible to predict and to prevent similar events with preventive strategies (Bird, 1990, Gatfield, 1999, Thompson *et al*., 1998).

Analysis of injury rates in a specific sector could be very helpful in order to establish some guidelines in basic aspects such as safety training, equipment and working methods (Camino *et al*., 2008, Rikhardsson and Impgaard, 2004) or the distribution of shifts (Lilley *et al*., 2002).

In this sense, certain sectors and industries have been studied extensively due to their particular features, the incidence of accidents and the gravity of their consequences. The electrical sector (Cawley and Homce, 2003), mining (Sanmiquel *et al*., 2010) and construction (Cattledge *et al*.,1996; and Haslam et al., 2005) are instances of such industries.

The construction industry is known to have a relatively high occupational injury rate in Europe (Eurostat, 2011), but the problem is not limited to this continent. In the United States of America (USA), according to the Bureau of Labor and Statistics (BLS, 2010), the construction industry accounts for a disproportionate fatality rate that is nearly three times the figure for industry as a whole. In the rest of the world, accidents rates in construction fare no better (ILO, 2013). Consequently, research into occupational health and safety (OHS) management in construction is clearly a priority.

International researchers have found evidence to the effect that construction OHS management is an issue meriting particular attention. In the United Kingdom (UK), for instance, researchers have found that construction workers are five times more likely to be killed and twice as likely to suffer serious injury than the average worker (Carter and Smith, 2006).

In order to identify solutions for accidents in construction, different researchers have investigated the problem in many countries. Examples of these studies for various countries include: Taiwan (Cheng, Leu, Lin & Fan, 2010), Scotland (Cameron, Hare & Davies, 2008), Turkey (Etiler, Colak, Bicer, & Barut, 2004; Mungen and Gürcanli, 2005), Portugal (Macedo and Silva, 2005), and South Korea (Lim *et al*., 2009).

Based on previous research, it can be said that when an accident is analysed, many variables and factors are taken into account. For example a study about contributing factors in construction accidents in the UK (Haslam *et al*., 2005) concluded that problems arising from workers or the work team were present in 70% of the accidents, workplace issues in 49%, shortcomings with equipment (including PPE) in 56%, problems with suitability and condition of materials in 27% and deficiencies with risk management in 84%. Also studying the influence of different factors, another significant research work in the UK (Brace *et al*., 2009) found that the underlying factors in fatal accidents and high-potential incidents can be grouped into three categories: macro factors, relating to stakeholders such as society, education, industry, corporate organisation and trade unions; mezzo factors, referring to aspects such as project management, organisation and procurement; and micro factors, meaning worker, workplace and supervisor issues.

The next step is to consider the influence of different variables in the severity of the injuries. The impact of the variables on the frequency and severity of accidents depends on many circumstances, and it often proves difficult to evaluate all of them. Indeed, many research studies along these lines focus only on certain specific variables. For example, Sawacha, Naoum & Fong (1999) showed that operatives between the ages of 16–20 were more likely to have accidents than others. Further analysis of the data in the same paper suggests that the incidence of accidents tends to decline steadily among workers over the age of 28, reaching the lowest point among those in their mid-forties. Similarly, Salminen (2004) concluded that young workers had a higher injury rate than older workers, though the injuries of young workers were less often fatal. In addition, Chau *et al*. (2004) suggested that the workers' risk of injury depends on age, body mass index, hearing disorders, sleep disorders and sporting activities. Workers that are young, overweight, or have any hearing or sleep disorder and do no sport are at greater risk than those without these risk factors. However, it should be borne in mind that construction accidents arise from a failure in the interaction between workers, their workplace and the materials and equipment they are using (Haslam *et al*., 2003). In Spain, the most significant contribution concerning the influence of different variables in construction accidents was developed by Camino *et al*. (2008). Their findings showed that, depending on the severity of accidents, different training was needed according to age, length of service in the company, work organisation and the work period or shift .

The majority of the above-cited variables regarding workforce, company, equipment, materials or workplace conditions considered by researchers, are frequently identified and implemented by construction companies in their daily tasks in the construction phase, but safety conditions should be described earlier in the design phase of the project (Hallowell & Gambatese, 2008). The explicit consideration of construction safety issues by the designers of facilities (i.e. architects and engineers) is known as design for construction safety.

Research focused on the influence of the concept of design for construction safety also known as Prevention through Design (PtD) is especially relevant when studying accidents in civil construction. The concept was defined by the National Institute for Safety and Health (NIOSH) as:

> Addressing occupational safety and health needs in the design process to prevent or minimise the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials and equipment.

Many of the studies based on the PtD concept have concluded that a great percentage of accidents in construction could have been prevented, or their severity lessened, had occupational safety been considered in the design phase and the development of the project (HSE, 2003, Weinstein, Gambatese, & Hecker, 2005, Behm, 2005, Gambatese, Behm, Rajendran, 2008, Gibb, 2001, Haslam, 2005, Toole, 2005). Authors such as Behm (2005) and Gambatese *et al*.(2008) studied the influence of the project design on construction workers' safety. They analysed links between construction fatalities and the design for construction safety concept. In both cases their results showed that 42% of the fatalities reviewed were linked to the cited concept. The importance of PtD as a preventive tool cannot, therefore, be denied, but the question remains as to who is responsible for its correct implementation in a construction project.

Effective implementation of PtD during the construction project is not the responsibility of a single person or group. Different influence groups are involved in the health and safety of construction site employees from the commencement of the project design to its completion. Although different groups are linked to different impacts and responsibilities in the projects, their level of influence is not the only reason to investigate more than one group of interest. The performance feedback literature (Borman, 1997; Brutus *et al*., 1998; London & Wohlers, 1991) recommends that in order to acquire a better, more accurate understanding of occupational safety levels, feedback should be sought from multiple sources. It is assumed that multi-source feedback provides unique information from different perspectives, adding incremental validity to performance assessment (Borman, 1997). In this research, it was expected that feedback would vary among the different groups of interest and that each group would provide a unique perspective to improve the current situation.

Studies on groups of contractors have been conducted by such authors as Hinze & Gambatese (2003), Thomas (2005), Huang & Hinze (2006), Wang *et al*., (2006), Saurin *et al*.,(2008) or Fadier & De la Garza (2006). Their results showed that while contractors play an important role, they are not solely responsible for accidents in the workplace.

Although they are present in most civil construction works, the influence of formwork manufacturing companies on the occupational health and safety of construction sites has not been clearly established in previous research. The case of formwork manufacturing companies as a group of influence in construction projects deserves special attention. Among construction tasks, formwork activities are frequently associated with high rates of accidents and injuries. According to Huang and Hinze (2003), 5.83% of falls were attributed to the construction of formwork or to the construction of temporary structures, and around 21% of all accidents involved wood framing or formwork construction.

The influence of designers or structural engineers has been analysed by Gambatese & Hinze (1999), Behm (2005), Frijters & Swuste (2008), Gambatese *et al*. (2008) and Gangolells *et al*. (2010), among others. The methodology developed by Gangolells *et al*. (2010) is of particular interest for designers, as it allows them to compare construction techniques and systems during the design phase and determine the corresponding level of safety risk without restricting their creative talents.

In order to achieve a better understanding of this group of interest, certain specific characteristics and singularities of these professionals should be taken into account.

In Europe, architects and design engineers are required to implement design for construction safety (Directive 92/57/EEC). It would seem logical to assume that PtD should be integrated into the professionals' academic training in order to ensure its correct implementation in construction projects. Nonetheless, previous research works have not identified inclusion of the PtD concept as a legal requirement of Engineering and Architecture university syllabi. Consequently, many professionals are required to implement a concept that they may have studied only briefly, or not at all, during their training. This is only a part of a larger scale problem, since on the whole occupational safety contents are not integrated in undergraduate curricula as they should be (HSE, 2009). Similarly, some authors found that Engineering syllabi often lack courses covering occupational risk prevention. In the case of Spain, new graduates are certified in areas in which they have received little or no training, such as occupational risk prevention (Cortés *et al*., 2012). This scenario may prove difficult to change, since under/graduate curricula are already crowded (Culvenor & Else, 1997).

The literature also includes similar studies on occupational health and safety courses (OHS) at universities (Heinrich, 1956; Nolan, 1991; Grossel, 1992; Senkbeil, 1994; Phoon,1997; Hill & Nelson, 2005; Arezes & Swuste, 2012). Although PtD is a very important concept inside the OHS topic, specific studies focused on the presence of PtD in courses and attempts to quantify their impact on the design and construction of concrete structures in Engineering and Architecture programmes have not been found.

Despite the scientific value of previous research, accidents still occur. The present research work aims to contribute to the improvement of occupational health and safety levels in the construction of concrete structures by analysing accidents, collecting construction professionals' opinions and using preventive tools such as the PtD concept.

RESULTS AND DISCUSSION

2. RESULTS AND DISCUSSION.

In accordance with the previously described objectives and methodologies, the results obtained were classified in two main groups:

- Accident analysis (official statistical data).
  This group includes the results from the analysis of all accidents recorded in the Spanish construction sector from 2003-2008, as well as those from the separate analysis of concrete construction companies only. This group of results was obtained using quantitative methodologies.

- Professionals' opinion and stakeholders' perception.
  This group consists of the results obtained from the opinion and perception of different experts and professional stakeholders as reflected in interviews or questionnaires. It includes results regarding safety risk assessment in construction activities, perception of design in safety and the presence of PtD in professional training courses. Qualitative methodologies were employed to analyse this group of results.

2.1 RESULTS AND DISCUSSION BASED ON ACCIDENT ANALYSIS.

The results based on accident analysis were classified in two categories. The first consists of the results of a global analysis of Spain's construction sector, while the second is a specific analysis of accident data in concrete construction companies.

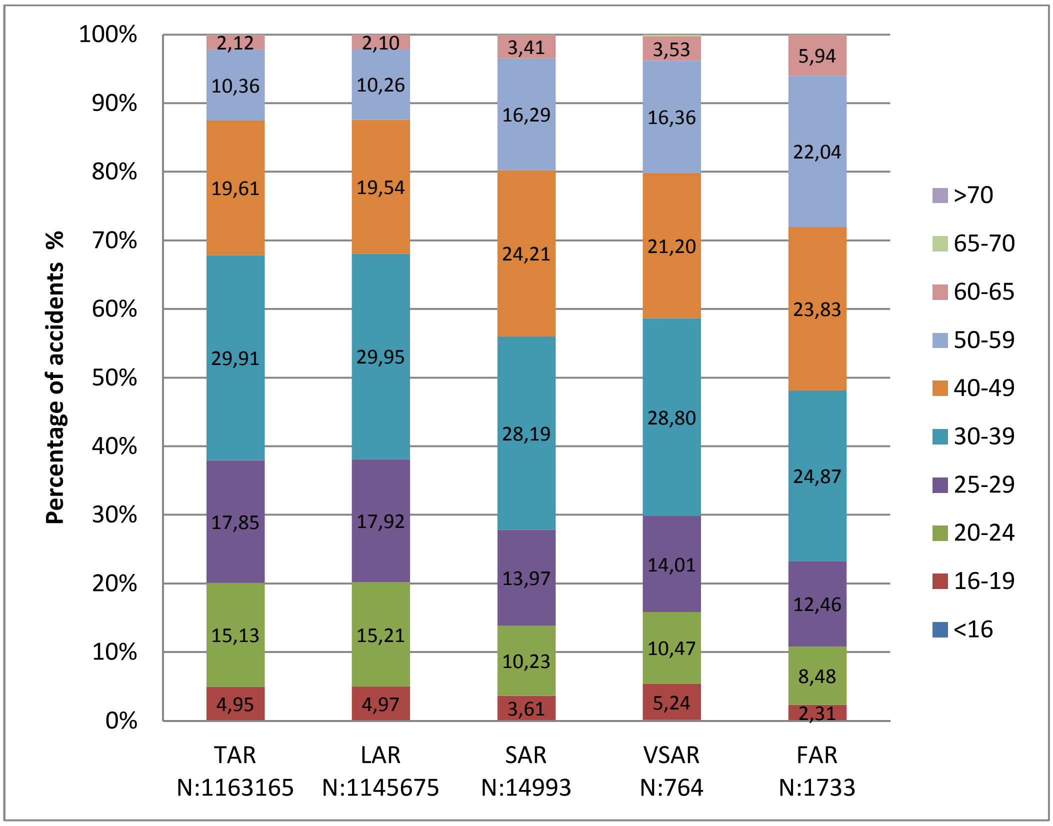
2.1.1 Results and discussion based on accidents in construction in Spain.

In the analysis of construction accidents in Spain the following groups of variables were studied:

- Personal variables describe characteristics of the worker involved in the accident. This group includes the age variable.
- Business variables describe aspects of the activity and its organisation. This group includes the following variables: National Classification of Economic Activities (CNAE), company staff, length of service and the location of the accident.
- Temporal variables include the day of the week and days of absence.
- Material variables include deviation from accepted practice, as a not expected event, and injury.
- Geographic variables reflect the severity of the accidents according to the climatic zone.

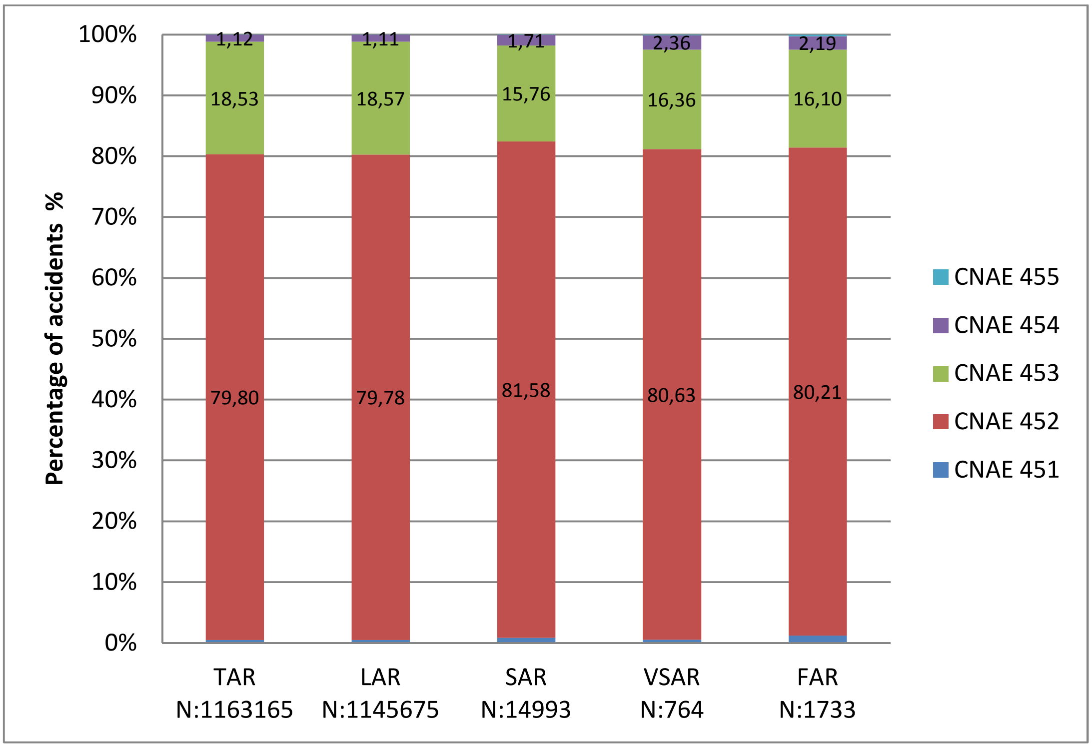
The results obtained showed that, when an accident happens, the probability that severity will be high increases with the age of the worker. This fact is especially significant in groups of ages between 60 and 65 years, and between 20 and 24 years. In the older group it was observed that light accident rate had very similar value to the total accident rate (LAR 2.10 %, TAR 2.12 %) but the fatal accident rate was more than double (FAR 5.94%). In the younger group the light accident rate and total accident rate were very similar too (LAR 15.21%, TAR 15.13%) but the fatal accident rate decreased considerably in this group (8.48 %). In figure 1, the distribution of accidents according to the age of worker and severity rates (Light Accident Rate (LAR), Serious Accident Rate (SAR), Very Serious Accident Rate (VSAR), and Fatal Accident Rate (FAR)) were showed.

Figure 1.Total accidents in Spanish construction comparing age and severity.



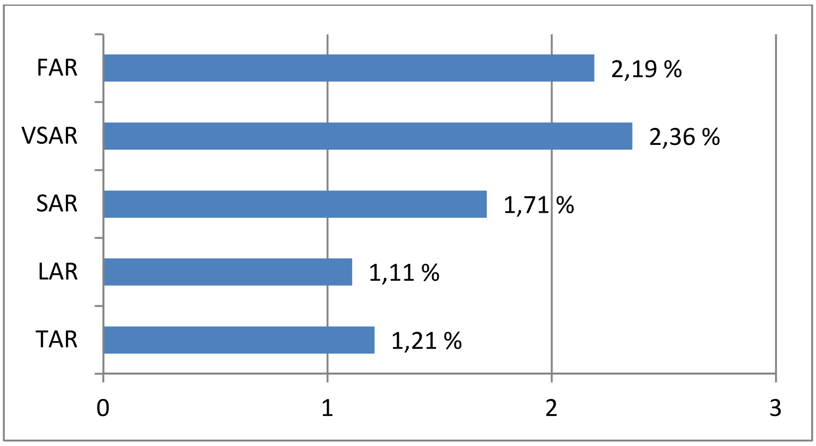
The distribution of the accidents is concentrated in activities 452 *Construction of buildings and civil construction*, and 453 *Fit out of construction works*. The incidence rates cannot be calculated because the total of workers occupied in these specific activities is not known, but we can evaluate the percentage evolution in the calculated rates.

Figure 2. Total accidents in Spanish construction comparing CNAE-code and severity.



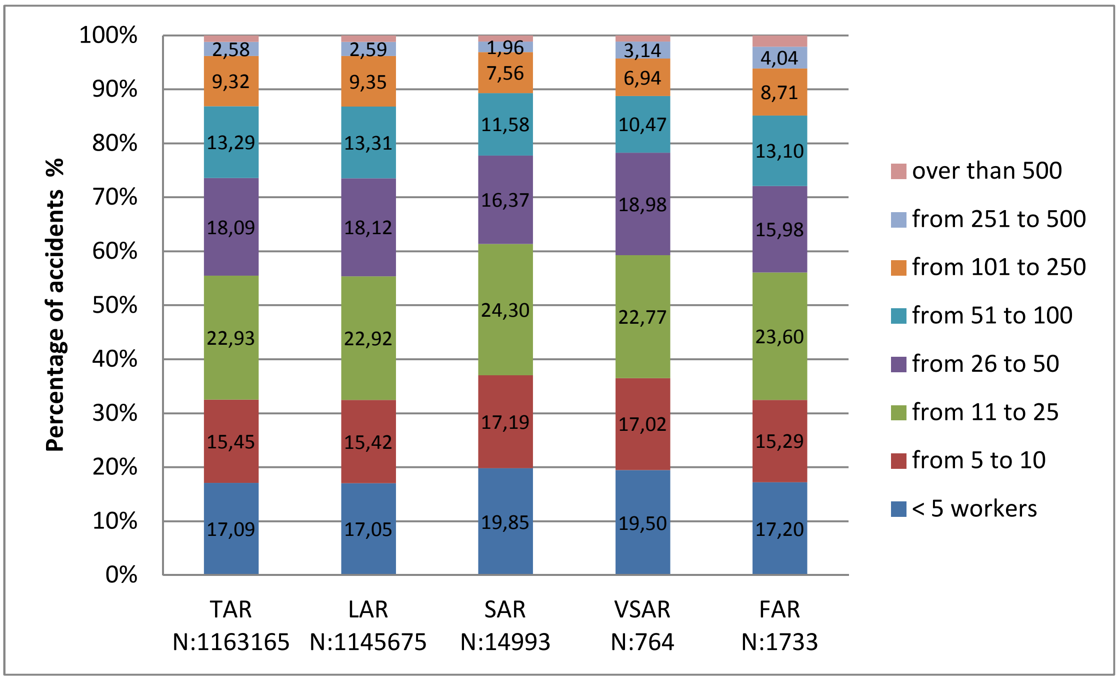
It is significant that, although activity 454 *Completion of construction works* only has 1.12% of the total accidents (TAR) in the sector, the percentage increases with the severity of the accidents (SAR (1.71%) > LAR (1.11%)) and peaks at VSAR (2.36%). The fatal rate is lower but very close (2.19%) as can be observed in Figure 3.

Figure 3. Severity rates of accidents in activity 454 Completion of construction works as a percentage of total accidents in the sector.



In relation to company size, comparing TAR and FAR, the data tend to suggest that the larger the company the more likely the chance of a fatal accident occurring.

Figure 4. Total accidents in Spanish construction comparing company staff and severity.



The percentages of fatal accidents with respect to total accidents according to company size, shown in table 1, reveal that an accident in a large company was more likely to be fatal than accident occuring in a smaller one. Companies with more than 500 workers obtained the worst result (0.2489% of accidents in the company were fatal). On the other hand, companies with 26 to 50 employees obtained the best result (0.1316% of accidents in such companies were fatal). Those with up to 250 workers obtained similar percentages, between 0.13 and 0.16 %, while for those with more than 250 workers the value was over 0.23 %.

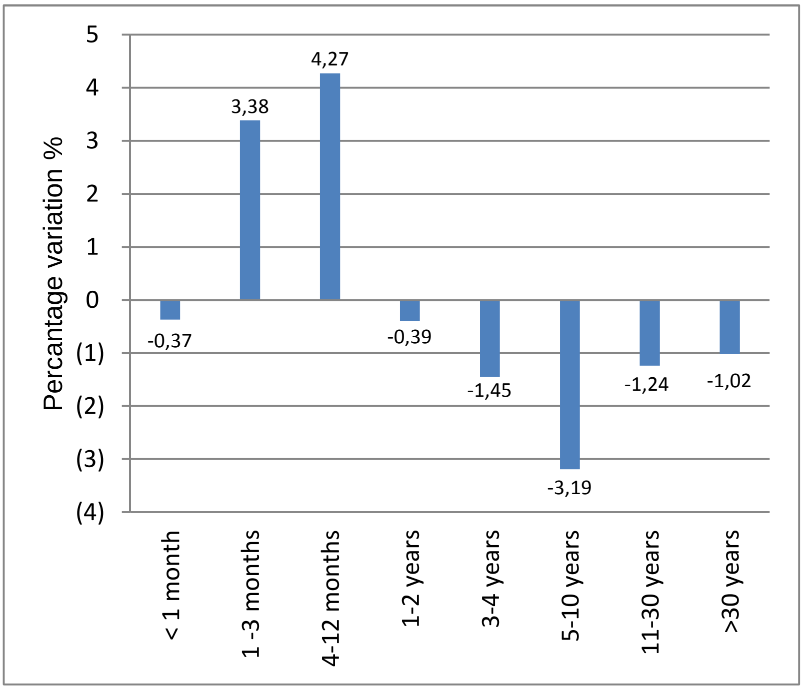
Table 1. Percentages of fatal accidents respect total accidents.

Company Staff	**Number of Total accidents (NTA)**	**Number of Fatal Accidents (NFA)**	**% (NFA/NTA)**
< 5 workers	198802	298	**0,1499**
from 5 to 10	179659	265	**0,1475**
from 11 to 25	266766	409	**0,1533**
from 26 to 50	210446	277	**0,1316**
from 51 to 100	154558	227	**0,1469**
from 101 to 250	108428	151	**0,1393**
from 251 to 500	30058	70	**0,2329**
over 500	14461	36	**0,2489**

However, these data may be misleading as they are only based on the total number of accidents that occurred and are not weighted according to the number of employees. It has been shown that a large company is associated with better safety levels than a small one (Hinze & Gambatese 2003). In this sense a study of 231 deaths in the construction industry (Buskin & Palouzzi 1987) concluded that there was a significant trend towards increasing mortality with decreasing company size in the proportionate mortality ratios (PMRs) studied.

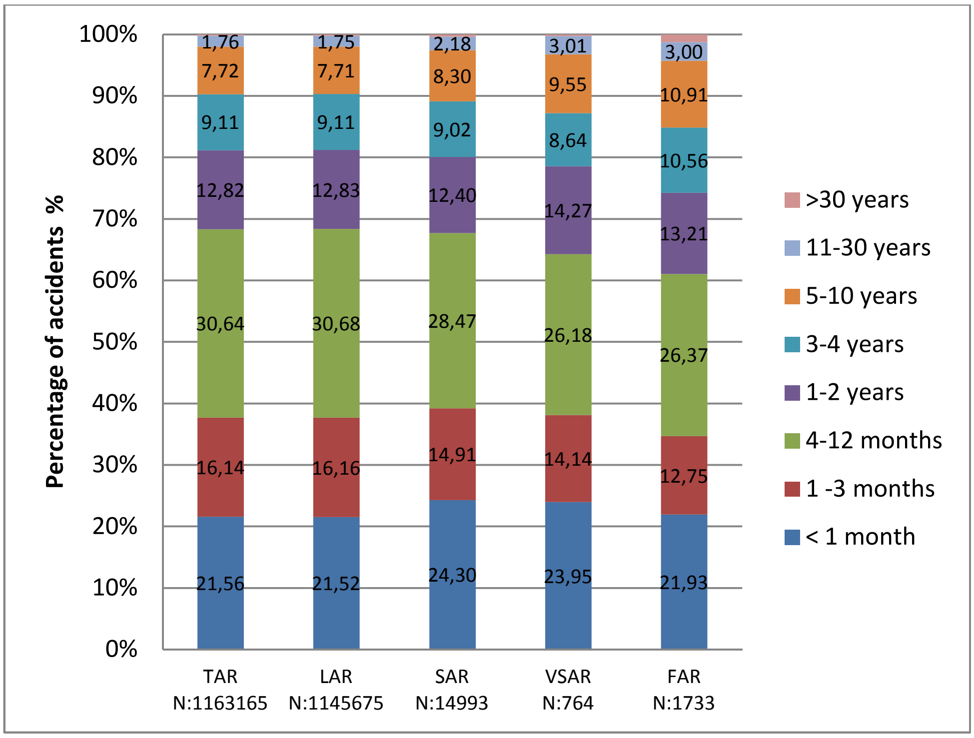
Length of service with the company was studied by Cattledge *et al* (1996), with particular reference to falls from different levels. Length of employment with the company at the time of injury ranged from one week to more than 30 years. It is important to note that these data deal with how long the person has been employed by a particular company rather than their experience in the industry as a whole. Despite the wide range, 60% of all those involved in accidents reported had been employed for two years or less, and 26% for six months or less. In our study, accidents involving workers with less than 3 years' experience in the company represented 81% of the total number of accidents. This percentage is lower when considering fatal accidents among this group of workers (74%).

Figure 5. Difference between rates. TAR-FAR (%), against length of service.



It is noteworthy that the FAR decreases in relation to the TAR when the employee's experience in the company increases from a month to one year, but this tendency is reversed after one year's experience. That can be observed better by calculating the difference between TAR and FAR in each experience group (Figure 5). Figure 5 shows in terms of variation of the rates, the best improvement of FAR with respect to TAR is in the group of workers with 4-12 months' experience (TAR-FAR= 4.27%), while the worst rate difference is in workers with 5-10 years' experience (TAR-FAR= -3.19%). The problem among workers with less than one month's experience could potentially be fixed with safety training programmes (Xiuwen *et al* 2004). In the group of workers with 5-10 years' experience, this solution is less likely to be successful, because hazards are often misjudged by them (Huang & Hinze 2003). Other strategies must be developed to prevent fatal accidents in this group.

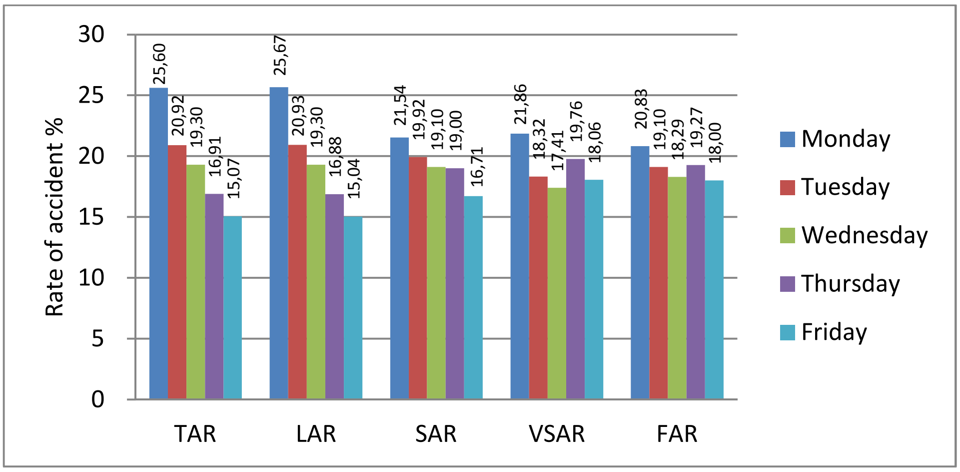
Figure 6. Total accidents in Spanish construction comparing length of service and severity.



The safety of construction sites has been considered in various studies (Sawacha, Naoum & Fong 1999, Toole 2002), but not all accidents occurring in the construction sector actually occur at the construction site. The workforce of construction firms do not work all the time in their habitual worksite, sometimes they are moving between sites or between different areas of their habitual site. Considering the results obtained, a high percentage of accidents analysed occurred on the habitual worksite (TA 83%), but their fatality rate was considerably lower (FA 48%). On the other hand, accidents occurring on a non-habitual site represented less than 11% of TA, but 25% of fatalities. These data highlight the problem with fatalities of workers not based on one specific worksite, which is an issue that must be considered more deeply in future research. The other two categories, on the way from worksite to worksite, and going to the worksite or back home, are difficult to evaluate because they are often considered as traffic accidents as opposed to work accidents, and as such they are not entered in the industrial sector statistics.

As regards the day of the week, Monday is the day of the week when most accidents occur. Known as the “Monday Effect”, this phenomenon has been studied by Card & McCall (1996) and Campolieti & Hyatt (2006). This effect assumes that some of the injuries reported on Monday actually occurred at the weekend but were not reported immediately. One explanation for this effect is that social benefits from the insurance company would change with more compensation paid for work-related injuries than for those incurred during leisure activities. In figure 7, the values for light accidents (LAR) and serious accidents (SAR) are very similar to their respective TAR, but the remaining rates, VSAR and FAR, decrease from Monday to Wednesday, increase from Wednesday to Thursday and decrease again from Thursday to Friday.

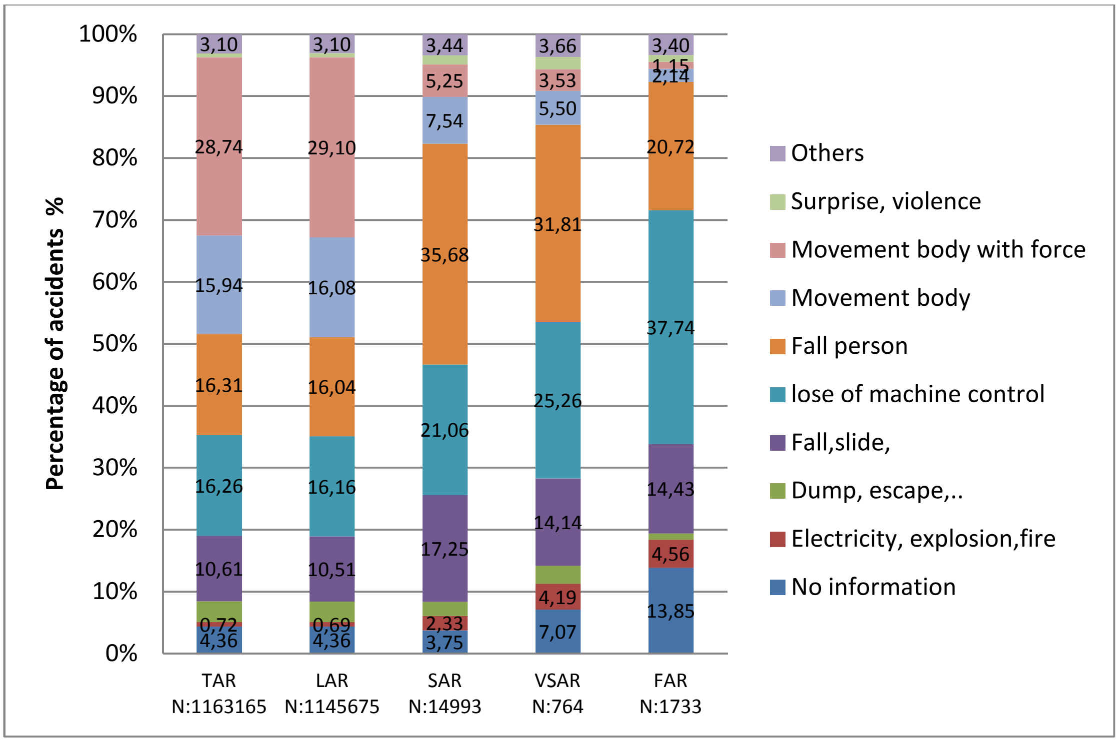
Figure 7. Accident rates comparing day of the week against severity.



With regard to days of absence form the workplace, it must be considered that sometimes light accidents are longer than a few days because the real recovery time is longer than the nominally expected one. Another consideration must be made with respect to fatal accidents. If the death is instantaneous or on the same day, one day of absence is registered in the database. However, for all other fatalities, the difference between the day of the accident and the day of the death is registered. It is remarkable that the group of accidents resulting in 16-30 days off work, presented the highest value in three of the five rates calculated (TAR, LAR, VSAR). In the other two rates this group figured second. Consequently, accidents resulting in 16-30 days of absence merit special consideration, as they represented nearly a third of all accidents.

As regards the material deviation, it should be noted that accidents produced by loss of machine control and falls account for one third of the total. In fact, they account for over half of the total when we compare the aggregate of both deviations with serious, very serious and fatal accidents (Aggregates: TAR 33%, SAR 57%, VSAR 57%, FAR 51%). These deviations must therefore be afforded special attention in order to reduce them as far as possible with preventative measures, training workers in safety and safety equipment. In addition to these data, a study about causes of accidents (Gibb *et al* 2006) concluded that greater attention should be given to the design and selection of tools, equipment and materials. Safety, rather than price, should be the paramount consideration.

Figure 8. Total accidents in Spanish construction comparing deviation and severity.



In Spain, wounds and superficial injuries, dislocations sprains and strains constitute 80% of TAR (from figure 8). This group of accidents have an insignificant impact on fatalities (0.75%). The most dangerous injuries are concussions and internal injuries, multiple lesions, heart attacks, strokes and other non-traumatic diseases. The last three of these merit special attention, because they represented only 1,319 of the 1,163,178 total accidents (0.11%), but 287 of the 1,733 fatalities (17%). The increase in the FAR value with respect to the TAR value is especially high in this group. Training workers or supervisors in first aid for these cases may result in improved figures.

Another factor that must be considered is that the severity of an accident differs depending on the climatic zone where it occurs. Spain has been divided into four climatic zones according to data obtained from the Spanish National Weather Service (AEMET, 2011). These climatic zones have been called Continental, Mediterranean, Oceanic and Tropical.

Climatic zones showed different evolutions of their severity rates. In the area under the influence of Mediterranean weather, the Fatal Accident Rate is lower than Total Accident Rate (FAR 41%, TAR 48%). On the other hand, in the Continental zone rates the fatality rate was higher than the total rate (FAR 38%, TAR 35%). The conclusion that Mediterranean weather is more conducive to safety than continental weather is not valid, because the evolution of the serious accident rates do not agree. In order to obtain better results about the climatic influence on accidents in construction, a more detailed study must be performed about this phenomenon.

2.1.2 Results and discussion based on accidents in concrete construction companies in Spain.

Having provided an overall perspective of accidents in the sector in the previous section, the present section goes on to explain the results of a detailed analysis of the accidents in concrete construction companies in Spain.

This part of the study focuses solely on concrete construction companies. Some of the variables studied previously considering the entire construction sector, were analysed again reducing the original sample from 1,163,178 accidents to the 125,021 accidents that occurred in concrete construction companies. It was not possible to compare all the variables studied previously because some of them do not reach statistically significant values when the size of the sample is reduced to the specific companies selected. As a result, the following variables were studied: *Occupation*, *Age*, *Company staff*, *Length of Service*, *Location of the Accident* and *Injury*. The distribution of accidents according to severity is shown in Table 2.

Table 2. Accidents in concrete structure construction companies according to severity.

	TAR		**LAR**		**SAR**		**VSAR**		**FAR**	
	Number	**%**	Number	**%**	Number	**%**	Number	**%**	Number	**%**
TOTAL	125021	100,00	122698	98,12	2017	1,61	88	0,07	218	0,714

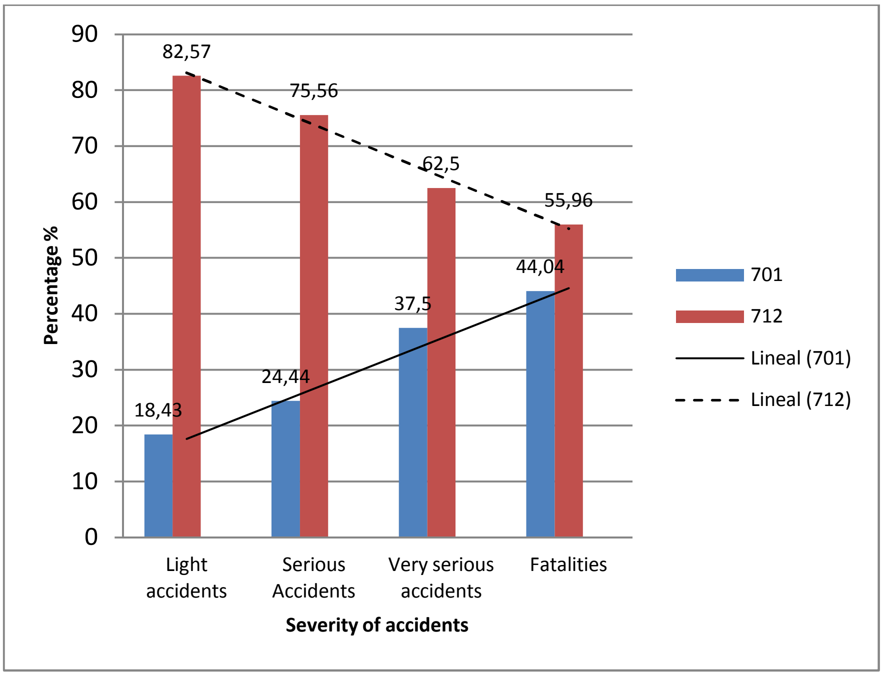
The occupation variable was the first to be analysed in this section. It should be highlighted that an accident suffered by a qualified worker (white-collar; Code 701) is more likely to be serious or fatal than one suffered by a non-qualified worker (blue-collar; Code 712).

Table 3. Accidents in concrete structure construction companies according to occupation and severity .

Chi-Squared	1820.92									
	d.f = 27	Sig=0.000								
	TAR (%)		LAR (%)		SAR (%)		VSAR (%)		FAR (%)	
CNO-94	**701**	**712**	**701**	**712**	**701**	**712**	**701**	**712**	**701**	**712**
Percentages	18.58	81.42	18.43	82.57	24.44	75.56	37.50	62.50	44.04	55.96

In the construction of structural works the accidents registered for foremen and management were 18.58% of all the accidents under analysis, a figure which increased to 44.04% for all fatal accidents. By contrast, blue-collar workers were involved in 81.42% of the accidents under study. However, this percentage decreased to 55.96% for the total number of fatal accidents. Figure 9 shows an increasing trend in relation to the severity of accidents among white-collar workers and a decreasing trend for those among blue-collar workers.

Figure 9. Accidents in concrete structure construction companies according to occupation and severity.



Analysis of the occupation variable showed differences between qualified and non-qualified workers. In order to obtain better results, after the analysis of concrete construction workers aggregated data, the differences between both groups were analysed disaggregated.

Table 4 shows that as the age of the worker involved in the accident increases the probability that the accident will not be light also increases in concrete structure construction companies. It must be noted that when the absolute value of corrected standardised residuals (csr) was less than 1.96, they were marked with an asterisk because they do not reach a statistical significance of 95% in order to reject the hypothesis of independence of variables, and we could not confirm the existence of more than a random influence for the severity variable. These results are in line with the previous results obtained for the whole sector.

A comparison of the differences between TAR and FAR for each age group and occupation (Figure 10) reveals that the 50-59 age group between shows the highest increase in fatalities in relation to the total number of accidents (TAR%-FAR% = -8.92% blue-collar; TAR%-FAR% = -6.28% white-collar). By contrast, the probability that the accident will be fatal decreases in the group of workers aged 25-29 (TAR%-FAR% = 11.11% blue-collar; TAR%-FAR% = 9 % white-collar).

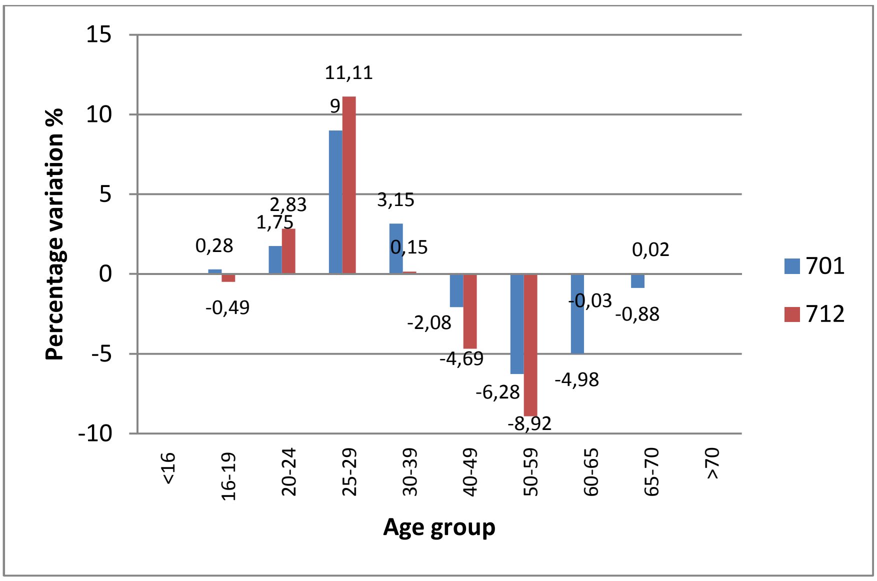
Table 4. Accidents in concrete structure construction companies according to age and severity .

AGE		
Chi-Squared	278,53	
	d.f=30	Sig=0,000

	TAR		LAR		SAR		VSAR		FAR	
	Number	%	Number	%	Number	%	Number	%	Number	%
<16	5	0,00	5	0,00*	0	0,00*	0	0,00*	0	0,00*
16-19	2908	2,33	2874	2,34	30	1,49	0	0,00*	4	1,83*
20-24	14385	11,51	14234	11,60	131	6,49	6	6,82*	14	6,42
25-29	21749	17,40	21436	17,47	291	14,43	12	13,64*	10	4,59
30-39	40899	32,71	40227	32,79	582	28,85	25	28,41*	65	29,82*
40-49	27035	21,62	26427	21,54	521	25,83	27	30,68	60	27,52
50-59	14590	11,67	14148	11,53	377	18,69	15	17,05*	50	22,94
60-65	3389	2,71	3290	2,68	82	4,07	3	3,41*	14	6,42
65-70	55	0,04	51	0,04	3	0,15	0	0,00*	1	0,46
>70	6	0,00	6	0,00*	0	0,00*	0	0,00*	0	0,00*
TOTAL	125021	100,00	122698	100,00	2017	100,00	88	100,00	218	100,00

These values indicate that age is a factor which behaves similarly for all workers. Nevertheless, the variation of the results obtained from the operation TAR-FAR is a little higher among blue-collar workers.

Figure 10. Difference between TAR-FAR (%) rates in relation to age.
Comparison between white-collar (701) and blue-collar workers (712)



The variable *Company staff* was not found to have an impact on the severity of accidents in the construction companies studied. As can be observed in Table 5, the majority of FAR results did not confirm the existence of more than a random influence for the severity variable. As occurred in the previous section on the entire construction sector, the results regarding company staff are not especially conclusive.

Table 5. Accidents in concrete structure construction companies according to company size and severity..

COMPANY STAFF

Chi-Squared 91,734

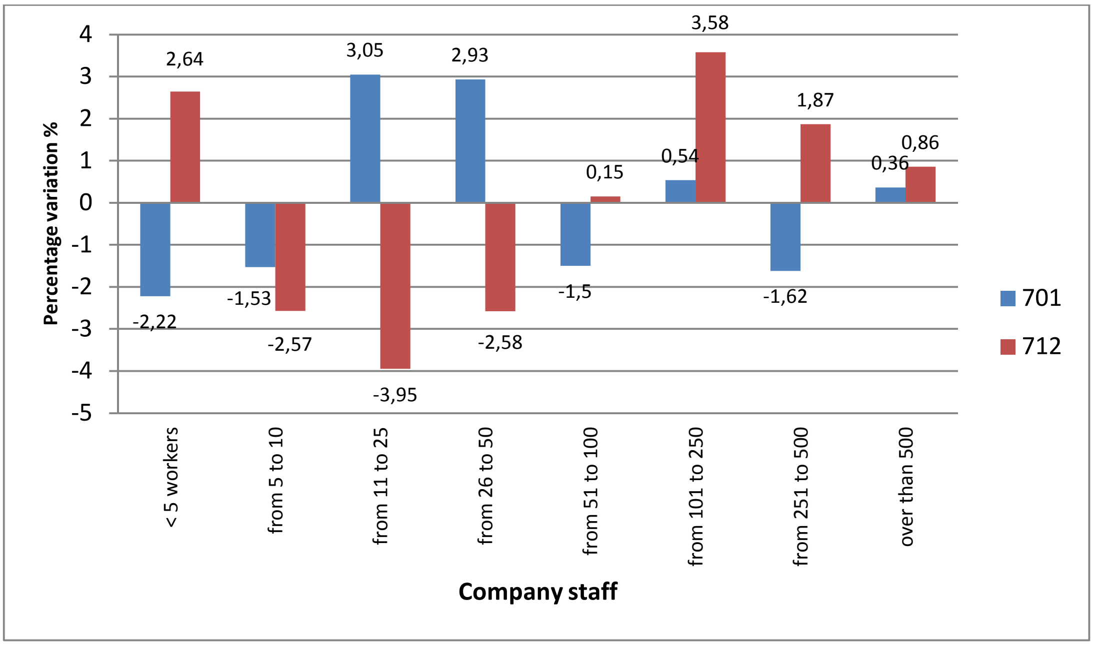
d.f=21 Sig=0,000

	TAR		LAR		SAR		VSAR		FAR	
	Number	%	Number	%	Number	%	Number	%	Number	%
< 5 workers	13443	10,75	13152	10,72	251	12,44	13	14,77*	27	12,39*
from 5 to 10	11265	9,01	10982	8,95	243	12,05	13	14,77	27	12,39
from 11 to 25	23325	18,66	22819	18,60	445	22,06	17	19,32*	44	20,18*
from 26 to 50	25639	20,51	25183	20,52*	397	19,68*	16	18,18*	43	19,72*
from 51 to 100	24289	19,43	23886	19,47	352	17,45	11	12,50*	40	18,35*
from 101 to 250	18714	14,97	18425	15,02	250	12,39	14	15,91*	25	11,47*
from 251 to 500	6071	4,86	5998	4,89	60	2,97	4	4,55*	9	4,13*
over 500	2275	1,82	2253	1,84	19	0,94	0	0,00*	3	1,38*
TOTAL	125021	100,00	122698	100,00	2017	100,00	88	100,00	218	100,00

In addition, the data obtained when calculating the difference between TAR and FAR (Figure 11) revealed significant differences as far as the category of workers is concerned.

Figure 11. Difference between TAR-FAR (%) rates, in relation to company staff.

Comparison between white-collar (701) and blue-collar workers (712).



A white-collar worker is less likely to suffer a fatal accident when the incident occurs in companies with 11 to 25 employees. However, in the case of blue-collar workers this probability is lower in companies with 101 to 250 employees. On the other hand, companies with less than 5 employees and companies with 11 to 25 employees had the worst results for both white-collar and blue-collar workers. In particular, the results for companies with 11 to 25 employees clearly reveal that records are very different for the two groups.

Many authors mention a short length of service in the company as a relevant causative factor for accidents in the sector (Horwitz and McCall, 2004) (Cattledge, Hendricks and Stanevich, 1996), (Huang and Hinze, 2003), but the impact of this factor on the severity of the accident is not clear.

Table 6. Accidents in concrete structure construction companies according to length of service and severity.

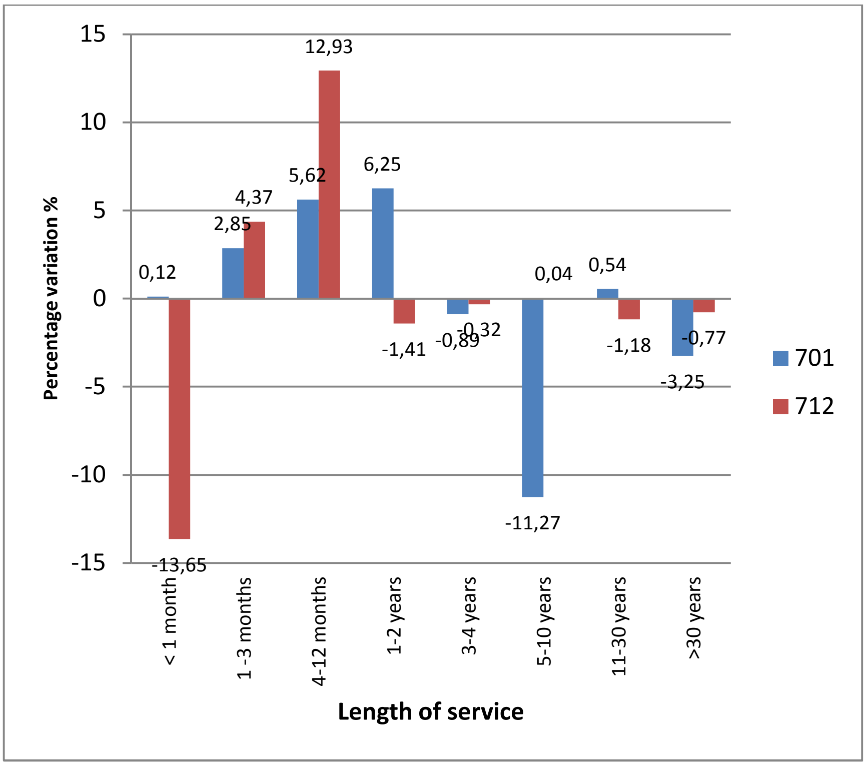
LENGTH OF SERVICE										
Chi-Squared	143,57									
	d.f=21	Sig=0,000								
	TAR		**LAR**		**SAR**		**VSAR**		**FAR**	
	Number	%	Number	%	Number	%	Number	%	Number	%
< 1 month	28596	22,87	28009	22,83	511	25,33	18	20,45*	58	26,61*
1 -3 months	21575	17,26	21223	17,30	321	15,91*	7	7,95	24	11,01
4-12 months	39676	31,74	39028	31,81	583	28,90	22	25,00	43	19,72
1-2 years	15541	12,43	15244	12,42*	256	12,69*	16	18,18	25	11,47*
3-4 years	9778	7,82	9587	7,81*	161	7,98*	7	7,95*	23	10,55*
5-10 years	7784	6,23	7592	6,19	146	7,24*	13	14,77	33	15,14
11-30 years	1807	1,45	1762	1,44	33	1,64*	5	5,68	7	3,21
>30 years	264	0,21	253	0,21	6	0,30*	0	0,00*	5	2,29
TOTAL	125021	100,00	122698	100,00	2017	100,00	88	100,00	218	100,00

It is especially significant (Table 6) that the worst rate difference was found in workers with 5-10 years' experience (TAR-FAR = -8.91). On the contrary, workers with 4-12 months' experience obtained the best rates. This means that experienced workers who suffer an accident in concrete construction companies are less likely to die as a result than are non-experienced workers.

In a disaggregate analysis, the probability of an accident being fatal is not homogeneous in the concrete construction companies studied because it is not the same in the groups under study.

As Figure 12 illustrates, a very short length of service can increase the severity of the accident among blue-collar workers. Lack of experience in blue-collar workers is shown to have a high impact on the severity of the accident.

Figure 12. Difference between TAR.-FAR rates in relation to length of service. Comparison between white-collars (701) and blue-collars workers (712).



In order to reduce fatalities among these workers, special attention must be paid to the first month at work. Efforts to improve safety standards must focus particularly on this period of time.

On the other hand, white-collar workers present different results as far as this variable is concerned: workers with no experience are not the ones with the worst rates. Figure 12 shows that special attention must be paid to workers with 5-10 years' experience at work. This group of workers presented a difference of 11.27% between TAR and FAR (TAR%-FAR% = -11.27%).

Many authors (Sawacha, Naoum & Fong, 1999, Toole, 2002) have considered safety on construction sites, but nowadays not all accidents occurring in the construction sector take place on construction sites.

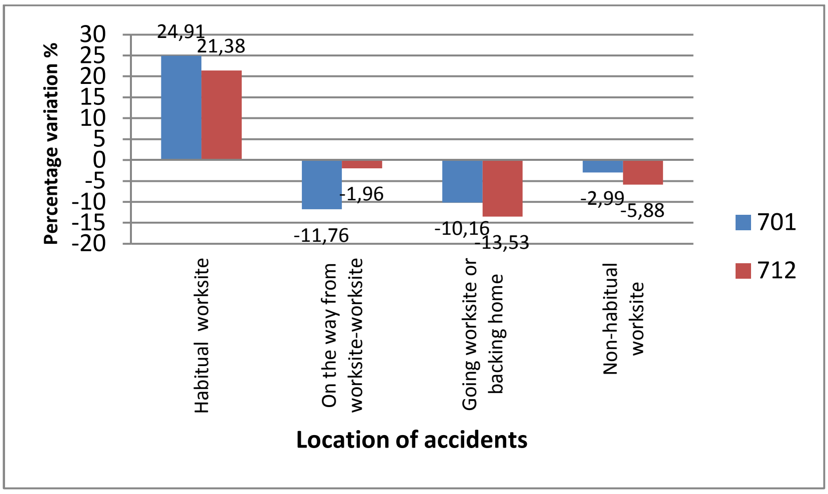
Table 7 shows that although most accidents took place on the habitual worksite, fatality rates were considerably lower. Similar results were obtained in the previous section regarding total accidents in the sector. A high percentage of the accidents occurred on the habitual worksite (TA 83%), but their fatality rate was considerably lower (FA 48%).

Table 7. Accidents in concrete structure construction companies according to place and severity.

ACCIDENT PLACE	TAR		LAR		SAR		VSAR		FAR	
Chi-Squared 670,82 d.f=9 Sig=0,000	Number	%	Number	%	Number	%	Number	%	Number	%
Habitual worksite	107601	86,07	105927	86,33	1484	73,57	55	62,50	135	61,93
On the way from worksite to worksite	1165	0,93	1099	0,90	38	1,88	11	12,50	17	7,80
Going to worksite or going home	4180	3,34	3978	3,24	159	7,88	8	9,09	35	16,06
Non-habitual worksite	12075	9,66	11694	9,53	336	16,66	14	15,91	31	14,22
TOTAL	125021	100,00	122698	100,00	2017	100,00	88	100,00	218	100,00

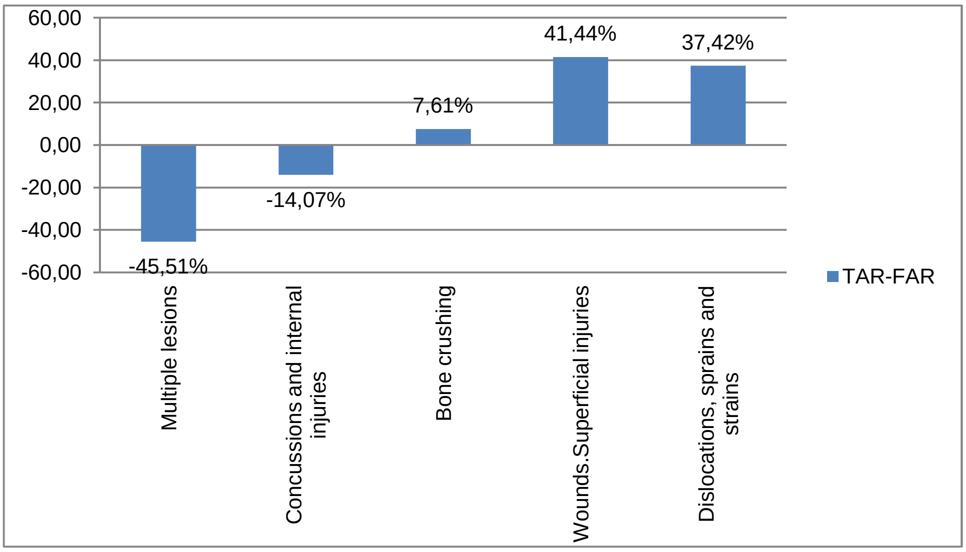
Differences between TAR and FAR rates were again calculated for each group of workers (Figure 13) and reveal that there are no significant differences between white and blue-collar workers. Both groups presented the highest risk levels in accidents on the way to work or going back home. This fact must be taken into account, because road traffic accidents going to the workplace or going back home are considered as occupational accidents in Spain.

Figure 13. Difference between TAR-FAR rates in relation to location of accidents. Comparison between white-collar (701) and blue-collar workers (712).



As regards the injury variable in the accidents analysed, it can be said that the majority of accidents involved only 5 type of injuries (multiple lesions, concussion and internal injuries, bone crushing, wounds and superficial injuries, and dislocations, sprains or strains). They accounted for 93.87% of all accidents studied. Figure 14 shows that the percentage of fatal injuries with respect to the total accidents occurred differed according to the type of injury, with multiple lesion injury the most likely to be fatal in the companies studied.

Figure 14 .Difference between rates TAR-FAR in relation to injury for concrete structure construction companies.



The distribution of injuries is not the same in all the groups analysed. The highest percentage of blue-collar accidents (43.99 %) is related to wounds and superficial injuries, while the highest percentage of white-collar accidents involves dislocations, sprains and strains (45.57 %).

Figure 15. Distribution of accidents in relation to injuries. Comparison between white-collar (701) and blue-collar workers (712).

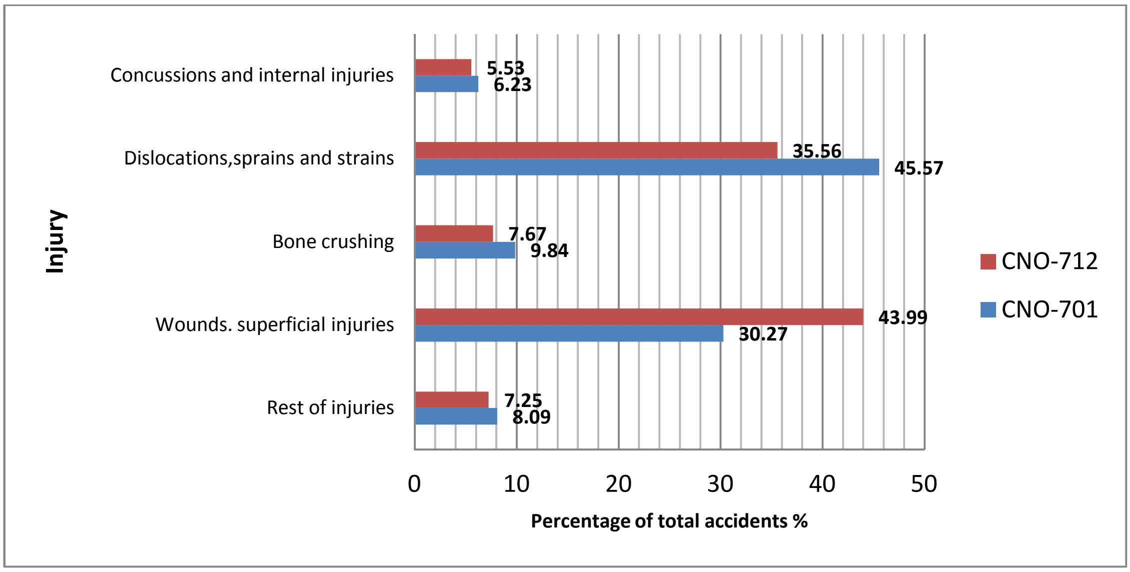
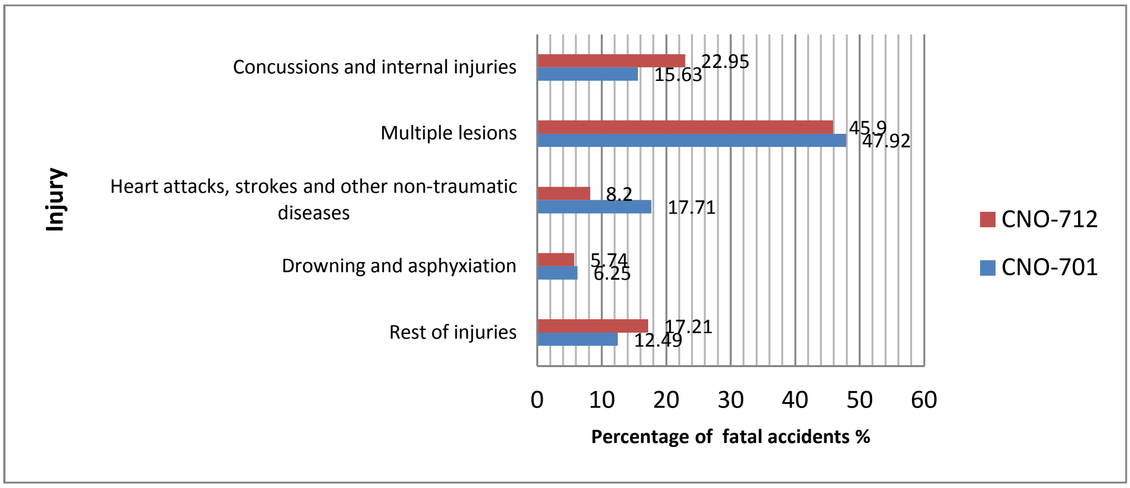


Figure 16. Distribution of accidents in relation to fatal injuries. Comparison between white-collar (701) and blue-collar workers (712).



With regard to fatal accident injuries, multiple lesions showed similar results among all workers. They were the main cause of of both blue-collar and white-collar fatalities (45.9% and 47.92 %, respectively). Concussion and internal injuries were the second cause of death for blue-collar workers (22.95 %), while heart attacks, strokes and other non-traumatic diseases were the second cause for white-collar employees (17.71 %).

2.2 RESULTS AND DISCUSSION BASED ON PROFESSIONALS' OPINION AND STAKEHOLDERS' PERCEPTION.

As was cited previously, the literature recommends that in order to gain a better and more accurate understanding of occupational safety levels, feedback should be sought from multiple sources. With a view to enhancing the validity of the current research, opinions were collected from several groups of experts and stakeholders using different prospective tools. It was expected that feedback from different groups of interest would improve the quality of the final results.

The results from professional experts can be classified in three groups: results of occupational safety performance, results of activity risk assessment, and results of Prevention through Design (PtD) indicators, all of which appear below.

2.2.1 Results and discussion of Occupational safety performance.

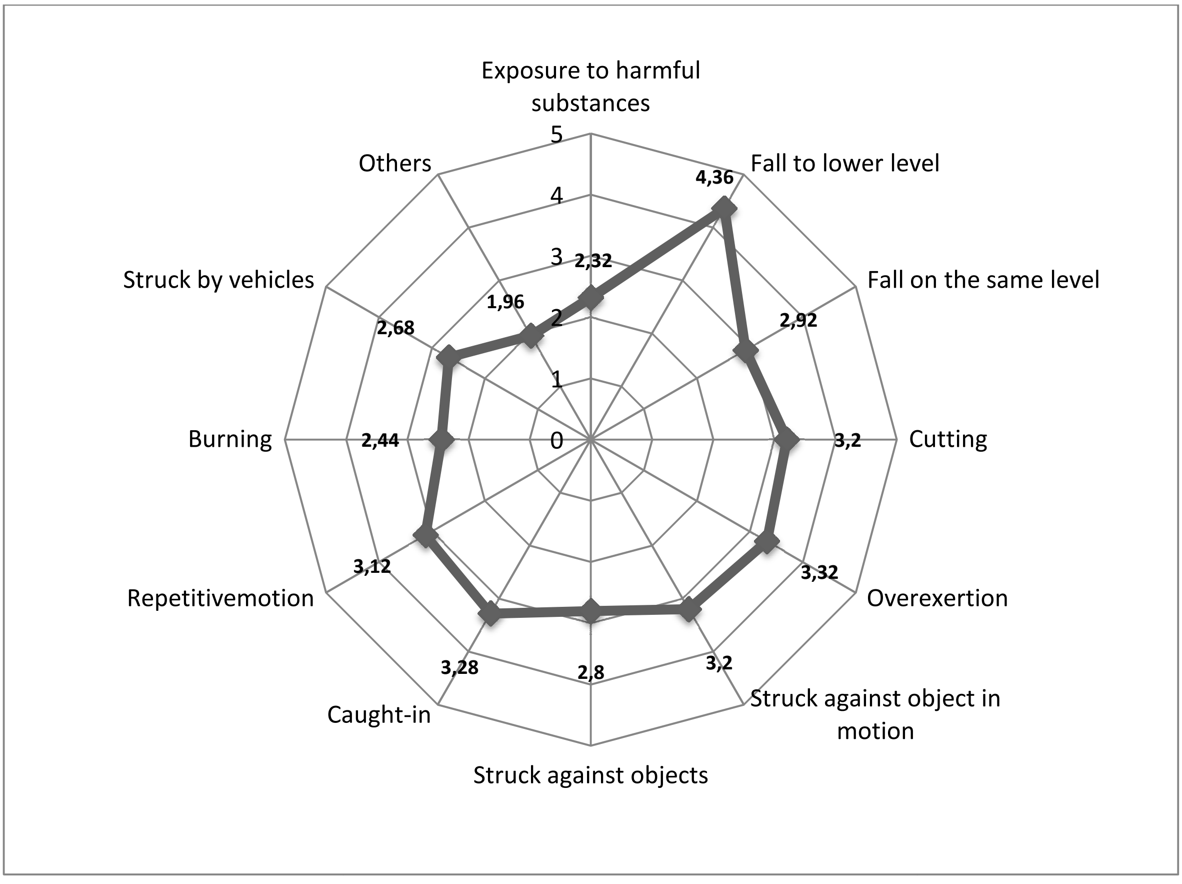
The results obtained from experts were divided into four categories:

a) safety risk assessment, b) preventive activities, c) effectiveness of safety programme elements and d) perception of preventive measures.

The first category analysed included a safety risk assessment based on Occupational Safety & Health Administration and Bureau of Labour Statistics. The second category included a list with the most frequent activities in civil construction companies based on Hallowell and Gambatese (2009), while the third one evaluated the effectiveness of preventive strategies for each activity studied, also based on previous research by Hallowell and Gambatese (2009). The final category included questions about the perception of some preventive measures and safety management in civil construction works.

In the safety risk assessment category experts were asked to evaluate each selected safety risk in civil construction with a value of risk from 1 [Low] to 5 [High], considering the frequency of the risk and the severity in case of accident. Answers were based on the respondent's experience and they were not based on the safest case scenario.

Figure 17. Safety risk score.

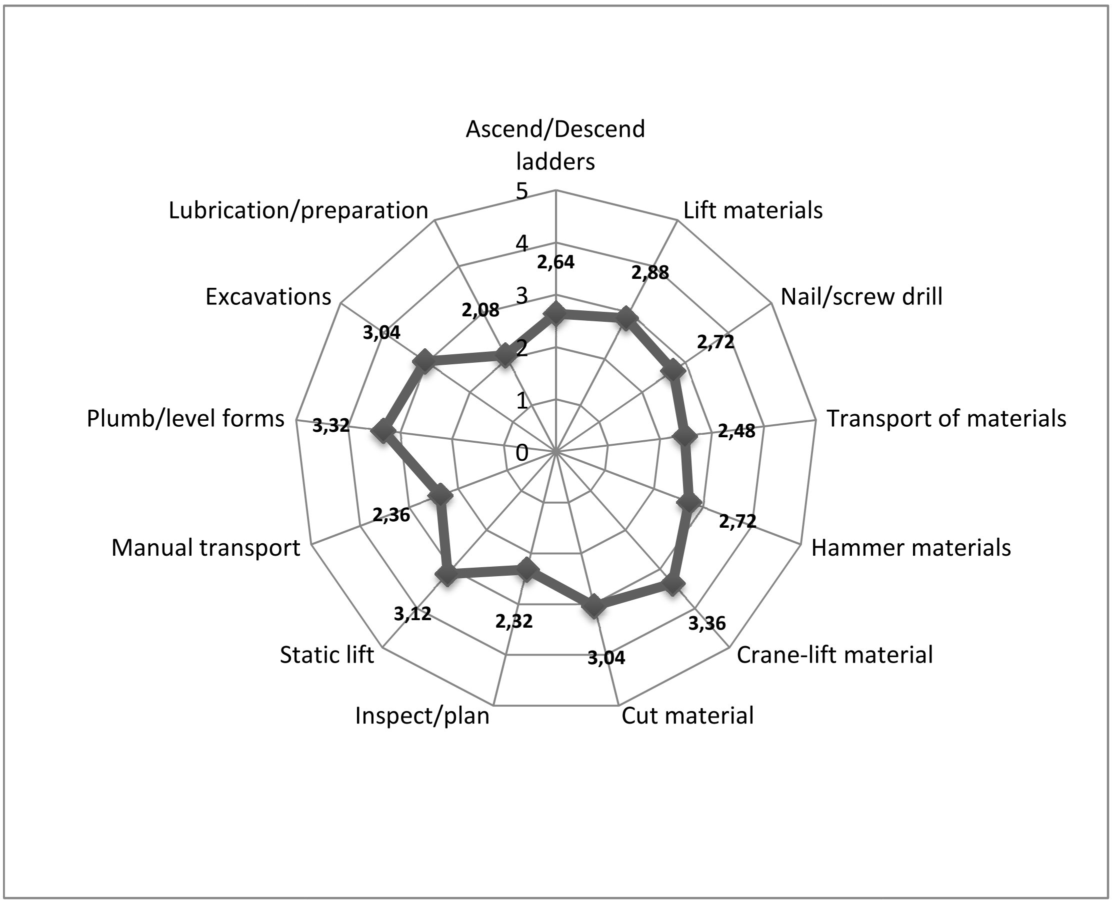


Safety risk scores (figure 17) showed that a fall to a lower level was considered as the most serious risk by construction companies in civil construction projects (Average = 4.36). It was given the highest risk score by sixty percent of the experts and the lowest score by no one. In accordance with the results obtained, falls to a lower level in construction had been addressed previously by authors like Cattledge *et al.* (1996), Derr et *et al*. (2001) or Dong *et al*. (2009). The risks of cutting (Average = 3.2), fall to same level (Average = 2.92), or overexertion (Average = 3.32) were also considered important but their average risk score was always below four.

To obtain results in this section, selected experts were asked to evaluate the risk level of the most frequent tasks related with civil construction works. The list of activities included was based on previous research conducted by Hallowell and Gambatese (2009) and it was also verified by the experts.

Although each activity is linked with a group of different risks and some risks tend to be more significant than others, the experts were asked to evaluate the global risk of each activity bearing in mind the frequency and severity of all the possible risks during the development of the activity. The possible score values ranged from 1 [Low] to 5 [High].

Figure 18. Activities risk score.



The results (figure 18) showed that the respondents considered crane materials to be the most dangerous activity (Average=3.36). Similar levels of risk were obtained by other activities: plumb and level forms (Average= 3.32), transport material (Average= 3.12), cutting (Average = 3.04) and excavations (Average= 3.04). The remaining activities obtained average safety risk scores of under three.

Table 8. Programme element activity matrix.

Program element \ Activity	Ascend /descend ladder	Lift /lower materials	Nail /screw/drill	Transport of material	Hammer material	Crane lift material	Cut material	Inspect/plan	Manual transport	Static lift	Excavation	Lubrication/preparation	Mean
E1	6.25	6.88	5.13	5.50	4.63	6.25	6.00	6.75	5.88	6.25	6.63	5.63	**7.13**
E2	6.00	5.75	5.13	5.13	5.00	5.63	5.63	5.38	5.13	5.75	7.25	6.50	**6.82**
E3	4.63	5.00	4.88	5.00	4.88	5.38	5.38	5.13	4.88	4.88	5.38	5.00	**5.97**
E4	5.75	5.88	5.25	5.00	5.25	4.75	5.50	5.75	5.63	5.63	6.00	5.63	**6.52**
E5	5.63	6.38	5.25	5.38	5.13	4.88	5.63	6.38	6.25	6.00	6.63	6.13	**6.90**
E6	5.75	6.13	5.13	5.88	5.50	6.00	5.50	5.75	6.00	6.00	6.13	5.88	**6.89**
E7	6.63	7.00	5.50	6.13	5.50	6.25	5.88	6.50	6.63	6.63	7.13	6.63	**7.56**
E8	5.38	5.63	4.38	5.75	4.75	6.00	5.50	6.38	6.13	6.50	6.50	6.00	**6.80**
E9	5.88	5.88	5.13	5.63	5.13	6.00	5.50	5.50	5.88	5.88	6.00	6.25	**6.78**
E10	5.88	5.75	5.13	5.50	5.13	6.00	5.75	6.25	6.00	6.13	6.13	5.88	**6.88**
E11	6.13	6.38	4.63	5.88	4.25	5.25	5.13	7.00	6.38	6.38	6.75	6.38	**7.00**
E12	6.00	6.63	5.63	5.50	5.63	6.50	4.75	5.63	6.00	6.00	6.50	6.25	**7.05**
Mean	**5.82**	**6.10**	**5.09**	**5.52**	**5.06**	**5.74**	**5.51**	**6.03**	**5.90**	**6.00**	**6.42**	**6.01**	

The effectiveness of construction safety programme elements was also evaluated. The data matrix drawn up from the experts' opinion showed the effectiveness of each specific preventive programme element for each civil construction activity studied. Mean values of each element's effectiveness were calculated. According to the experts, the two most effective elements were job hazard analyses and communication (Mean= 7.56) and upper management support (Mean= 7.13), followed by safety and health and orientation training (Mean= 7.05) and safety manager on site (Mean= 7.00). On the other hand, written and comprehensive safety and health plans (Mean=6.52) and substance abuse programmes (Mean=5.97) obtained the lowest values.

Table 9. Comparison of effectiveness of safety programme elements.

Ranking	Safety program element	Effectiveness score
1	Job hazard analyses and communication (E7)	7.56
2	Upper management support (E1)	7.13
3	Safety and health and orientation training (E12)	7.05
4	Safety manager on site (E11)	7.00
5	Project-specific training and regular safety meeting (E5)	6.90
6	Subcontractor selection and management (E6)	6.89
7	Safety and health committees (E10)	6.88
8	Employee involvement safety and evaluation (E2)	6.82
9	Record keeping and accident analyses (E8)	6.80
10	Emergency response planning(E9)	6.78
11	Written and comprehensive safety and health plan (E4)	6.52
12	Substance abuse programmes (E3)	5.97

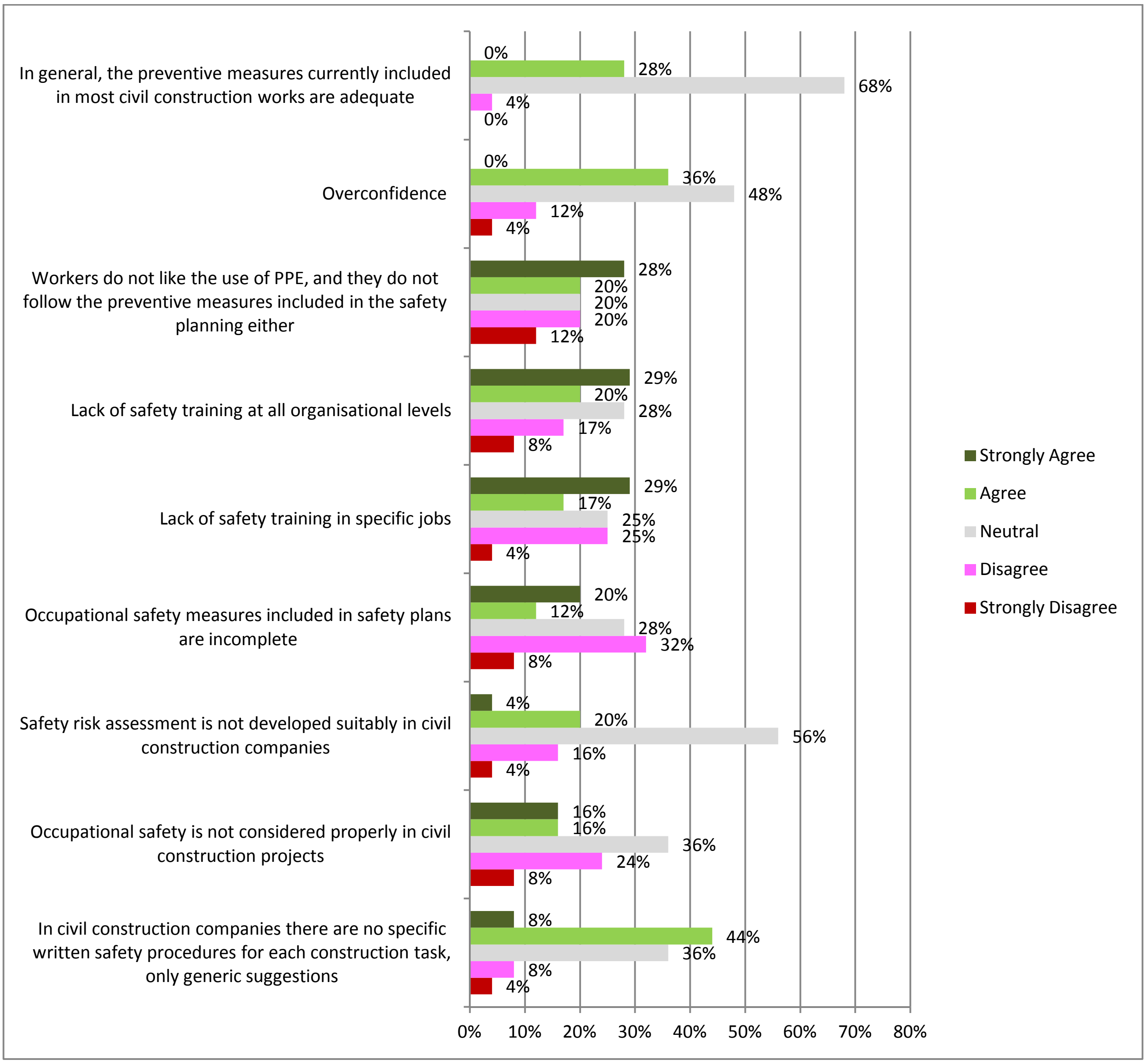
In order to ascertain the experts' opinions regarding general safety perception of the civil construction contractors, some specific questions were asked (table 10). The respondents were asked to specify their level of agreement with the statement in each item. Possible answers ranged from values 1 [strongly disagree] to 5 [strongly agree].

Table 10 shows the percentage of respondents for each value associated with each item. The values which obtained the highest percentage for each question were highlighted in the table in bold and shaded in grey.

Table 10. Preventive measures items.

	Likert Scale				
Question	**1**	**2**	**3**	**4**	**5**
In civil construction companies there are no specific written safety procedures for each construction task, only generic suggestions	4%	8%	36%	**44%**	8%
Occupational safety is not considered properly in civil construction projects	8%	24%	**36%**	16%	16%
Safety risk assessment is not developed suitably in civil construction companies	4%	16%	**56%**	20%	4%
Occupational safety measures included in safety plans are incomplete	8%	**32%**	28%	12%	20%
Lack of safety training in specific jobs	4%	25%	25%	17%	**29%**
Lack of safety training at all organisational levels	8%	17%	28%	20%	**29%**
Workers do not like the use of PPE, and they do not follow the preventive measures included in the safety planning either	12%	20%	20%	20%	**28%**
Overconfidence	4%	12%	**48%**	36%	0%
In general, the preventive measures currently included in most civil construction works are adequate	0%	4%	**68%**	28%	0%

Figure 19. Results from preventive measure items.



It is particularly noteworthy that the majority of participants strongly agreed that there is a lack of safety training in specific jobs and at all organisational levels. A similar proportion strongly agreed that workers do not like the use of Personal Protection Equipment and that they do not follow the preventive measures included in the safety planning.

The remaining items in this section did not obtain a majority opinion at extreme values according to the proposed Likert scale.

A most interesting finding of this study is that the other preventive measures were in the middle of the scale. This indicates that while they are not considered especially negatively, they can be improved.

2.2.2 Results and discussion from activity risk expert panel.

After the general quantification of the activities' risks in the previous section, a more specific study was designed in order to obtain values with more accuracy. A new expert panel was designed, and a new survey was developed. In this new survey, the influence of each risk on each activity was evaluated for all risks and activities selected, and a matrix of risk was compiled with all the results. Further details about the experts, activities, calculations and results are included in the second paper included in the publication's chapter.

The results showed that the highest risk scores for the construction activities under study were obtained by the activities plumb/level forms (0.4772 S/w-h), cut material (0.0585 S/w-h), crane material (0.0194 S/w-h) and ascending/descending ladders (0.0187 S/w-h). On the other hand, the lowest risk scores were obtained by lubrication/preparation (0.0008 S/w-h), manual transport (0.0006S/w-h) and inspect/plan (0.0002 S/w-h). Some of the activities with the highest risk scores, such as crane material or ascending and descending ladders, have been dealt with in other papers using a more general approach (Cattledge *et al*., 1996, Beavers *et al*., 2006, or Tam and Fung, 2011). Our specific results for vertical formwork activities in construction are in line with other general results that are discussed below.

Surprisingly, the two highest risk activities, that are plumb/level forms and cut material, had not been studied before. This fact could be due to the highly specific activities involved. Consequently, further research concerning these issues is needed. It is especially significant that plumb/level forms accounted for approximately 80% of all of the risk. This activity should therefore be the primary focus of safety management on the worksite.

Crane-lifting of material is one of the major causes of fatalities in construction (Beavers *et al*., 2006). To reduce the rate of crane fatalities, these authors believe that crane operators and riggers should be qualified and that requalification courses should be complusory every 3 years. Likewise, other researchers (Tam and Fung, 2011) highlighted the fact that large contractors and other agents provide insufficient training for crew members. In addition, these authors found difficulties in communication among crew members, including language and the correct understanding of signals. Consequently, to improve the health and safety levels in these tasks, education programmes should be redesigned for all workers engaged in crane operations. It should also be mentioned that according to other authors the risk is sometimes caused by deficiencies in the electrical system of the crane (Rubio-Romero and Simon-Donaire 2004).

Ascending and descending ladders has been associated with a high percentage (33.5%) of the non-fatal accidents in construction workers in the United States (Cattledge *et al*., 1996). Ladders were also associated with 11% of all fatal falls over the period 1980-1989 in the US. More recently, ladder-related accidents have been shown to be associated with risk factors that increased the probability of a serious or fatal accident (Camino *et al*., 2011). Hallowell and Gambatese (2009) found that this activity is one of the most dangerous. They studied formwork activities following a more general approach, that is, without concentrating on vertical civil works. To improve safety records in this activity, a more accurate risk assessment must be developed.

Regarding the health and safety risk values calculated, the highest risk scores were obtained by fall to a lower level (0.5247 S/w-h), cutting (0.0591 S/w-h) and overexertion (0.0079 S/w-h). The lowest risk scores correspond to falls on the same level (0.0001 S/w-h), exposure to harmful substances (0.0000 S/w-h) and others (0.0000 S/w-h). The health and safety risks studied had previously been addressed by many papers on construction activities (Derr *et al*., 2001,Dong *et al*., 2009, Gillen *et al*., 1999, Cattledge *et al*., 1996, Adam, Pallares and Calderon, 2009, Hallowell and Gambatese, 2009, Everett, 1999). The results provided here on specific vertical formwork safety risks are in line with those of other general studies on the same issue.

Given their fatal consequences, falls to a lower level in the construction industry have been extensively studied by many authors (Derr *et al*., 2001, Dong *et al*., 2009, Cattledge *et al*., 1996, Adam *et al*., 2009). Although these authors studied falls in the construction industry, their research was not focused on falls related to a formwork task. The most relevant work on falls and formwork is the study carried out by Adam, Pallarés, and Calderon (2009). In this study, falls from a height during floor slab formwork of buildings are dealt with specifically. They compared the fall protection systems commonly used during floor slab formwork construction in buildings and concluded that the suitability of the different systems depends greatly on the willingness of the workers to use them. This fact should be taken into account when making the choice. Hallowell and Gambatese (2009) found that falls to a lower level constitute a major risk, but this result was obtained without distinguishing between the two types of formwork (vertical or horizontal). Unfortunately, no literature about the risk of falls in vertical formwork in civil engineering is available. In a similar way to the studied activities, falls to lower levels accounted for almost 88% of the total risk score. Therefore concentration on this aspect of the work will produce the greatest improvement in health and safety performance.

Overexertion injury is the single largest category of injuries in construction work. It accounts for about 24% of all injuries (Everett 1999). Everett's analysis shows that virtually all construction activities have moderate-to-high ratings for at least one risk factor, and thereby place of workers at increased risk for overexertion injuries and disorders.

The authors of this paper have found no articles on the safety risk involved in formwork cutting activities.

To sum up, although there are several research papers on common health and safety issues in construction work, there is still a significant shortage of specific investigations on some of the activities and risks relating to tasks such as formwork erection dealt with in this thesis.

2.2.3 Results and discussion from construction formwork designers and users.

Throughout the construction process different participants are involved, and the communication and interaction between them is often not as effective as would be desired. In the current study three main interest groups were identified.

- Formwork manufacturing companies
- Construction companies
- Project designers

This section outlines the results extracted from the opinions of these construction project stakeholders regarding different construction issues (design, execution, legal questions).

Concerning questions on the design phase of the construction project it is worth noting that most of the respondents disagree or strongly disagree with the *“the project designer would ask the formwork manufacturing company for advice while they are designing the structure”*. Mean values from all groups were very low (Table 11), especially the values scored by project designers which also obtained the lowest variance (Variance = 0.474).

Table 11. Design phase statistics values.

DESIGN PHASE		MEAN	MEDIAN	MODE	VARIANCE
Q1	The project designer would ask the formwork manufacturing company for advice while they are designing the structure				
	Formwork manufacturing company	2.07	2	2	0.821
	Construction company	2.51	2	2	1.065
	Project designer	1.50	1	1	0.474
Q2	The project designer designs the structure without consulting the formwork/falsework manufacturing company. When the design is finished the construction company asks the formwork/falsework manufacturer for constructive solutions to suit the structure as designed.				
	Formwork manufacturing company	4.19	4	5	0.849
	Construction company	3.54	4	4	1.121
	Project designer	4.20	4	4	0.168
Q3	The majority of projects do not specify type of the formwork/falsework in the project´s documentation. Formwork/falsework selection is up to the construction company.				
	Formwork manufacturing company	4.10	4	4	0.555
	Construction company	3.83	4	4	1.13
	Project designer	4.20	4	4	0.379
Q4	When formwork/falsework is being designed safety is considered as a very important design factor.				
	Formwork manufacturing company	4.09	4	4	0.601
	Construction company	3.71	4	4	1.135
	Project designer	2.40	2.5	3	0.884
Q5	When formwork/falsework is being designed productivity is considered as a very important design factor.				
	Formwork manufacturing company	4.27	4	4	0.490
	Construction company	4.14	4	4	0.443
	Project designer	3.80	4	4	2.274
Q6	When a formwork/falsework is being designed final cost is considered as a very important design factor.				
	Formwork manufacturing company	4.36	4	5	0.436
	Construction company	4.14	4	4	0.588
	Project designer	4.00	5	5	2.526

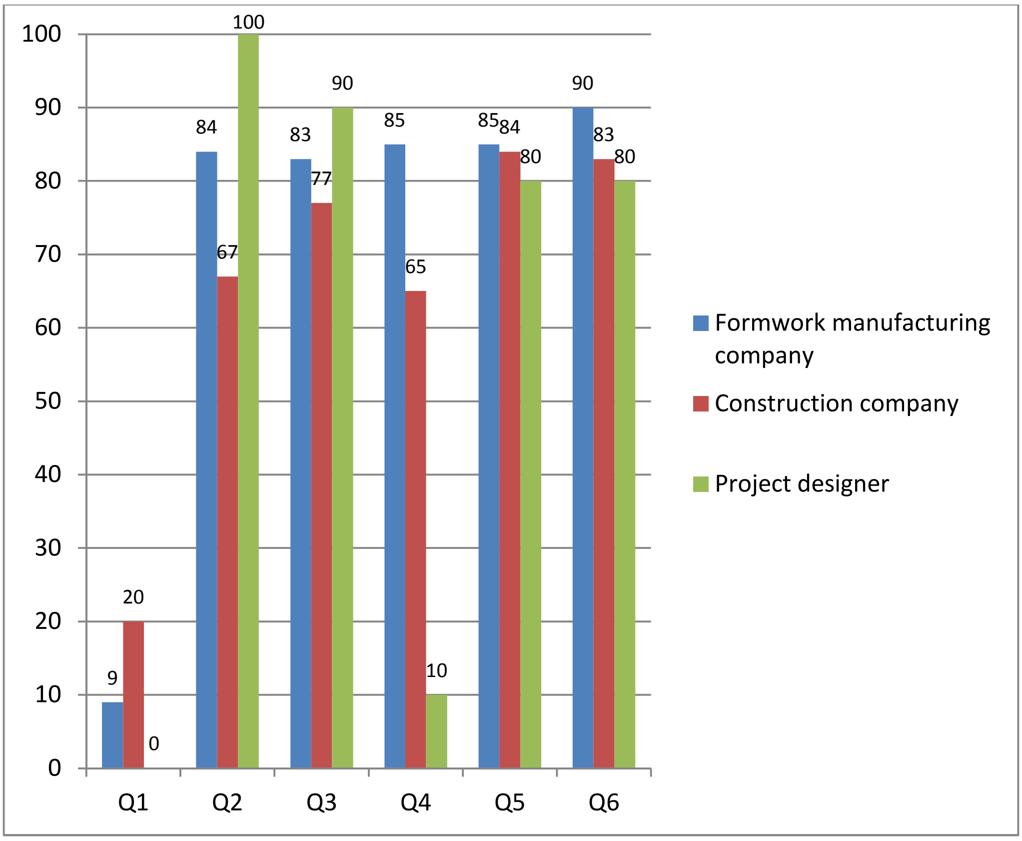
59% of the responses from formwork/falsework companies disagree, while 60 % of those from construction designers strongly disagree, scoring the lowest possible value of the cited statements. It is highly significant that in the opinion of most, designers design the project without the advice of the formwork companies.

Accordingly, designers may well not bear in mind the safest way to build their designs as they do not usually receive any advice about the safest formwork/falsework product from the formwork manufacturer.

The statement "*When the design is finished the construction company asks the formwork/falsework manufacturer for constructive solutions to suit the structure as designed*" obtained quite similar mean values from formwork workers (Mean = 4.19, Variance = 0.849) and project designers (Mean = 4.20; Variance = 0.168). Although this statement runs contrary to the principles of PtD, both groups agree that it reflects an extended practice.

In the opinion of the experts consulted, when formwork/falsework is being designed, safety is not considered as the most important design factor by any group. In contrast, the final cost of the formwork is considered as the most important factor by formwork companies (Mean=4.36), construction companies, (Mean=4.14) and project designers (Mean=4.00).

Figure 20. Percentages of responses which agree or strongly agree. Items Q1-Q6.



The construction phase results are shown in Table 12. It is significant that in the construction phase, customer and seller have different opinions regarding the election of the safest formwork. While only 40% of the constructors strongly disagree or disagree with the statement *“the formwork/falsework customer chooses always the safest one”* this percentage increase to 80% in responses from project designers and formwork companies. However, these differences disappear when they are asked about the cheapest formwork/falsework. The majority of them agree or strongly agree that customers always choose the cheapest one.

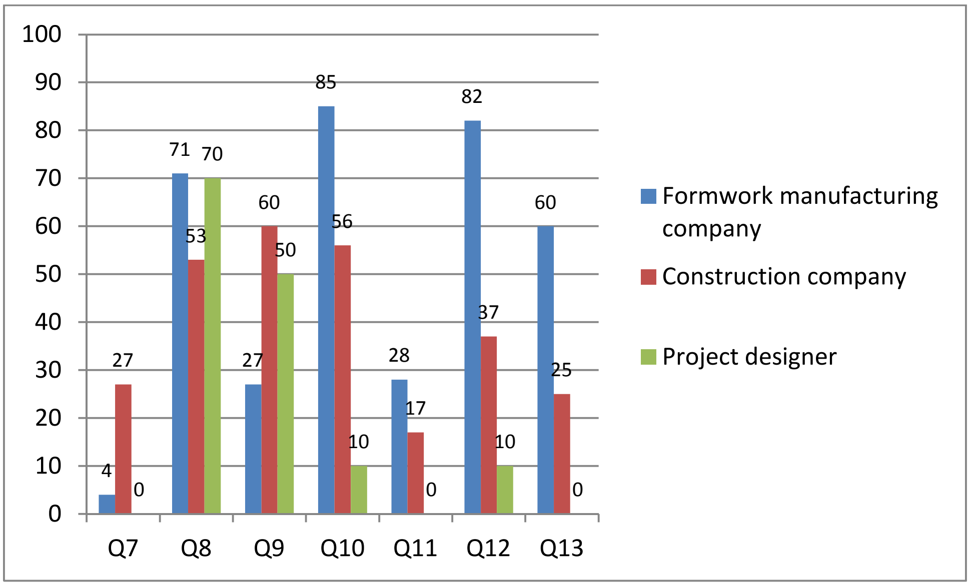
In questions related to training in health and safety provided by formwork/falsework and construction companies, it is remarkable that companies who received the training scored lower values than companies who provided the training or skilled staff.

Of the construction companies consulted, 73% neither agreed nor disagreed with the statement *“formwork/falsework manufacturers provide training in health and safety to their customers in the use of their products”*, and 57% of responses from formwork companies were the same. The percentages obtained by the statement *“manufacturers provide the customer with qualified technicians to erect, use and dismantle the formwork/falsework and their auxiliary equipment”* are along the same lines as the previous question. According to these results, the provision of training and qualified technicians by manufacturing companies is not an extended practice in construction works.

Table 12. Construction phase statistics values.

CONSTRUCTION PHASE		MEAN	MEDIAN	MODE	VARIANCE
Q7	The formwork/falsework customer chooses always the safest one.				
	Formwork manufacturing company	2.04	2	2	0.534
	Construction company	2.83	3	3	1.130
	Project designer	1.80	3	1	0.589
Q8	The formwork/falsework customer chooses always the cheapest one.				
	Formwork manufacturing company	3.84	4	4	0.569
	Construction company	3.63	4	3	1.016
	Project designer	3.60	4	4	1.305
Q9	The user always follows the manufacturer’s instructions about the product.				
	Formwork manufacturing company	2.99	3	3	0.594
	Construction company	3.57	4	4	0.915
	Project designer	3.50	3.5	3	0.263
Q10	Technical advice from formwork/falsework companies to users includes advice about safety issues related with use of theformwork/falsework.				
	Formwork manufacturing company	4.16	4	4	0.540
	Construction company	3.43	4	4	1.060
	Project designer	2.70	3	3	0.853
Q11	Formwork/falsework suppliers are the same suppliers for the rest of temporary equipment (e.g. scaffolds or hoists)				
	Formwork manufacturing company	2.77	3	2	0.990
	Construction company	2.66	3	3	0.721
	Project designer	2.40	2	2	0.253
Q12	Formwork/falsework manufacturers provide training in health and safety to their customers in the use of their products				
	Formwork manufacturing company	4.07	4	4	0.908
	Construction company	3.09	3	3	0.804
	Project designer	2.20	2	2	0.800
Q13	Formwork/falsework manufacturers provide the customer with qualified technicians to erect, use and dismantle the formwork/falsework and their auxiliary equipment.				
	Formwork manufacturing company	3.66	4	4	1.040
	Construction company	2.74	3	3	1.092
	Project designer	1.50	1	1	0.474

Figure 21. Percentage of responses which agree or strongly agree. Items Q7-Q13



The following section addresses legal issues regarding the design and use of formwork. Experts were asked about the possible health and safety improvements to be derived from the creation of compulsory and non-compulsory standards (International Standard Organization, British Standard, or similar).

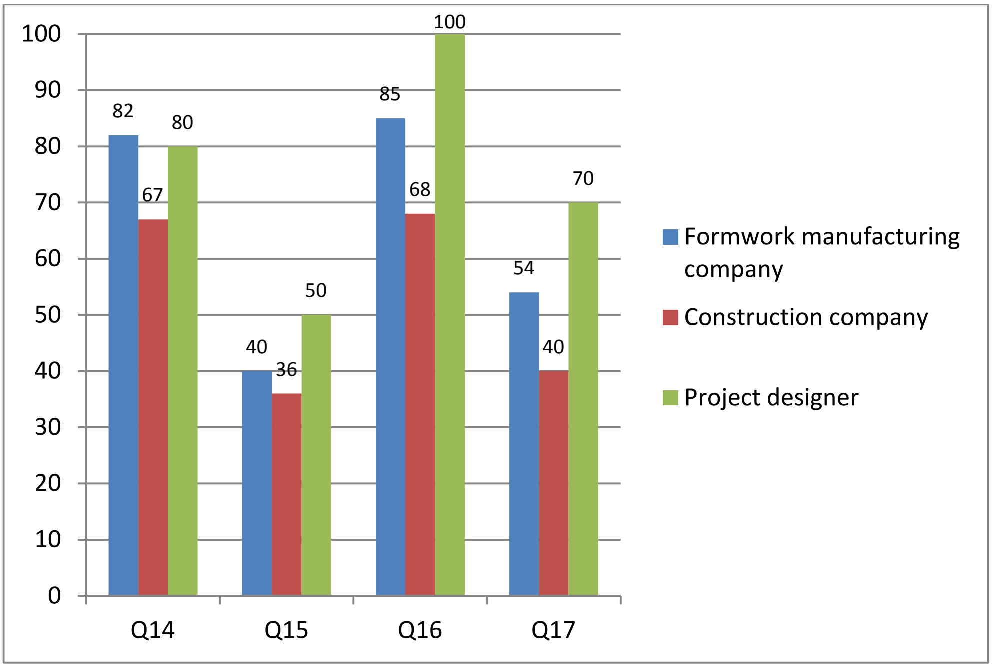
As can be observed in table 13, all mean values calculated were above three, and for many items the mean value was four or five.

Table 13. Legal issues statistics values.

LEGAL ISSUES		MEAN	MEDIAN	MODE	VARIANCE
Q14	A compulsory standard about formwork/falsework design and manufacture would improve health and safety in the final formwork/falsework as a product.				
	Formwork manufacturing company	4.26	4	5	0.629
	Construction company	3.73	4	4	1.128
	Project designer	3.90	4	4	1.147
Q15	A non-compulsory specific standard (ISO, BS or similar) about formwork/falsework design and manufacture would improve health and safety in the final formwork/falsework as a product.				
	Formwork manufacturing company	3.26	3	3	1.005
	Construction company	3.11	3	3	0.972
	Project designer	3.20	3.5	4	0.800
Q16	A compulsory standard about formwork/falsework use would improve health and safety for the formwork/falsework workers.				
	Formwork manufacturing company	4.37	5	5	0.643
	Construction company	3.80	4	4	0.916
	Project designer	4.50	4.5	4	0.263
Q17	A non-compulsory specific standard (ISO, BS or similar) about formwork/falsework use would improve health and safety for the formwork/falsework workers.				
	Formwork manufacturing company	3.49	4	4	1.239
	Construction company	3.17	3	3	1.043
	Project designer	3.40	4	4	2.147

If we compare answers from the same group, the effectiveness of hypothetical new standards were scored higher in the formworks' design phase than in their use by all groups of interest. Expert participants in this research considered the compulsory standards more effective than non-compulsory ones. It follows that the lack of specific legislation has a negative impact on the health and safety levels involved in the design and use of formworks.

Figure 22. Percentage of responses which agree or strongly agree. Items Q14-Q17.



2.2.4 Results and discussion on the importance of the PtD concept in engineering & architecture university courses.

Results were analysed for the three categories. The mean, median, mode and variance were calculated for all answers. In addition, Kruskal-Wallis and median tests were carried out in order to test the medians and distributions between answers from different groups with a confidence level of 95%.

Results from Occupational Health and Safety Training section (Table 14) showed that the integration of workers' occupational health and safety with the rest of the technical concepts obtained very poor results. Although the means were similar, the mode in the Bologna results obtained the lowest possible value.

Different results were found in the case of OHS-specific courses. OHS is studied in specific courses more often in Bologna degrees than in Old Degrees, although these courses are not necessarily related to construction courses.

Table 14. Results from OHS items

QUESTION		UNDER/DEGREE	MEAN	MEDIAN	MODE	VARIANCE
Q1	Workers' Occupational Health and Safety at vertical construction sites is integrated with the rest of the technical concepts in every lecture of the course	Old (OD)	2.17	2	2	1.00
		Bologna (BD)	2.13	2	1	1.07
Q2	Workers' Occupational Health and Safety at vertical construction sites is only considered in some lectures of the course	Old (OD)	2.86	3	4	1.48
		Bologna (BD)	2.26	2	1	1.30
Q3	Workers' Occupational Health and Safety is often confused with the structural safety of the construction	Old (OD)	2.60	3	1	1.61
		Bologna (BD)	2.50	3	3	1.25
Q4	Workers' Occupational Health and Safety is addressed in other specifics courses of the under/degree	Old (OD)	2.30	2	1	1.95
		Bologna (BD)	3.49	4	4	1.55
Q5	Knowledge of Workers' Occupational Health and Safety is evaluated in the course	Old (OD)	2.24	2	1	1.34
		Bologna (BD)	1.90	2	1	0.98

The survey showed that students' knowledge of Prevention through Design was poor in both groups, but worse results were obtained for Bologna degrees than for Old degrees. It is important to note that the lowest mode value for both groups of respondents was obtained for question 6 regarding knowledge of PtD. Ignorance with regard to PtD is not properly detected because the majority of the respondents agree that this knowledge is not evaluated during the course.The results indicated that OHS-related topics were addressed in other specific courses dealing with this issue, but this is no guarantee that students will have a better grasp or understanding of OHS concepts.

Despite the lack of training in PtD, student respondents considered it to be an important concept for improving workers' occupational health and safety in vertical constructions, with students studying Old degrees assigning a greater importance to PtD. There is a link between a deeper understanding of PtD by respondents and the greater importance they afforded the influence of the concept in the occupational safety of the workers.

Table 15. Results from PtD influence items

QUESTION		UNDER/DEGREE	MEAN	MEDIAN	MODE	VARIANCE
Q6	I know what Prevention through Design (PtD) is	Old (OD)	2.47	2	1	1.71
		Bologna (BD)	2.25	2	1	1.52
Q7	Worker safety when designing a construction project is taken into account during the course	Old (OD)	2.47	2	1	1.71
		Bologna (BD)	2.13	2	1	1.12
Q8	The concept of Prevention through Design (PtD) is addressed in many courses such as this one	Old (OD)	2.20	2	1	1.28
		Bologna (BD)	2.47	2	2	1.38
Q9	The concept of Prevention through Design (PtD) is important for improving workers' occupational health and safety in vertical constructions	Old (OD)	3.93	4	5	1.35
		Bologna (BD)	3.59	4	4	1.47
Q10	The concept of Prevention through Design (PtD) is not important when compared to the rest of the course content.	Old (OD)	2.67	3	3	1.51
		Bologna (BD)	2.78	3	3	1.72
Q11	Knowledge of Prevention through Design (PtD) is evaluated in this course	Old (OD)	2.24	2	1	1.29
		Bologna (BD)	1.89	2	1	1.06

Table 16. Results from value of PtD in the labour market

QUESTION		UNDER/DEGREE	MEAN	MEDIAN	MODE	VARIANCE
Q12	Training in OHS increases the value of the professional curricula	Old (OD)	3.69	4	4	1.10
		Bologna(BD)	3.79	4	4	1.23
Q13	Independent of its real value the labour market views training in OHS very positively	Old (OD)	3.31	3	3	0.90
		Bologna (BD)	3.30	3	3	1.23
Q14	Training in PtD increases the value of the professional curricula	Old (OD)	3.42	3	3	1.07
		Bologna (BD)	3.39	3	3	1.14
Q15	Independent of its real value, the labour market views training in PtD very positively	Old (OD)	3.21	3	3	0.93
		Bologna (BD)	3.16	3	3	1.08

The majority considered OHS and PtD to be very important and the items from this section obtained the highest level of agreement. The differences in the answers from both groups were very slight, and distribution of the answers can be considered similar in all items from this category.

Quantitative statistical tools were used to test the following hypotheses:

Hypothesis 1 (H1): The median of the items is the same in the two respondent categories: Old degrees and Bologna degrees.

Hypothesis 2 (H2): The distribution of the items is the same in the two respondent categories: Old degrees and Bologna degrees.

Hypothesis 1 was validated using the median test, and Hypothesis 2 was validated using the Kruskal-Wallis test. Results from these tests are shown in table 17. Results were obtained with a significance level of 0.05, with a confidence interval of 95%.

Table 17. Statistical test results

ISSUES	ITEM	MEDIAN TEST (H1)		KRUSKAL-WALLIS TEST (H2)	
		SIG	DECISION	SIG	DECISION
Occupational Health and Safety Training	**Q1**	0.771	Accepted	0.600	Accepted
	Q2	0.000	Rejected	0.000	Rejected
	Q3	0.051	Accepted	0.484	Accepted
	Q4	0.000	Rejected	0.000	Rejected
	Q5	0.008	Rejected	0.002	Rejected
The influence of Prevention through Design	**Q6**	0.107	Accepted	0.093	Accepted
	Q7	0.007	Rejected	0.002	Rejected
	Q8	0.046	Rejected	0.013	Rejected
	Q9	0.004	Rejected	0.041	Rejected
	Q10	0.190	Accepted	0.431	Accepted
	Q11	0.003	Rejected	0.001	Rejected
Value of occupational safety and PtD in labour market	**Q12**	0.014	Rejected	0.235	Accepted
	Q13	0.359	Accepted	0.801	Accepted
	Q14	0.991	Accepted	0.817	Accepted
	Q15	0.936	Accepted	0.814	Accepted

Statistical tests showed that in 7 of the 15 items there were no significant differences when comparing the medians of both groups of respondents. Similarly, the distribution of the answers was the same in the two groups for 8 of the 15 items on the questionnaire.

In order to contrast the results obtained from the student questionnaire in the previous section, a survey was conducted of the lecturers who teach the courses analysed. In the interview they completed the questionnaire and provided comments on some of the items, based on their own experience. Obviously, there are fewer lecturers than students, but their experience and academic background is greater. Interviews were held with 11 lecturers from the courses included in the study. They represent a total of 223 years of experience. The statistical comparison of results is not as accurate as we would like because the sizes of the student and lecturer samples are very different, but the results can provide us with an idea of the lecturers' opinions.

Most of the lecturers interviewed felt that it would be difficult to include OHS and PtD because time is limited and the curriculum is already quite crowded. This is in line with results from previous studies (Culvenor & Else, 1997). These concepts are not included in the specific course content, and as a result they are not considered a priority. Although lecturers were aware of PtD, many of them they did not study the concept when they were students.

It is interesting to note that a high level of consensus existed around the idea that training in OHS and PtD increases the value of professional curricula, but the labour market does not seem to place a great value on this.

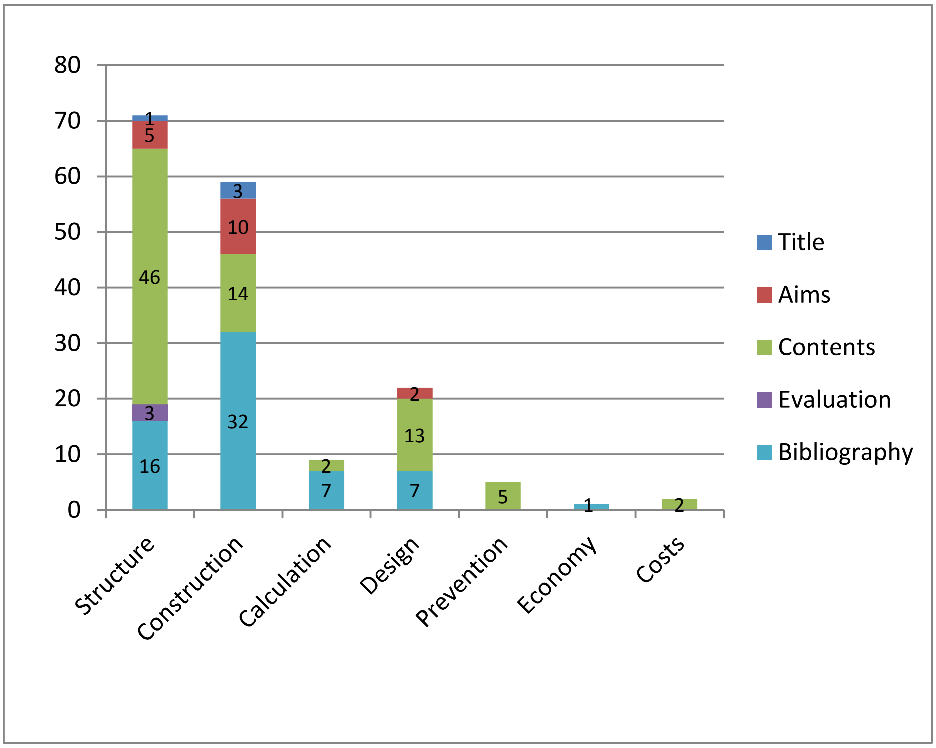
In addition, the syllabi from the 12 courses studied in the previous section were analysed for the frequency of specific keywords related to construction and occupational safety. The keywords included: structure, construction, calculation, design, prevention, economy, costs. The syllabi were divided into five different subsections: a) Title, b) Aims, c) Contents, d) Evaluation, and e) Bibliography. Statistics were generated based on the presence of each keyword in the different subsections of each syllabus. The results for the Old degree courses can be found in Figure 23 and those for Bologna degrees are in Figure 24.

No significant differences can be found in the presence and distribution of keywords such as "structure", and "construction". However the frequency of the term "calculation" increased in the Bologna degrees compared to the Old degrees, while the word "design" decreased. It is interesting to note that the term "design" was found in relation to "construction" or "structure" but not "prevention".

Table 18. Results and comments from lecturers.

	QUESTION	MEAN	MODE	NOTEWORTHY COMMENTS
Occupational Health and Safety Training				
Q1	Workers' Occupational Health and Safety at vertical construction sites is integrated with the rest of the technical concepts in every lecture of the course	2,45	1	*" Including OHS is difficult because there are other many other concepts in the courses and time is limited"* *"If I included OHS I would need to exclude other concepts because there just isn't time for everything"*
Q2	Workers' Occupational Health and Safety at vertical construction sites is only considered in some lectures of the course	2,00	1	*"OHS concepts are not formally included in the course" ; " OHS is not a specific aim of the course" ; "OHS is a transversal concept"*
Q3	Workers' Occupational Health and Safety is often confused with the structural safety of the construction	3,09	3	*"Many time the difference is not clear because structural failures are linked to accidents "* *"This is easily and frequently confused"*
Q4	Workers' Occupational Health and Safety is addressed in other specifics courses of the under/degree	3,45	5	*"OHS for workers is a priority on other courses"*
Q5	Knowledge of Workers' Occupational Health and Safety is evaluated in the course	2,91	1	*"Other concepts are evaluated in more detail"*
Prevention through Design influence				
Q6	I know what Prevention through Design (PtD) is	4,27	5	*"I am familiar with the concept, but I did not study this when I was student"*
Q7	Worker safety when designing a construction project is taken into account during the course	2,91	4	*"Worker safety is not considered during the course. It is not an objective here"*
Q8	The concept of Prevention through Design (PtD) is addressed in many courses such as this one	3,09	3	*"I am not sure what the contents of the rest of the courses are"*
Q9	The concept of Prevention through Design (PtD) is important for improving workers' occupational health and safety in vertical constructions	4,82	5	*"The importance of the concept is not reflected in its presence on syllabi"*
Q10	The concept of Prevention through Design (PtD) is not important when compared to the rest of the course content.	2,09	1	*"Design of the course contents is pre-established on the syllabi"*
Q11	Knowledge of Prevention through Design (PtD) is evaluated in this course	2,18	1	*"I cannot evaluate, concepts that I have no time to explain properly"*
Value of occupational safety and PtD in the labour market				
Q12	Training in OHS increases the value of the professional curricula	4,45	5	*"It is important, especially for future OHS managers, coordinators, etc."*
Q13	Independent of its real value the labour market views training in OHS very positively	3,36	5	*"The market focuses on productivity tools and OHS is not usually placed in this category"*
Q14	Training in PtD increases the value of the professional curricula	3,91	4	*"PtD increases the value of the curricula, but is not the most important aspect of a good engineer"*
Q15	Independent of its real value, the labour market views training in PtD very positively	3,18	4	*"PtD is important but is not a priority for the market"*

Figure 23. Frequency of keywords in syllabi for courses from the Old degrees.



It is significant that although the presence of the term "prevention in Old degrees" is especially low in comparison with keywords such as construction or structure, in the Bologna degrees this keyword was completely absent from all of the syllabi studied. "Economy" and "costs" were also absent.

Figure 24. Frequency of keywords in syllabi for courses from Bologna degrees.

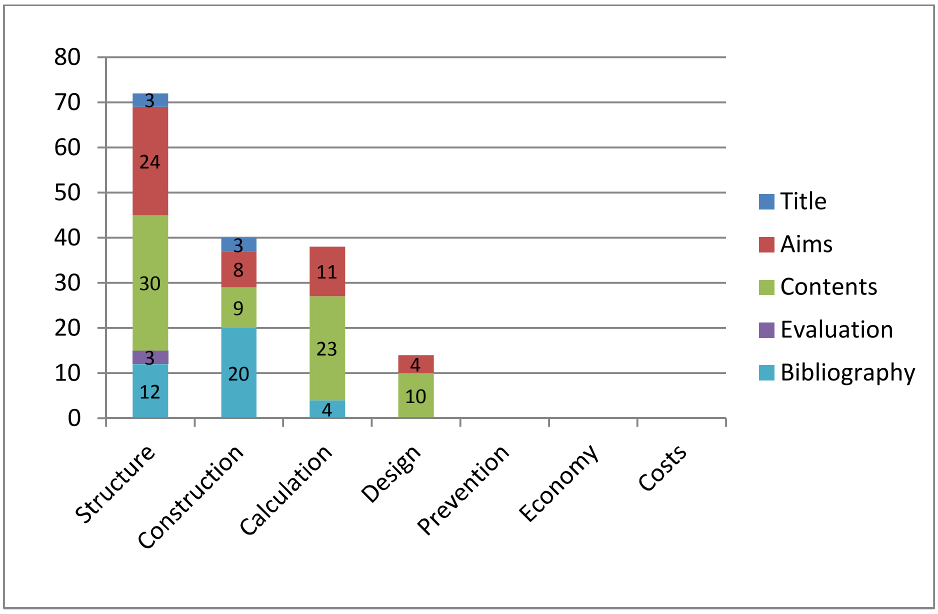


Table 19. Results from Old degrees and Bologna degrees.

Keywords		Structure	Construction	Calculation	Design	Prevention	Economy	Costs
Old degrees	Total appearances	71	59	9	22	5	1	2
	Mean per course	11.8	9.8	1.5	3.6	0.8	0.1	0.3
New degrees	Total appearances	73	39	38	14	0	0	0
	Mean per course	14.6	7.8	7.6	2.8	0	0	0

The absence of the concept of prevention in the new syllabi of the courses bodes negatively for the inclusion of OHS in the studies of future construction professionals. This is partially mitigated by the fact that specific courses on OHS have increased slightly in the global under/degree curricula. In addition, new courses are compulsory whereas in the old under/degrees the only course found on this subject was optional. Students could skip them and finish their university studies without any OHS background whatsoever.

Table 20.The presence of Occupational Health and Safety-related courses in the degrees studied.

	University	Degree	Number of courses related to OHS topics	Course credits	Compulsory Course	Degree Credits	Percentage of course credits of the total degree credits
Old degrees	University of Granada	Architect degree	0	0	NO	400	0.0
		Architect under degree	1	6	NO	307	1.95
		Civil Engineer	0	0	NO	400	0.0
	University of Málaga	Architect	0	0	NO	398	0.0
Bologna Degrees	University of Granada	Building engineer	1	6	YES	240	2.50
		Architect degree	0	0	NO	240	0
	University of Sevilla	Civil Engineer	1	3	YES	240	1.25
		Building engineer	1	9	YES	240	3.75

Although the contents of the OHS-specific courses are not part of the design or construction courses, an increase in the number of OHS courses can improve Architecture students' knowledge of the subject and provide them with some useful tools. However, as was pointed out previously, including OHS proves difficult due to the already crowded curricula (Culvenor & Else, 1997).

Table 21. Average presence of OHS courses in degrees studied.

	Average of credits of OHS contents (credits)	Classification of the courses	Percentage of OHS courses credits in the total degree credits (%)
Old degrees	1.5	Optional	0.40
Bologna degrees	4.5	Compulsory	1.87

2.3 GLOBAL DISCUSSION.

The previous sections have outlined the results and discussion from different parts of the study. Although certain aspects from these specific parts have already been compared, a global discussion will provide a better understanding of the findings. This section aims to highlight the main connections between the different issues addressed during the entire research.

Regarding accident factors, age was considered as an influence in both statistical analyses developed. In the first analysis, the sample contained all the accidents in the construction sector from 2003 to 2008, while the second one only studied accidents involving workers on concrete constructions.

In cases of accidents, workers in the 60-65 age group obtained the worst fatality rates in the first study, while in the second one, the worst rates were recorded among the 50-59 age group. In contrast, the best results were obtained by the 20-24 age group considering the entire construction sector, and and by those aged 25-29 considering concrete structure construction only. It should be noted as a limitation of the study that in the workplace incident notification forms studied no information was provided regarding the specific task of the worker involved at the moment of the accident. Consequently, although the results are quite similar between concrete construction and the rest of construction sector, the slight differences in age groups may be due to the fact that the most dangerous activities are not distributed equally in both samples studied. Unfortunately, it was not possible to verify this hypothesis.

In relation to company size, in both samples studied, TAR and FAR tend to suggest that in cases of accidents a company with over 250 employees is more likely to suffer a fatality. In other words, in cases of accident the largest companies are not necessarily the safest ones. More information is required on the companies and their activities and risks to establish a more accurate relationship between company size and the severity of the accidents.

Results concerning length of service showed similar results between concrete construction companies and the rest of the companies in the sector. Workers with 5-10 years' experience obtained the worst results, while those with only 4-12 months in the company obtained the lowest FAR values. It is remarkable that in cases of accidents, it is the experienced workers who are more likely to suffer fatal accidents. Special training programmes intended to maintain and enhance experienced workers' awareness of OHS issues would therefore be appropriatein order to prevent fatal accidents.

The most important fatal deviations identified in the first part of the study, fall and loss of machine control, are linked to the most relevant fatal injuries, concussions, internal injuries, and multiple lesions, found in the second part of the study focused on concrete construction companies. These findings were similar to the results obtained from professional experts when they were consulted as to the safety risk of the activities in a civil construction project, in the third part of the current research.

These experts highlighted falls to a lower level as the most important risk. Other major risks included cutting, overexertion, or blows against objects. There were no significant differences in the global results between the first approach where safety risk and activities were considered separately, and the second approach where the influence of each risk on each activity was evaluated for all risks and activities selected, and a risk matrix was obtained with all results. The activity of plumb and level forms was considered especially dangerous by experts in both approaches.

These results led to the following research step, which aimied to understand better safety needs by consulting formwork users and manufacturers. The opinions of stakeholders involved in the use and design of formworks did not always match, because they tended to consider themselves as isolated groups, rather than as part of the production process. For instance, project designers, who start the construction process, would not ask the manufacturing company for advice while they are designing the structure. In addition, most of the projects do not specify the type of formwork in the projects' documentation. Consequently, formwork election is left to the construction company, who designed neither the project nor the formworks.

Another occupational safety problem is the fact that users do not always follow the products' safety instructions, nor are they aware that manufacturers provide training in health and safety in relation to their products.

As regards the legal issues of formwork design and use, and according to the professionals' opinions, new standards and legislation about the design and use of formworks would probably improve their occupational safety. It should also be pointed out that more effective communication between the stakeholders would improve occupational health and safety levels.

The lack of communication between designers and the remaining stakeholders, indicated that the Prevention through Design (PtD) concept is frequently not well implemented during the design phase. This inadequate implementation of PtD could be explained by the construction professionals' poor training in PtD. In order to test the integration of the PtD concept in the academic trajectory of the designers, specific engineering degrees were studied. The results showed that the lack of training in PtD is due to many reasons: the importance of PtD is not recognised in the syllabi, PtD is not included in the contents, other concepts are evaluated in more detail and there is not enough course time available. Although the crowded curriculum may make it difficult to include PtD contents, an effort should be made to rectify this situation. PtD has proven to be a useful tool in the prevention of accidents, and it must therefore be considered from the beginning of the training of future professionals.

The connections analysed between the different results indicated that improving the integration of PtD in university degrees would enhance the implementation of this concept in the use and design of construction formworks. In turn, the adequate implementation of PtD in the use and design of formworks would improve the occupational safety levels of the projects, helping to decrease risk levels and to remove certain hazards completely. This improvement in safety risk levels would have a positive impact on accident rates and fatalities.

CONCLUSIONS

3. CONCLUSIONS.

3.1 PARTIAL AND SPECIFIC CONCLUSIONS.

3.1.1 Conclusions drawn from accident analysis.

This section outlines the conclusions to be drawn from the accident data analysis , which are divided into general conclusions regarding the construction sector in Spain and specific conclusions in relation to concrete construction companies.

The analysis of construction accidents in Spain showed that the seriousness of accidents is related to several of the variables studied. The conclusions for each variable can be summarised as follows:

Age. Analysis of the data does not show whether the accident rate varies with age, but it does indicate that the likely consequence of any accident varies according to this variable – with the 20-24 age group recording the least serious consequences. An accident involving an older worker would probably have more severe consequences. Consequently, special training plans should be considered for older workers, as should fitness programmes depending on the work regime.

CNAE Code. Regarding the different categories studied from the National Code of Activities in construction, the worst accident severity rates were found in the activity denominated “completion of construction works”.

Company size. It may be concluded that a large company is not always necessarily safer than a small one as regards fatal accidents. According to the data analysed, the ‘safest’ company size in this respect is between 26 and 50 workers, as their FAR is significantly lower than their TAR. However, these data could be misleading, since subcontractors are frequently employed and subcontract data are not included in these figures.

Length of service. Comparing once more the values of FAR and TAR from the accidents that occurred, it can be concluded that accidents suffered by workers with 5-10 years’ experience had the worst results. On the other hand, the same values indicated that workers with 4-12 months’ experience had the best results. Experienced workers must therefore receive especial training based on specific programmes according to their needs.

Place of accident. It was found that accidents occurring away from the usual workplace had more severe consequences than those at the usual workplace. More effort is required to improve the risk awareness and to implement preventive measures when workers change location. The problem of fatalities involving workers that are not based on one specific worksite merits more in-depth study in future research.

Deviation. In addition, analysis of the data showed that loss of machine control and falls from a height cause a third of the light accidents, while also causing over half of the accidents in other severity categories.

Injury. When heart attacks, strokes and other non-traumatic diseases are involved in an accident they prove especially fatal. Workers and supervisors must be trained in first aid for such cases. Adequate training along these lines would help to save workers' lives.

As far as the study of concrete construction companies in Spain is concerned, the following general conclusions about these companies can be extracted:

Age. Regarding fatal accidents, workers of 25-29 years of age obtained the best results, while those of 50-59 years of age obtained the worst ones. As a consequence, special strategies should be developed in order to improve the results of older people.

Location of the accident. Although most of the accidents took place at the habitual worksite, it was found that a fatal accident is more likely to occur on the journey to or from work. Workers, companies, and authorities frequently overlook this problem, because they do not consider these incidents as an occupational issue.

Injuries. Multiple lesions were the main cause of death in the accidents studied. This result should encourage occupational health and safety and health stakeholders to identify the circumstances involved in accidents with these injuries and to promote preventive measures concerning the relevant factors. There should be further research on this type of injuries.

It is noteworthy that some results from the construction sector were similar to the specific results from concrete construction companies. Once the accident happens, older workers are more likely to suffer a fatal accident than younger ones. Special attention must be given to the group of workers with 5-10 years' experience. Too often their hazards are misjudged by everybody involved. Managers, supervisors, and the workers themselves tend to rely on their experience and skill, but experience is not a never-failing life guard, and it can be a double-edged sword, leading to a greater acceptance of risk. That problem is difficult to solve because older workers are more difficult to train. Similarly, it is important to note that although most of the accidents took place at the habitual worksite, accidents on non-habitual worksites obtained worse fatal accidents rates. Special measures should be implemented when workers change work location, and during the journey from home to work.

It should be highlighted that in concrete construction enterprises some accident variables differ according to the workers' level of qualification. Consequently, measures to improve health and safety should be adapted to the similarities and differences found in the study. Along these lines, the main differences found in the variables studied in the research are the following:

Occupation. An accident involving a white-collar worker would probably have more severe consequences than an accident involving a blue-collar worker. Qualification is not necessarily tantamount to safety. In many cases the technical skills of workers are not related to education in prevention at work. Spanish university curricula do not always include compulsory courses on specific issues regarding occupational safety.

Company size. This variable presents a very heterogeneous tendency without a clearly applicable pattern. It cannot be said that safety increases or decreases according to company size for any of the groups under study. However, when accidents occur, the likelihood that a white-collar worker will suffer a fatality is low in companies with 11 to 25 workers. However, companies with 101 to 250 workers obtained the best rates for blue-collar workers. The need for more efficient preventive measures in a company differs in relation to the number and qualification of their employees.

Length of service. Lack of experience is an important factor in fatal accidents among blue-collar workers, especially during the first month of work. On the other hand, among white-collar workers those with 5 to 10 years' experience obtained the worst rates. A similar conclusion can be drawn in relation to workers' age. Special strategies must be developed in order to improve these results. Particular attention must be paid to the first month at work of blue-collar workers. White-collar workers should have further training on safety standards after 5 to 10 years of work experience.

Injuries. The second cause of death among blue-collar workers was "concussion and internal injuries", while among white-collar workers the second cause was "heart attacks, strokes and other non-traumatic diseases". These injuries should therefore be afforded more attention in future studies in order to enhance prevention.

3.1.2 Conclusions drawn from professional opinion and stakeholder perception.

This section presents the main conclusions to be drawn from the opinion and perception of the professionals and experts from interest groups that took part in the study.

The findings presented enhance our understanding of the contractors´ opinion regarding occupational safety in the civil construction sector. In the experts' opinion, a fall to lower level was highlighted as the major safety risk in civil construction works, and so preventive measures to minimise this risk shold be a priority. The activities crane materials, plumb and level forms, transport material, cutting and excavations merit particular consideration due to their high level of risk. The effectiveness of job hazard analyses and communication and upper management support were the safety programme elements that obtained the best scores the experts.

Regarding the experts' perception of preventive measures and conditions in civil construction works, occupational health and safety issues in are not always developed optimally in the projects. Most projects reflect a lack of written procedures and a low level of workers' safety training. Poor levels of safety training were not only indentified in specific jobs, they were also considered poor at organisational level. All employers must be trained with specific programmes according to their duties and assignments.

The findings obtained in the current study must be considered from the beginning of the project design phase to the completion of work at the construction site, and adequate preventive measures must be implemented following expert recommendations.

The results from the activity risk expert panel can be used as an important tool for making carrying out risk assessment when a vertical formwork task is scheduled. Each construction project involves specific health and safety issues because each has different circumstances and environment. However, the general health and safety topics described in this research can be addressed effectively on each project.

As for preventive measures, resources are always limited and must be managed efficiently. Construction practitioners must first identify the most dangerous activities and their safety risks. This is the first step for prioritising preventive measures according to a suitable scale of needs. The classification obtained according to the scores provided by expert panel members in this study placed plumb/level forms, cutting materials, crane-lift material, and ascending/descending ladders as the activities with highest risk factors. Likewise, a fall to a lower level, cutting and overexertion were the most dangerous safety risks according to the experts. Accordingly, special attention is needed to reduce these safety risks.

Although the construction issues addressed in this research obtained different values depending on the stakeholder or group of interest, most of the items did not score a mean difference in value of over the absolute value of one, between groups of respondent.

In the design phase of the construction project, lack of interaction between designers and formwork/falsework companies was detected by all stakeholders. In addition, they pointed to the failure to specify the type of the formwork/falsework in the projects as a usual practice.

With regard to the design phase of the formwork/falsework, the final cost of the product was considered the most important factor while the product is being designed. The productivity factor was also considered to be important. In contrast, the safety factor obtained the lowest score. These results were corroborated by the ones obtained in the construction phase, which show that the cheapest formwork is chosen rather than the safest one.

Special attention must be given to training in health and safety for formwork users, and the provision of qualified technicians by manufacturers. Questions on this issue revealed the greatest difference between the perception of manufacturers and that of constructors. Both groups noted the current lack of training in health and safety for formwork users from the manufacturers.

There was considerable consensus regarding the legal issues studied. All the groups considered that standards about design and use of formwork would improve health and safety levels, and that the improvement would be greater if the standard was compulsory.

In addition, it can be concluded that training in Prevention through Design for Engineering and Architecture students is not especially good, and significant improvements are required to rectify this situation.

A higher level of understanding of PtD corresponded to a higher consideration of the importance of PtD in construction. Although the inclusion of PtD in construction courses from Bologna degrees is lower than in those from Old degrees, the total amount of OHS-specific courses identified in Bologna degrees was greater. In addition, the new courses included in new academic itineraries were compulsory rather than optional, thus ensuring that students cannot finish their degrees without some OHS training. However, OHS is still dealt with insufficiently and requires better integration in Engineering and Architecture under/degrees. The results from the surveys given to lecturers showed that PtD and OHS are not priority subjects in the construction courses examined in this study. Although it is assumed that future professionals will be qualified in OHS and PtD, current education and training are insufficient to achieve this.

The absence of PtD in many construction degrees could be solved in two ways: including PtD concepts with the other technical concepts or creating specific OHS courses that focus on construction issues.

Although this would require an extra effort in the already crowded engineering and architecture curricula, this occupational education and training would prevent many accidents in the future.

3.2 GLOBAL CONCLUSIONS.

The global conclusions are based on this extended and updated insight to the likely risks in the construction of vertical structures and the management of Occupational Health and Safety using the PtD concept.

FIRST CONCLUSION
Several variables are related to the severity of the accidents that have occurred in Spanish construction. Factors such as age, size of company, place of the accident or deviation proved significant in the cases studied. Consequently, a better understanding of these factors can improve planning of preventive measures and reduce accident rates.

SECOND CONCLUSION
Training in safety is an accident factor that must be highlighted, as the study revealed more differences than similarities when comparing qualified and non-qualified workers´ accident rates in the construction of vertical concrete structures.

THIRD CONCLUSION
Construction practitioners must first identify the most dangerous activities and their safety risks. This is the first step for prioritising preventive measures according to a suitable scale of needs.

FOURTH CONCLUSION
Occupational health and safety needs are not perceived in the same way by stakeholders with influence in the implementation of PtD during the development of the construction project (project designer, contractor, formwork manufacturer). PtD is lacking in construction projects.

The low incidence of PtD may be motivated by a lack of knowledge and bad comunication between participants. More PtD training and better comunication between construction participants would improve the occupational health and safety levels from the outset of a project to its completion.

FIFTH CONCLUSION

Last but not least, the Prevention through Design concept is of little import in the academic contents of the engineering and architecture degrees studied. This fact explains the lack of awareness of PtD strategies among current and future construction professionals. The lack of training in PtD is a major hurdle impeding the improvement of occupational health and safety in construction projects and the decrease of accident rates.

3.3 IMPACT ON THE INDUSTRY.

3.3.1 Impact from the accident analysis in construction.

Identification of the main variables present in construction accidents is the first step towards minimising and reducing accidents and their consequences. The conclusions of this paper can be used by companies in their occupational safety strategies as well as in their safety training programmes. Specific training can be designed taking into account the specific needs of each group of workers and each type of company.

3.3.2 Impact from the professional opinion and stakeholder perception

The results from the activity risk study can be used by construction companies when they are designing safety systems. They provide them with forewarning about the most dangerous safety risks and activities, thus allowing them to bear them in mind when elaborating occupational safety plans. In addition, these results can be used to prioritise the most effective safety elements for construction projects in order to control construction safety risk. This strategic information may prove especially useful when project resources are limited, because it can be used to select the most effective measures.

The conclusions from this research can be used by construction companies in several ways. Health and Safety managers and supervisors can improve associated risks with specific activities, especially with plumb/level form activities and risks of falls to lower levels. Project engineers and designers can estimate the exposure time for their specific project and calculate the total risk. This calculation can be made considering the different formwork types and design solutions. Companies can use the results obtained in their occupational safety strategies and in their safety training programmes. Further research on this issue is recommended to promote means by which to prevent the risks involved.

Identification of the sector´s needs through the opinion of the main participants in the formwork trade is an important step towards improving health and safety levels. According to the perception of these participants, any improvement will have a positive impact on every organisation involved. Knowledge of the other participants' perceptions could facilitate communication and interaction between those involved and generate a positive atmosphere of cooperation between groups in order to improve health and safety levels from the very beginning of the construction at the design phase.

The results obtained concerning the integration of PtD in university courses should help to improve the academic contents of such courses.

3.4 LIMITATIONS.

3.4.1 Accident analysis.

The findings of this research are based on the data available from the official accident notification forms. Further knowledge could be derived from such studies if richer data were collected, such as the factors proposed by Haslam *et al*. (2005).

The data analysed are only from Spain, and so the conclusions may prove different in other countries. Nonetheless, they should at least provide an indication of sensitive common variables.

Unreported accidents are of course excluded as no data are available on them. The data of the people employed for each variable analysed have not been segregated, and so the likelihood of an accident being serious or fatal has only been studied once it occurs. The likelihood of the accident occurring in the first place has not been considered.

3.4.2 Professionals' opinion.

This research does not consider the exposure [worker-hours] to the hazards. The total risk will depend on the magnitude of the exposure. The exposure can vary significantly depending on the specific construction project.

If the exposure is high but the unit risk is low, then the total risk may be high relative to the other activities. Similarly, if the exposure is low, but the unit risk is high, then the total risk may be low compared to the other activities. In spite of this fact, unit risk is a very important tool to quantify health and safety needs.

The results allow us to compare risk values between different activities, and valuate them in order to prioritise preventive resources. However, as a relative subjective scale, it cannot be said that over a specific value the risk is greater and under this value the risk is minor.

Although the most important international commercial formwork companies were represented in the research, other companies rejected the invitation to participate. A similar limitation is observed in the participation of construction company professionals. Although the construction companies selected are international companies that are present in several countries, they are only a sample from the population studied. The small number of project designers selected in comparison with the other two categories of respondent, was due to the fact that there are few such designers.

3.5 FUTURE RESEARCH.

Some variables in the accident analysis merit more in-depth study in future research to obtain a more accurate estimation of their influence. One example of this is the climatic zone or weather variable. It is not clear why differences exist in the severity of accidents between Mediterranean and Continental Zones.

Different training strategies should be investigated and developed in order to improve the effectiveness of training experienced workers. Tasks away from the habitual worksite should be addressed better, and new safety procedures and measures must be implemented.
In addition, new risk assessment of other construction activities other than formwork/falsework construction could be developed following the methodology of expert panels.

Communication channels between different stakeholders could be an interesting issue in future investigations.

Education and training in the concept of prevention through design and should be improved, affording it greater importance in courses for current and future engineers and architects. The evolution of syllabi contents and their impact on accident rates should also be addressed in future research works.

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4. REFERENCES.

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PUBLICATIONS

5. PUBLICATIONS.

5.1 PUBLICATION I. ANALYSIS OF CONSTRUCTION ACCIDENTS IN SPAIN, 2003-2008.

Journal of Safety Research 43 (2012) 381–388

Contents lists available at SciVerse ScienceDirect

Journal of Safety Research

journal homepage: www.elsevier.com/locate/jsr

Analysis of construction accidents in Spain, 2003-2008

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ARTICLE INFO

Article history:
Received 16 January 2012
Received in revised form 2 July 2012
Accepted 30 July 2012
Available online 24 October 2012

Keywords:
Construction
Accidents
Severity
Rates
Variables

ABSTRACT

Introduction: The research objective for this paper is to obtain a new extended and updated insight to the likely causes of construction accidents in Spain, in order to identify suitable mitigating actions. *Method:* The paper analyzes all construction sector accidents in Spain between 2003 and 2008. Ten variables were chosen and the influence of each variable is evaluated with respect to the severity of the accident. The descriptive analysis is based on a total of 1,163,178 accidents. *Results:* Results showed that the severity of accidents was related to variables including age, CNAE (National Classification of Economic Activities) code, size of company, length of service, location of accident, day of the week, days of absence, deviation, injury, and climatic zones. *Conclusions:* According to data analyzed, a large company is not always necessarily safer than a small company in the aspect of fatal accidents, experienced workers do not have the best accident fatality rates, and accidents occurring away from the usual workplace had more severe consequences. *Impact on the industry:* Results obtained in this paper can be used by companies in their occupational safety strategies, and in their safety training programs.

1. Introduction

Accident rates in construction continue to be an international cause of concern. This concern is justified because construction has the highest casualty rates in many countries (Camino López, Ritzel, Fontaneda, & González Alcantara, 2008). There are significant differences in the submission of reports and work accident registration procedures in different EU countries, such as the definition of a workplace accident and consideration of road traffic accidents (Aires, Rubio, & Gibb, 2010). Harmonization of the data by Eurostat allows some comparison of the results of member states, but it is important to note that these comparisons between countries are still not completely reliable (Aires et al.).

An example is provided in Fig. 1 where we see the accident rates in construction across the European Union, Spain, and UK in recent years (Eurostat, 2010). Incidence rates in Spain are around twice those of the European average. On the other hand, the United Kingdom rates are very low compared to the rest of Europe. Although incidence rates have decreased in the last decade in the majority of European states, Spain has not decreased enough to reach the European average levels.

In order to identify solutions for accidents in construction, different researchers have investigated the problem in many countries. Examples of these studies for various countries include: Taiwan (Cheng, Leu, Lin, & Fan, 2010), Scotland (Cameron, Hare, & Davies, 2008), Turkey (Etiler, Colak, Bicer, & Barut, 2004; Mungen & Gürcanli, 2005), Portugal (Macedo & Silva, 2005), and South Korea (Im et al., 2009). A significant investigation in the UK (Brace, Gibb, Pendlebury, & Bust, 2009) identified that the underlying factors in fatal accidents and high-potential incidents can be grouped into three categories: (a) macro factors, relating to stakeholders such as society, education, industry, corporate organization and trades unions; (b) mezzo factors, referring to aspects such as project management, organization, and procurement; and (c) micro factors, meaning worker, workplace, and supervisor issues.

When an accident is analyzed, many variables and factors are present. For example, a study about contributing factors in construction accidents in the UK (Haslam et al., 2005) concluded that problems arising from workers or the work team were present in 70% of the accidents, workplace issues in 49%, shortcomings with equipment (including PPE) in 56%, problems with suitability and condition of materials (27%), and deficiencies with risk management in 84% of accidents.

The influence of the difference variables in the severity of the injuries must be considered. There are a number of research studies in this direction. For example, Sawacha, Naoum, and Fong (1999) showed that operatives between the ages of 16–20 were more likely to have accidents than others. Further analysis of the data in the same paper suggests that the level of accidents tends to decline steadily after the age of 28 to reach a low point in the mid-40s. In a similar way, Salminen (2004) concluded that young workers had a higher injury rate than older workers, however, the injuries of young workers were reported as less often fatal than those of older workers. In addition, Chau et al. (2004) showed that risks of injury for each worker depend on age, body mass index, hearing disorders, sleep disorders, and sporting activities. If you are young, or overweight, or have any hearing or sleep

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http://dx.doi.org/10.1016/j.jsr.2012.07.005

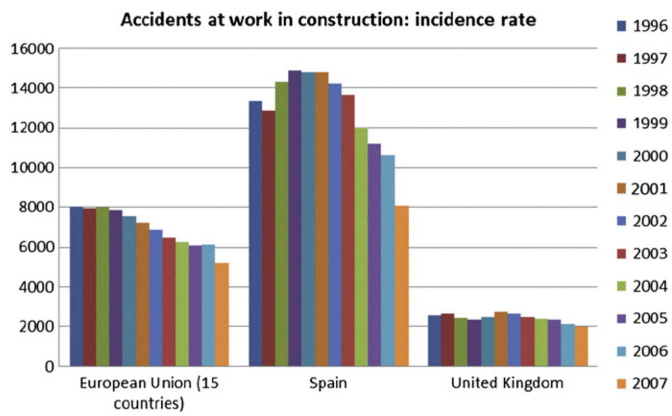


Fig. 1. Accidents at work in construction: incidence rate. Source Eurostat, 2010.

disorder and no sports activities, then your risk is higher than another person without these risk factors. However, it is necessary to remember that construction accidents arise from a failure in the interaction between workers, their workplace, and the materials and equipment they are using (Haslam et al., 2003).

In this paper, the research objective is to obtain a new extended and updated insight to the likely causes of construction accidents in Spain, in order to identify appropriate mitigating actions.

2. Methodology

2.1. Accidents data

Since 2003, the Spanish National Institute of Safety and Hygiene at Works must be notified of all accidents that result in an absence from work of one or more days. This is compulsory according to Spanish Law (BOE. Boletín Oficial del Estado [BOE], 2002; ORDEN TAS/2926/2002, de 19 de noviembre, por la que se establecen nuevos modelos para la notificación de los accidentes de trabajo y se posibilita su transmisión por procedimiento electrónico). Notification must be sent through the electronic system called DELT@, filling an Official Workplace Incident Notification Form. [Parte Oficial de Accidente de Trabajo]. For this study, the Ministry of Labour and Immigration supplied the anonymous data of all workplace accidents in the Spanish construction sector as defined by the National Classification of Economic Activities in Spain (CNAE 93.Rev 1) during the period 2003-2008. A total number of 1,163,178 Notification Forms were supplied. Although reporting is mandatory, it is possible that some cases remain unreported.

2.2. Analysis design

The analysis design for this paper was based on previous research by Camino López et al. (2008). First the study variables were chosen and then categorized in groups to assess the relationship between all the variables and the severity of the outcomes of each accident. Although main aspects of the methodology employed are similar to Camino Lopez et al., this research introduces some differences in the following aspects:

- Data periods of time analyzed are different.
- Data analyzed in the present study include, in line with the law, all the accidents reported in the construction sector between 2003-2008. In Camino Lopez et al.'s previous study (2008) it is possible that more accidents were not included, because from 1990-2000 reporting accidents through Delt@ system was not compulsory.
- Some of the chosen variables were not analyzed in the previous paper.
- In the results, the severity of the accident is shown in four different levels: light, serious, very serious, and fatal.

2.3. Variables and period of time

The authors' original idea was use a similar methodology to Haslam et al. (2005) studying shaping factors and originating influences. However, differences between data sets did not allow us to implement it properly. Haslam et al. analyzed fewer accidents (only 100 individual accidents) but more deeply and gathered site-based data entailing interviews with accident-involved personnel and their supervisor or manager, inspection of the accident site, and review of relevant documentation such as accident notification form. In our case, we only had access to the official accident notification form, but from 1,163,178 accidents.

In a preliminary approach we analyzed all variables included in the accident notification form (57 variables) elaborating contingency tables. In some variables the majority of the values in the contingency tables did not reach a statistical significance of 95% in order to reject the hypothesis of independence of variables, and we could not confirm the existence of more than a random influence for severity-variable. Accordingly, the majority of the 57 variables were rejected for this paper.

Therefore, variables chosen were categorized into five groups after Camino López et al. (2008). These groups are personal, business, material, temporal and geographic.

- **Personal variables** describe characteristics of the worker involved in the accident. Included in this group is variable age.
- **Business variables** describe aspects about the activity and its organization. Included in this group are: National Classification of Economic Activities (CNAE), company staff, length service, and the location of the accident.
- **Temporal variables** include day of the week, days of absence.
- **Material variables** include deviation from accepted practice, as a not expected event, and injury.
- **Geographic variables** used in this study describe the severity of the accidents in the different zones according to the climatic zone. (Table 1).

The period of time between 2003 and 2008 was elected for this study because, in this period, the National Classification of Economic Activities in Spain (CNAE 93.Rev 1) was not changed. Before 2003 and after 2008 there were some modifications to this classification.

2.4. Statistical analysis

Continuing with the methodology performed by Camino López et al. (2008) contingency tables were made and chi-square values were calculated to test hypotheses of the independence of the each variable with respect to severity.

Again following Camino López et al. (2008), the corrected standardized residuals (csr) were also calculated. When their absolute value was less than 1.96, they were marked with an asterisk because

Table 1
Summary of variables.

Variable Group	Variable
Personal	Age
Business	National Classification of Economic Activities (CNAE)
	Company Staff
	Length service
	Location of Accident
Temporal	Day of the week
	Days of absence
Material	Deviation
	Injury
Geographic	Climatic Zones

Table 2
Total accidents in Spanish construction comparing age and severity.

Chi-Squared	1820.92									
	d.f = 27	Sig = 0.000								
	Total Accidents		**Light Accidents**		**Serious Accidents**		**Very Serious Accidents**		**Fatalities**	
	N = **1163165**		N = **1145675**		N = **14993**		N = **764**		N = **1733**	
Age	Number	**TAR%**	Number	**LAR%**	Number	**SAR%**	Number	**VSAR%**	Number	**FAR%**
<16	68	**0.01**	65	**0.01**	2	**0.01***	1	**0.13**	0	**0.00***
16-19	57,564	**4.95**	56,943	**4.97**	541	**3.61**	40	**5.24***	40	**2.31**
20-24	176,038	**15.13**	174,277	**15.21**	1,534	**10.23**	80	**10.47**	147	**8.48**
25-29	207,681	**17.85**	205,263	**17.92**	2,095	**13.97**	107	**14.01**	216	**12.46**
30-39	347,958	**29.91**	343,081	**29.95**	4,226	**28.19**	220	**28.80***	431	**24.87**
40-49	228,121	**19.61**	223,916	**19.54**	3,630	**24.21**	162	**21.20***	413	**23.83**
50-59	120,546	**10.36**	117,596	**10.26**	2,443	**16.29**	125	**16.36**	382	**22.04**
60-65	24,654	**2.12**	24,013	**2.10**	511	**3.41**	27	**3.53**	103	**5.94**
65-70	428	**0.04**	414	**0.04**	11	**0.07**	2	**0.26**	1	**0.06***
>70	107	**0.01***	107	**0.01***	0	**0.00**	0	**0.00**	0	**0.00**

* : Corrected Standardised Residuals <1.96 in absolute value.

they do not reach a statistical significance of 95% in order to reject the hypothesis of independence of variables, and we could not confirm the existence of more than a random influence for severity-variable.

In a preliminary approach we analyzed all variables included in the anonymous Official Workplace Incident Notification elaborating their contingency tables. Variables whose majority of the values in their contingency tables did not reach a statistical significance were rejected for this paper. Finally, we chose the statistically better 10 variables.

The classification of the accidents analyzed is based on medical criteria, because Spanish health authorities have the obligation to diagnose the severity of each accident. For this purpose the severity of an accident can be classified into four different levels: light accident, serious accident, very serious accident, and fatal accident. The severity level marked in the Official Workplace Incident Notification Form must be the same severity level described by a doctor, in the Medical Injuries Form (BOE. Boletín Oficial del Estado [BOE], 2002. ORDEN TAS/2926/2002, de 19 de noviembre, por la que se establecen nuevos modelos para la notificación de los accidentes de trabajo y se posibilita su transmisión por procedimiento electrónico). In addition, different accident ratios were calculated and expressed in percentage terms.

Rates were obtained by dividing the number of accidents chosen in the community studied by the number of total accidents chosen. Thus, the Total Accident Rate (TAR) was obtained dividing the number of total accidents in the community studied by the number of total accidents analyzed. The Light Accident Rate (LAR) was obtained by dividing the number of light accidents in the community studied by the number of total light accidents. The Serious Accident Rate (SAR) was obtained by dividing the number of serious accident in the community studied by the number of total serious accidents. The Very Serious Accident Rate (VSAR) was obtained by dividing the number of very serious accidents in the community studied by the number of total very serious accidents. Finally, the Fatal Accident Rate (FAR) was obtained by dividing the number of fatal accidents in the community studied by the total number of fatal accidents.

It is very important not to forget that data studied are only about accidents that have occurred. Rates obtained in this study are not the typical incidence rate (number of accidents per number of workers at risk) because data about workers at risk in each category studied are not available. However rates calculated in this paper have allowed the difference between the severities of the accidents that have occurred to be studied. In this way, the findings show the probability of an accident to be serious or fatal once it occurs, but not the probability that the accident occurs in the first place.

The statistical analysis package SPSS (Statistical Package for the Social Sciences) was used to analyze the data.

3. Results and discussion

3.1. Personal variables

Results obtained in Table 2 showed that, when an accident happens, the probability that severity will be high increases with the age of the worker. This fact is especially significant in groups of ages between 60 and 65 years, and between 20 and 24 years. In the older group it was observed that the light accident rate had very similar value to the total accident rate (LAR 2.10%, TAR 2.12%) but the fatal accident rate was more than double (FAR 5.94%). In the younger group the light accident rate and total accident rate were very similar too (LAR 15.21%, TAR 15.13%), but the fatal accident rate decreased considerably in this group (8.48%).

3.2. Business variables

3.2.1. CNAE

Activity of the organizations is one of the aspects to be considered when analyzing accidents in construction. Using the National Classification of Economic Activities (CNAE 93.Rev 1) the construction sector in Spain in the period of time 2003-2008 can be classified in five groups (Table 3).

Table 4 shows that the distribution of the accidents is concentrated in activities 452 *Construction of buildings and civil construction*, and 453 *Fit out of construction works*. The incidence rates cannot be calculated because the total of workers occupied in these specific activities is not

Table 3
Construction Activities.

Activity	CNAE CODE
Preparation of construction sites (Demolitions, earth moving, land survey, excavations)	451
Construction of buildings and civil construction (Buildings, civil works, electrical nets, hydraulic works)	452
Fit out of construction work (Partitions, acoustic, electrical, plumbing works, etc)	453
Completion of construction works (Painting, Glazing, wood, others)	454
Hiring of construction equipment with a worker (Not including contractors with their own equipment)	455

Table 4
Total accidents in Spanish construction comparing CNAE and severity.

Chi-Squared	234.142									
	d.f = 12	**Sig = 0.000**								
	Total Accidents		**Light Accidents**		**Serious Accidents**		**Very Serious Accidents**		**Fatal Accidents**	
	N = **1163178**		N = **1145688**		N = **14993**		N = **764**		N = **1733**	
CNAE CODE	Number	**TAR%**	Number	**LAR%**	Number	**SAR%**	Number	**VSAR%**	Number	**FAR%**
451	5,800	**0.50**	5,646	**0.49**	129	**0.86**	4	**0.52***	21	**1.21**
452	928,214	**79.80**	913,976	**79.78**	12,232	**81.58**	616	**80.63***	1,390	**80.21***
453	215,530	**18.53**	212,763	**18.57**	2,363	**15.76**	125	**16.36***	279	**16.10**
454	13,054	**1.12**	12,741	**1.11**	257	**1.71**	18	**2.36**	38	**2.19**
455	580	**0.05**	562	**0.05**	12	**0.08**	1	**0.13***	5	**0.29**

* : Corrected Standardised Residuals <1.96 in absolute value.

known, but we can evaluate the percentage evolution in the calculated rates.

It is significant that, although activity 454 *Completion of construction works* only has 1.12% of the total accidents (TAR) in the sector, the percentage increases with the severity of the accidents (SAR (1.71%) > LAR (1.11%)) and peaks at VSAR (2.36%). The fatal rate is lower but very close (2.19%).

3.2.2. Company staff

Fig. 2 compares accident outcome severity with company size. Comparing TAR and FAR, the data tend to suggest that the larger the company the more likely the chance of having a fatal accident.

According to the percentages calculated of fatal accidents respect total accidents occurred for each company size, shown in Table 5, an accident that occurred in a big company was more likely to be fatal than one occurring in a smaller one. Companies with more than 500 workers obtained the worst result (0.2489% of accidents that occurred in the company were fatal). On the other hand companies from 26 to 50 obtained the best result (0.1316% of accidents that occurred in the company were fatal). Companies with up to 250 workers obtained similar percentages between 0.13 and 0.16%, and big companies over 250 workers obtained percentages bigger than 0.23%.

However, these data are only from accidents that occurred, and do not take account of the numbers of people employed in these companies and therefore could be misleading. It has been shown that a large company is associated with better safety levels than a small one (Hinze & Gambatese, 2003). In this sense a study of 231 deaths in the construction industry (Buskin & Paulozzi, 1987) concluded that there was a significant trend towards increasing mortality with decreasing company size in the proportionate mortality ratios (PMRs) studied.

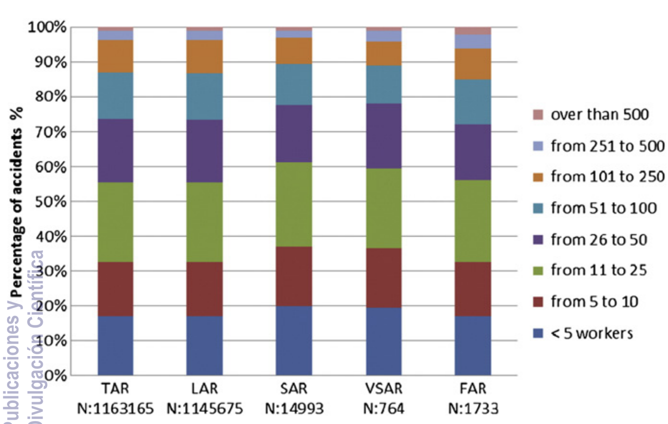


Fig. 2. Total accidents in Spanish construction comparing company staff and severity.

3.2.3. Length of service with the company

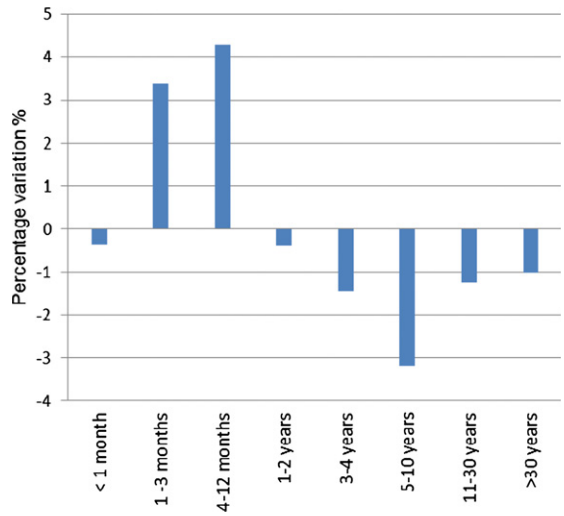
This factor was studied by Cattledge, Hendricks, and Stanevich (1996), with particular reference to falls from different levels. Length of employment with the company at the time of injury ranged from one week to more than 30 years. It is important to note that these data deal with how long the person has been employed by a particular company rather than their experience in the industry as a whole. Despite the wide range, 60% of all accidents claimed were employed for two years or less, of which 26% were employed for six months or less. In our study, accidents involving workers with less than three years' experience in the company represented 81% of the total number of accidents. This percentage gets lower when considering fatal accidents of this group of workers (74%). It is remarkable that the FAR decreases compared with TAR, when the individual's experience in the company increases from a month to one year's experience, but this tendency is the opposite from one year to more experienced people. That can be observed better by calculating the difference between TAR and FAR in each experience group (Fig. 3). Fig. 3 shows in terms of variation of the rates, the best rate improvement of FAR with respect to TAR, is in the group of workers with experience between 4-12 months (TAR-FAR = 4.27%) and the worst rate difference is in worker with 5-10 year experience (TAR-FAR = -3.19%). The problem in the first temporal group with less than one month's experience could potentially be fixed with safety training programs (Xiuwen, Entzel, Men, Chowdhury, & Schneider, 2004). In the group of workers with 5-10 years' experience, this solution is less likely to be successful, because hazards are often misjudged by them (Huang & Hinze, 2003). In a study of causality of fatal accidents for the UK Government, Brace et al. (2009) argued that workers often developed a 'risk accepting' attitude towards construction hazards – claiming 'it won't happen to me.' Other strategies must be developed to prevent fatal accidents in this group.

3.2.4. Location of accident

Safety of construction sites has been considered in various studies (Sawacha et al., 1999; Toole, 2002), but not all accidents occurring

Table 5
Percentages of fatal accidents respect total accidents.

Company Staff	Number of Total accidents (NTA)	Number of Fatal Accidents (NFA)	% (NFA/NTA)
<5 workers	198,802	298	**0,1499**
from 5 to 10	179,659	265	**0,1475**
from 11 to 25	266,766	409	**0,1533**
from 26 to 50	210,446	277	**0,1316**
from 51 to 100	154,558	227	**0,1469**
from 101 to 250	108,428	151	**0,1393**
from 251 to 500	30,058	70	**0,2329**
over 500	14,461	36	**0,2489**



Length service	TAR - FAR
< 1 month	-0.37
1-3 months	3.38
4-12 months	4.27
1-2 years	-0.39
3-4 years	-1.45
5-10 years	-3.19
11-30 years	-1.24
>30 years	-1.02

Fig. 3. Difference between rates. TAR-FAR (%), against length of service.

in the construction sector actually occur at the construction site. The workforce of construction firms do not work all the time in their habitual worksite, sometimes they are moving between sites or between different areas of their habitual site. Considering results of Table 6, a high percentage of accidents analyzed occurred on the habitual worksite (TA 83%), but their fatality rate was considerably lower (FA 48%). On the other hand, accidents occurring on a non-habitual site represented less than 11% of TA, but 25% of fatalities. These data highlight the problem with fatalities of workers not based on one specific worksite, which is a problem that must be considered more deeply in future research. The other two categories, on the way from worksite to worksite, and going to the worksite or back home, are difficult to evaluate because many times they are considered only traffic accidents and they are not considered work accidents so are not entered in the industrial sector statistics.

3.2.5. Day of the week

In Fig. 4 we see that Monday is the day of the week with more accidents. This fact, called the "Monday Effect," has been studied by Card and McCall (1996) and Campolieti and Hyatt (2006). This effect assumes that some of the injuries reported on Monday actually occurred on the weekend, but they were not reported the real day of the accident, one explanation for this effect is because social benefits from the insurance company would change with more compensation paid for work-related injuries than for those incurred during leisure activities. The values for light accidents (LAR) and serious accidents (SAR) are very similar to their respective TAR, but rest of the rates, VSAR, and FAR decrease from Monday to Wednesday, increase from Wednesday to Thursday, and decrease again from Thursday to Friday.

3.2.6. Days of absence

In Table 7, days of absence are shown. It must be considered that sometimes light accidents are longer than a few days because their real recovery time is longer than nominally expected recovery time. Another consideration must be made in respect of fatal accidents. If the death is instantaneous or in the same day, one day of absence is registered in the database. In the rest of cases, the difference between the day of the accident and the day of the death are registered. It is remarkable that the group of accidents resulting in time off work of between 16-30 days presented the highest value in three of the five rates calculated (TAR, LAR, VSAR). In the other two rates this group was not the first but it was the second. So accidents, causing 16-30 days of absence must be considered and investigated especially because they represented nearly a third of the accidents occurring.

3.3. Material

3.3.1. Deviation

Accidents produced by loss of machine control and falls are the third of the total accidents. This percentage is more than half when we compare the aggregate of both deviations with serious, very serious, and fatal accidents (Aggregates: TAR 33%, SAR 57%, VSAR 57%, FAR 51%) (Fig. 5). Therefore these deviations must be given special attention, and must be reduced as far as possible with preventative measures, training workers in safety, and safety equipment. In addition to

Table 6
Total accidents in Spanish construction comparing accident location against severity.

Chi-Squared	5404.93									
	d.f = 9	Sig = 0.000								
	Total Accidents		Light Accidents		Serious Accidents		Very serious Accidents		Fatal Accidents	
	N = 1163178		N = 1145688		N = 14993		N = 764		N = 1733	
Accident Place	Number	TAR%	Number	LAR%	Number	SAR%	Number	VSAR%	Number	FAR%
Habitual worksite	962,628	**82.76**	951,247	**83.03**	10,120	**67.50**	435	**56.94**	826	**47.66**
On the way from worksite-worksite	22,388	**1.92**	21,693	**1.89**	489	**3.26**	62	**8.12**	144	**8.31**
Going worksite or backing home	54,795	**4.71**	52,654	**4.60**	1,571	**10.48**	137	**17.93**	433	**24.99**
Non-habitual worksite	123,367	**10.61**	120,094	**10.48**	2,813	**18.76**	130	**17.02**	330	**19.04**

*: Corrected Standardised Residuals <1.96 in absolute value.

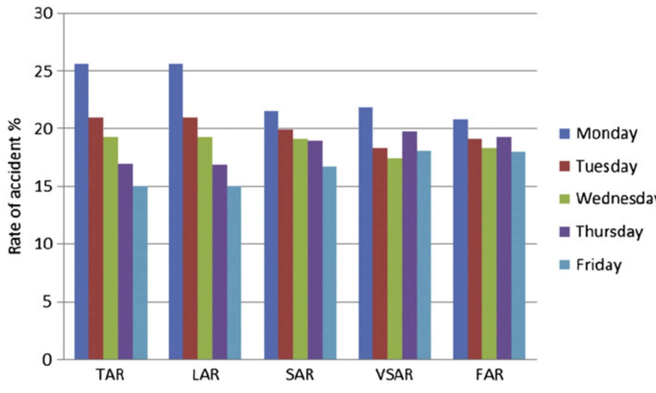


Fig. 4. Accident rates comparing day of the week against severity.

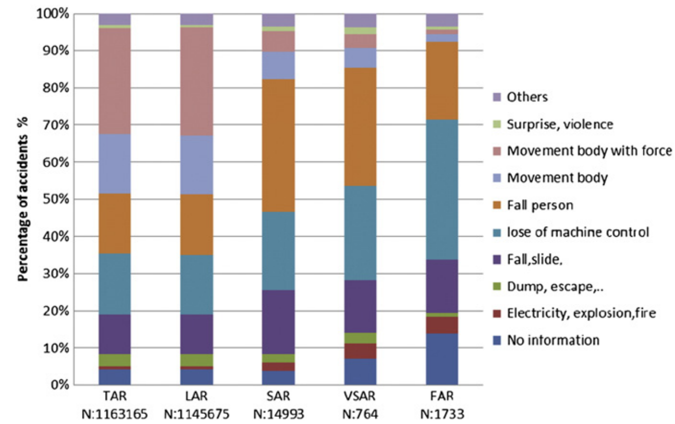


Fig. 5. Total accidents in Spanish construction comparing deviation and severity.

these data, a study about causes of accidents (Gibb, Haslam, Hide, Gyi, & Duff, 2006) concluded that greater attention should be given to the design and selection of tools, equipment, and materials. Safety, rather than price, should be the paramount consideration (Fig. 5).

3.3.2. Injuries

In Spain, wounds and superficial injuries, dislocations sprains, and strains are 80% of TAR (from Table 8). This group of accidents has an insignificant impact on fatalities (0.75%). The most dangerous injuries are concentrated in: concussions and internal injuries, multiple lesions, heart attacks, strokes, and other non-traumatic diseases. Special attention should be given to heart attacks, strokes, and other non-traumatic diseases, because they represented only 1,319 of the 1,163,178 total accidents (0.11%), but they represented 287 accidents of the 1,733 fatalities (17%). The FAR value increase with respect to TAR value is especially high in this group. A solution could be training workers or supervisors in first aid for these cases. This finding is supported by the general increase in availability of equipment such as defibrillators in work places and public areas.

3.4. Climatic zones

The severity of accidents vary depending on the climatic zone where they happened. This is demonstrated in Table 10. Spain has been divided into four climatic zones according to data obtained from Spanish National Weather Service (AEMET, 2011). These climatic zones have been called Continental, Mediterranean, Oceanic, and Tropical. The main characteristics of each zone are described in Table 9.

Climatic zones showed different evolutions of their severity rates. In the area under influence of Mediterranean weather, the Fatal Accident Rate is lower than the Total Accident (FAR 41%, TAR 48%). On the other hand, continental weather rates increased when Total Accidents Rates were compared with fatalities rates (FAR 38%, TAR 35%). The conclusion that Mediterranean weather is more conducive to safety than continental is not valid because the evolution of the serious accident rate is opposite in each case. In order to get better results about the climatic influence in accidents in construction, a more detailed study must be performed about this phenomenon.

4. Conclusions

These analyses showed that seriousness of accidents are related to various different variables studied. Concluding remarks for each variable are described as follows.

- *Age*. Analysis of the data does not show whether the accident rate varies with age, but rather, the likely consequence of any accident does vary with age – with the lowest consequence being at the 20-24 age group. An accident involving an older worker would probably have more severe consequences. Special training plans must be considered for older workers and fitness for work regimes established. Assignment of the tasks inside the works must be adapted to the age of the worker, a task with low risk for a young worker can become a high risk task for an older one.
- *CNAE Code*. Regarding different National Code of Activities in construction studied, the "completion of construction works" activity had the

Table 7
Total accidents in Spanish construction comparing days of absence with severity.

Chi-Squared	540441									
	d.f = 21	**Sig = 0.000**								
	Total Accidents		**Light Accidents**		**Serious Accidents**		**Very Serious Accidents**		**Fatal Accidents**	
	N = **1163178**		N = **1145688**		N = **14993**		N = **764**		N = **1733**	
Absence	Number	**TAR%**	Number	**LAR%**	Number	**SAR%**	Number	**VSAR%**	Number	**FAR%**
1 day	3,148	**0.27**	1,675	**0.15**	69	**0.46**	12	**1.57**	1,392	**80.32**
2–7 days	307,141	**26.41**	306,869	**26.78**	163	**1.09**	50	**6.54**	59	**3.40**
8–15 days	306,764	**26.37**	306,441	**26.75**	291	**1.94**	27	**3.53**	5	**0.29**
16-30 days	366,289	**31.49**	362,037	**31.60**	3,742	**24.96**	238	**31.15***	272	**15.70**
1-3 months	137,725	**11.84**	134,978	**11.78**	2,698	**18.00**	49	**6.41**	0	**0.00**
4-6 months	30,036	**2.58**	25,020	**2.18**	4,835	**32.25**	179	**23.43**	2	**0.12**
7 months-12 months	10,895	**0.94**	7,971	**0.70**	2,747	**18.32**	175	**22.91**	2	**0.12**
more than 1 year	1,180	**0.10**	697	**0.06**	448	**2.99**	34	**4.45**	1	**0.06***

* : Corrected Standardised Residuals <1.96 in absolute value.

Table 8
Total accidents in Spain compared to injury-severity.

Chi-Squared	165752									
	d.f = 42	**Sig = 0.000**								
	Total Accidents		**Light Accidents**		**Serious Accidents**		**Very Serious Accidents**		**Fatal Accidents**	
	N = **1163178**		N = **1145688**		N = **14993**		N = **764**		N = **1733**	
Injury	Number	**TAR%**	Number	**LAR%**	Number	**SAR%**	Number	**VSAR%**	Number	**FAR%**
Unknown	19,557	**1.68**	19,221	**1.68**	238	**1.59***	23	**3.01**	75	**4.33**
Wounds. superficial injuries	451,352	**38.80**	449,924	**39.27**	1391	**9.28**	29	**3.80**	8	**0.46**
Bone crushing	83,982	**7.22**	76,126	**6.64**	7671	**51.16**	147	**19.24**	38	**2.19**
Dislocations, sprains and strains	474,939	**40.83**	474,098	**41.38**	812	**5.42**	24	**3.14**	5	**0.29**
Amputations	2,414	**0.21**	1,744	**0.15**	642	**4.28**	21	**2.75**	7	**0.40**
Concussions and internal injuries	61,775	**5.31**	59,975	**5.23**	1,349	**9.00**	169	**22.12**	282	**16.27**
Burns	12,916	**1.11**	12,531	**1.09**	349	**2.33**	17	**2.23**	19	**1.10***
Poisonings and infections	1,557	**0.13**	1,541	**0.13***	13	**0.09**	1	**0.13***	2	**0.12***
Drowning and asphyxiation	1,359	**0.12**	1,277	**0.11**	19	**0.13***	7	**0.92**	56	**3.23**
Effects of noise. Vibration and pressure	996	**0.09**	984	**0.09***	12	**0.08***	0	**0.00**	0	**0.00***
Extreme Temp Effects	919	**0.08**	908	**0.08***	9	**0.06***	0	**0.00**	2	**0.12***
Psychic trauma. traumatic shock	2,049	**0.18**	1,958	**0.17**	49	**0.33**	6	**0.79**	36	**2.08**
Multiple lesions	14,944	**1.28**	12,099	**1.06**	1,795	**11.97**	248	**32.46**	802	**46.28**
Heart attacks. strokes and other non-traumatic diseases	1,319	**0.11**	610	**0.05**	369	**2.46**	53	**6.94**	287	**16.56**
Other injuries	33,100	**2.85**	32,692	**2.85**	275	**1.83**	19	**2.49***	114	**6.58**

worst severity rates. More dangerous activities will need more specific preventive measures and more stringent safety procedures.

- *Size of company*. It may be concluded that a large company is not always necessary more safe than a small company in the aspect of fatal accidents. According to the data analyzed, the 'safest' size of a company with respect to fatal accidents is between 26 and 50 workers because their FAR is significantly lower than their TAR. However, these data could be misleading due to the numbers of employees and the effect of employing subcontractors and subcontract data not being included in these figures. Hence, if a worker employed by a large company has an accident it is more likely to be fatal than if they worked for a small organization. Differences and similarities between safety management procedures, safety integration in the tasks, and work organization must be identified relative to the size of the company with the aim to identify the best safety behaviors and promote their adoption to other companies.
- *Length of service*. Comparing again FAR with TAR from accidents occurred, it can be concluded that accidents suffered by workers with 5-10 years' experience had the worst consequences. On the other hand, workers with 4-12 months experience had the best accident fatal rates comparing the same cited rates. Experienced workers must be specially trained with specific programs according their needs. Often, refreshing safety knowledge is not enough. Training for more experienced workers must address their predisposition not to accept training or instruction and the likelihood that they have become risk accepting with regards to construction hazards.
- *Place of accident*. It was found that accidents occurred away from the usual workplace had more severe consequences, than accidents occurred at the usual workplace. More effort is required to improve the knowledge of risk, and preventive measures, when a worker changes his/her working location. Specific procedures must be designed and implemented when a worker is assigned for a task in a non-habitual worksite. New management techniques should be introduced in construction works to reduce the fatalities in this group

Table 9
Summary of climatic zones characteristics.

Continental	Winters are cold enough for snow and most of the rainfall occurs in late spring. Summers can be hot
Mediterranean	Temperatures are moderate and there is not a wide range between the summer highs and winter lows.
Oceanic	Winters are not as cold as in the continental climate zones. Summers tend to be warm, but not hot. Precipitation is relatively consistent throughout the year.
Tropical	Winters are relatively warm-mild, but not as hot as the summer season

The problem with fatalities of workers not based on one specific worksite is a problem that must be considered more deeply in future research.

- *Deviation*. In addition, analysis of the data showed that loss of machine control and falls from height cause a third of the light accidents. The addition of both deviations caused more than half of the rest of accidents. Activities where machines and work at height are present must be designed taking into account the possible deviation of these important factors. Risk assessment in these tasks must be exhaustive and procedures for their normal development very accurate and clear.
- *Injury*. Heart attacks, strokes and other non-traumatic diseases are especially fatal when they are present in an accident. Workers and supervisors must be trained in first aid for these cases and life-saving equipment be made readily available. Training in first aid can save workers lives.

4.1. Implications for the industry and government

Identification of main variables present in construction accidents is the first step to minimize and reduce accidents and their consequences. The conclusions of this paper can be used by companies in their occupational safety strategies, and in their safety training programs. Specific training can be designed taking account of specific needs for each group of workers and for each type of company.

Special attention must be given to the group of workers with 5-10 years' experience. Too often their hazards are misjudged by everybody in the works. Their managers, supervisors, and themselves tend to rely on their experience and skill, but experience is not a never-failing life guard, and it can be a double-edged sword, leading to a greater acceptance of risk.

Effort must be made in all companies, relative to their size and each worker's location, especially when they are not at the habitual worksite.

The findings of this research are based on the data available from the official accident notification forms. Further knowledge could be derived from such studies if richer data were collected for accidents, such as factors proposed by Haslam et al. (2005). However, the

Table 10
Total accidents in Spanish construction comparing climatic zone-Severity.

Chi-Squared	335.904									
	d.f = 9	**Sig = 0.000**								
	Total Accidents		**Light Accidents**		**Serious Accidents**		**Very Serious Accidents**		**Fatal Accidents**	
	N = **1163178**		N = **1145688**		N = **14993**		N = **764**		N = **1733**	
CLIMATIC ZONE	Number	**TAR%**	Number	**LAR%**	Number	**SAR%**	Number	**VSAR%**	Number	**FAR%**
Continental	405,221	**34.84**	399,521	**34.87**	4,751	**31.69**	294	**38.48**	655	**37.80**
Mediterranean	562,586	**48.37**	553,891	**48.35**	7,655	**51.06**	325	**42.54**	715	**41.26**
Oceanic	128,052	**11.01**	125,655	**10.97**	1,984	**13.23**	123	**16.10**	290	**16.73**
Tropical	67,319	**5.79**	66,621	**5.81**	603	**4.02**	22	**2.88**	73	**4.21**

authors acknowledge the challenges associated with such a proposal and further work is required to establish appropriate strategies.

4.2. Study limitations

Data analyzed are only from Spain, so the conclusions may be different to other countries, but they can give some indications of sensitive common variables.

Accidents where the employee was not absent from work are not compulsory to report to the government, so these accidents are not included. In addition, accidents that are not reported are, of course, also excluded, because there are no data about them.

The data of the people employed for each variable analyzed have not been segregated, so the probability of an accident to be serious or fatal has only been studied once it occurs. The probability that the accident occurs in the first place has not been considered.

4.3. Future research

Some variables should be studied more in-depth in future research to obtain a more accurate approach about their influence. An example of this it is the climatic zone variable, because it is not clear why differences in severity of accidents between Mediterranean and Continental Zones exist.

Different training strategies should be investigated and developed in order to improve the effectiveness of training in experienced workers. Tasks away from the habitual worksite must be addressed better; new safety procedures and measures must be implemented.

Acknowledgements

This study was financed by Spanish Government [Ministry of Science and Technology] through the project named Safety from Design in performance of formwork activities at civil works, (reference BIA2011-27338) an approved project in the National Plan of Research and Development.

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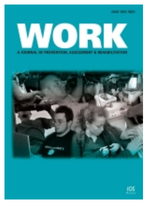
5.2 PUBLICATION II. SAFETY RISK ASSESSMENT FOR VERTICAL CONCRETE FORMWORK ACTIVITIES IN CIVIL ENGINEERING CONSTRUCTION.



Safety risk assessment for vertical concrete formwork activities in civil engineering construction.

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Received 10 January 2013
Accepted 6 April 2013

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Abstract:

BACKGROUND: The construction sector has one of the worst occupational health and safety records in Europe. Of all construction tasks, formwork activities are associated with a high frequency of accidents and injuries.
OBJECTIVE: This paper presents an investigation of the activities and related safety risks present in vertical formwork for in-situ concrete construction in the civil engineering sector. **METHODS:** Using the methodology of staticized groups, twelve activities and ten safety risks were identified and validated by experts. Every safety risk identified in this manner was quantified for each activity using binary methodology according to the frequency and severity scales developed in prior research. A panel of experts was selected according to the relevant literature on staticized groups.
RESULTS: The results obtained show that the activities with the highest risk in vertical formwork tasks are: Plumbing and leveling of forms, cutting of material, handling materials with cranes, and climbing or descending ladders. The most dangerous health and safety risks detected were falls from height, cutting and overexertion.
CONCLUSIONS The research findings provide construction practitioners with further evidence of the hazardous activities associated with concrete formwork construction and a starting point for targeting worker health and safety programmes.

Keywords: Occupational, expert panel, fall from height,

1. Introduction

According to the European Agency for Safety and Health at Work, the construction sector has one of the worst occupational health and safety records in Europe [1]. In the original 15 European Union (EU) Member States alone, about 1,300 construction workers die every year, another 800,000 are injured, and countless more suffer work-related ill health [2].
In the United States, 751 deaths occurred on construction sites in 2010 [3]. This figure accounts for about 17% of all fatal occupational injuries and is the fourth highest fatality rate for all U.S. industries. A similar problem exists in Spain where the fatality rate on construction sites in 2011 was 11.2 fatalities per 100,000 workers [4], with a total of 120 worker deaths.

Formwork is defined as a temporary structure whose purpose is to provide support and containment for fresh concrete until it can support itself. It molds the concrete to the desired shape and size, and controls its position and alignment [5].Of all construction tasks, formwork activities are associated with a high frequency of accidents and injuries. Huang and Hinze [6] observed that 5.83% of falls were attributed to the construction of formwork or to the construction of temporary structures and approximately 21% of all accidents involved wood framing or formwork construction. Many studies on construction safety are focused on topics such as contributing factors in construction accidents [7] or the impact of the different variables on the severity of the accidents [8,9,10,11,12,13,14,15]. Research studies have tried to quantify the safety risks of large-scale processes, such as underground construction projects [16] or buildings [17]. However, only one study was found in which the authors actually quantified the relative health and safety risks of specific construction tasks [18]. The objective of the latter study was to quantify the comprehensive health and safety risk at the activity level for a common construction process, such as formwork activities, using the Delphi method.

The aim of the present study is to quantify the health and safety risks indifferent vertical formwork activities in civil engineering construction using the binary method and the methodology of staticized groups.

2. Methodology

To achieve the study aim, the researchers used two different methodologies. A general research methodology was used to define the study ́s structure and a specific methodology inside this structure was used as a tool to elaborate the safety risk assessment.

With regard to the specific methodology, some authors have developed methods of risk quantification with different levels of complexity and application. An example of this is a study where ergonomic risks were analysed using ratings for each risk factor on a three-point scale [*insignificant*, *moderate* and *high*] in 65 construction activities to identify the presence of risk factors concerning overexertion injuries [19]. Other studies quantifying safety risk defined it as the product of frequency and severity [20]. A similar methodology with the addition of the exposure factor was used by Jannadi and Almishari [21].The method we have chosen for this study is the approach known as the binary method [22], where the unit risk is defined as the product of frequency and severity (see Equation 1).Frequency is defined in terms of worker hours per incident, while severity is defined in terms of impact on the worker per incident.

$$\text{UNIT RISK}\left(\frac{\text{severity}}{\text{work-hour}}\right)=\text{Frequency}\left(\frac{\text{incident}}{\text{work-hour}}\right)\times\text{Severity}\left(\frac{\text{severity}}{\text{incident}}\right)\quad(1)$$

Once the method for risk quantification was defined, the next step was to define a suitable research strategy to accomplish our specific goal.

According to a previous civil construction research [23] based on the Delphi method, cited method can be defined as systematic and interactive research technique for obtaining the judgment of a panel of independent experts on a specific topic. Panel members are selected according to predefined guidelines and are asked to participate in two or more rounds of structured surveys. After each round, an anonymous summary of the experts' input from the previous survey is provided as a part of the subsequent survey. In each subsequent round, participants are encouraged to review the anonymous opinion of the other panelists and consider revising their previous response. The goal during this process is to decrease the variability of the responses and achieve group consensus about a correct value. Finally, the process is concluded after a predefined criterion (as number of rounds or the achievement of consensus) is met and a statistical aggregation of the responses in the final round determines the results.

The staticized group technique is very similar to the Delphi method. The only methodological difference is the exclusion of feedback or iterations in the staticized group technique. Several studies have reported different opinions about the accuracy of both methods. Some of these studies have reported a significant increase of the staticized group technique over Delphi rounds as far as accuracy is concerned [24,25]. By contrast, other studies found no substantial difference in the accuracy records when the Delphi and staticized group approaches were compared [26, 27]. Meanwhile, two other surveys suggested that the accuracy of the Delphi method is worse when there is a high level of iterations [28,29].

Authors such as Erffmeyer and Lane [30] are in favour of using the staticized group approach because panel members are not led to achieve a consensus on a value that could be wrong. This is the main reason why the present study was carried out using the method of staticized groups.

2.1 Panel Members

As in the Delphi procedure, in the staticized group approach the selection of experts is a very important factor in determining the quality of the study. Hallowell and Gambatese [23] maintain that the level of expertise is the most important facet in a panel member and propose guidelines for a flexible point system for the selection of an expert panel member. A suitable adaptation of the suggested point system to the specific goals of our research project resulted in the requirements listed in Table 1.

The authors contacted 15 construction companies and 10 universities. After a review of the background and availability of the possible candidates, 12 experts were selected from 7 large high profile companies from the engineering construction sector, and from 5 Schools of Engineering. In addition to the flexible point system requirements, only one expert per company or per University was selected in order to ensure diversity in the origin of the experts.

According to the guidelines proposed by Hallowell and Gambatese [23], all members of the panel met the minimum level of requirements. As can be seen in Table 2, all of the panellists scored a total of at least 17 points and in at least four different achievement or experience categories. Four other professionals were selected as panel members, but they did not complete the survey and so were excluded from the final list of panel members and also from the results shown in Table 2.

The qualifications of the selected members of the staticized groups are as follows.

- As a guarantee of expertise in Safety at Work and Occupational Risk, all members of the panel have obtained a Master in Occupational Risk Prevention degree. In our opinion, this is the most valuable requirement for our research, because it shows that the person has completed specific courses on occupational health and safety and, therefore, that he or she has the expertise to evaluate risks in the activities under study.
- Every member has a technical Bachelor’s or Master’s degree. Formwork activities in construction have a very important technical profile. Consequently, this requirement is considered highly relevant because previous training in technical issues is necessary to be able to form an accurate evaluation.
- Between them, the panellists have 94 years of experience in the construction sector. Experience is another extremely relevant requirement.
- Four of the panellists have contributed to 24 books related to construction safety and health or risk management.

2.2 Study Design

A web-survey used for collecting the expert responses was developed on a specialized site and was made available to the experts. Experts had access to the survey only by using a password supplied by the researchers. The web-survey expired after the collection of data in the above mentioned period of time.

In order to improve the quality of the study, certain strategies for study design and the elimination of bias were adopted. For example:

- The order of the questions and the order of the potential safety risk in the survey were randomized for each panel member to reduce the contrast effect and the primacy effect.
- Independent frequency and severity rates were implemented.
- The anonymity of each expert was ensured.

2.3 Survey Content

Following the guidelines of Hallowell and Gambatese [18],experts were provided with the incident classification descriptions (Table 3) and the formwork construction activity descriptions (Table 4). In line with the above, the selected incidents or health and safety risk classification were based on the Occupational Safety & Health Administration, Bureau of Labour Statistics, and Hinze accident classification systems [31].

The panellists were asked to provide their opinion on frequency rates and severity levels using the frequency and severity scales provided previously (Table 5&Table 6). These scales were created by Hallowell and Gambatese [18], and cover a complete spectrum of frequency and severity levels.

3. Results and Discussion

Although consensus is not a requirement for the methodology of staticized groups, it was also calculated in order to compare the results with the Delphi approach (Table 7). To measure the variation in the responses, the absolute deviation was calculated using the following equation:

$$\text{Average Deviation from Median} = \text{Average}(\text{Median}j - \text{Value } ij) \quad (2)$$

After calculating the absolute deviation from the median, and accepting that consensus is achieved with a value less than1/10 of the possible value for the quantitative study developed, the target consensus was found to be achieved in this case.

Table 8 shows the quantified risk when all formwork activities are included by the following methods. First, the frequency ratings chosen by the expert from a range of values from table 5 with units of worker-hours per incident were converted into a single point value with units of incidents per worker-hour. Then single point values were multiplied by the severity values chosen by the experts according to the severity scale from Table6.
For example, if the expert rated the average frequency as 10-100 w-h /incident, the mean value of 55 w-h/incident was identified in order to convert to a single value, and the inverted value 0.018 [1/55] represented the frequency value for the particular risk and activity. The product of this frequency and the severity rating from table 6 represents the unit risk for the activities.

In a further analysis of the data matrix shown in Table 8, two different comparative tables were produced according to the sum values from a row [Activities] and from a column [Safety risks]. Table 9 summarizes the total safety risk score for each activity, and Table 10 shows the quantified risks when all formwork activities are included.

Table 9 shows that the highest risk scores for the construction activities under study were obtained by the activities plumb/level forms (0.4772 S/w-h) cut material (0.0585 S/w-h), crane material (0.0194 S/w-h)and ascend/descend ladder (0.0187S/w-h). On the other hand, the lowest risk scores were obtained by lubrication/preparation (0.0008S/w-h),manual transport (0.0006S/w-h) and inspect/plan (0.0002S/w-h). Some of the activities with the highest risk scores such as crane material or ascend and descend ladders, have been dealt with in other papers with a more general approach [32,33,34,35,36].Our specific results for vertical formwork activities in construction are in line with other general results that are discussed below.

Surprisingly, the first and second highest risk score activities, that is, plumb/level forms and cut material, had not been studied before. This fact could be due to the highly specific activities involved. Consequently, further research concerning these issues is needed. It is especially significant that plumb/level forms accumulated approximately 80% of all of the risk. Therefore, it should be an activity which is the primary focus of safety management on the worksite.

- Crane-lifting of material is one of the major causes of fatalities in construction [32]. To reduce the rate of crane fatalities, these authors believe that crane operators and riggers should be qualified and requalification courses should take place every 3 years. Likewise, other researchers [33] highlighted the fact that big contractors and other agents provide insufficient training for crew members. In addition, these authors found difficulties in communication among crew members, including language and a proper understanding of signals. Consequently, to improve the health and safety levels in these tasks, education programmes should be redesigned for all workers engaged in crane operations. Sometimes the risk is caused by deficiencies in the electrical system of the crane [34].
- Ascending and descending ladders has been associated with a high percentage (33.5%) of the non-fatal accidents in construction workers in the United States [35]. Ladders were also associated with 11% of all fatal falls over the period 1980-1989 in the US. More recently, ladder-related accidents have been shown to be associated with risk factors that increased the probability of a serious or fatal accident [36]. Hallowell and Gambatese [18] found that this activity is one of the most dangerous. They studied formwork activities following a more general approach, that is, without concentrating on vertical civil works. To improve the safety records at work in this activity, we must make a more accurate risk assessment.

Regarding the health and safety risk values included in Table 10, the highest risk scores were obtained by fall to a lower level (0.5247 S/w-h), cutting (0.0591 S/w-h) and overexertion (0.0079 S/w-h). The lowest risk scores correspond to fall on the same level (0.0001 S/w-h), exposure to harmful substances (0.0000 S/w-h) and others (0.0000 S/w-h). The health and safety risks studied had previously been addressed by many papers on construction activities [18,19,37,38,39,40,41]. The results provided here on specific vertical formwork safety risks are in line with the results of other general studies on the same issue.

- Given their fatal consequences, falls to a lower level in the construction industry have been extensively studied by many authors [35, 36, 37, 38,39]. Although these authors studied falls in the construction industry, their research was not focused on falls related toa formwork task. The most relevant work on falls and formwork is the study carried out by Adam, Pallarés, and Calderon [41]. In this study, falls from a height during floor slab formwork of buildings are dealt with specifically. They compared the fall protection systems commonly used during floor slab formwork construction in buildings and concluded that the suitability of the different systems depends greatly on the willingness of the workers to use the systems. This fact should be taken into account when making the choice. Hallowell and Gambatese [18] found that falls to a lower level is a very important risk, but this result was obtained without distinguishing between the two types of formwork (vertical or horizontal).Unfortunately, no literature about the risk of falls in vertical form work in civil engineering is available. In a similar way to the studied activities, fall to lower levels accumulated almost 88% of the total risk score. Therefore concentration on this aspect of the work will produce the greatest improvement in health and safety performance.

- Overexertion injury is the single largest category of injuries in construction work. They account for about 24% of all injuries [19]. Everett's analysis shows that virtually all construction activities have moderate-to-high ratings for at least one risk factor, and thereby place craft workers at increased risk for overexertion injuries and disorders.
- The authors of this paper have found no articles on the safety risk involved in formwork cutting activities.

To sum up, although there are several research papers on common health and safety issues in construction work, there is still a significant shortage of specific investigations on some of the activities and risks relating to tasks such as formwork erection dealt with in this paper.

4. Conclusions

The results of this study can be used as an important tool for making a risk assessment when a vertical formwork task is scheduled. Each construction project involves specific health and safety issues because each has different circumstances and environment. However, the general health and safety topics described in this research can be addressed effectively on each project.

As for preventive measures, resources are always limited and must be managed efficiently. Construction practitioners must first identify the most dangerous activities and their safety risks. This is the first step for prioritizing preventive measures according to a suitable scale of needs. The classification obtained according to the scores provided by expert panel members in this study placed plumb/level forms, cut material, crane-lift material, and ascend/descend ladder at the top of the list of activities with high risk factors. Likewise, fall to a lower level, cutting, and overexertion were the most dangerous safety risks according to the experts. Accordingly, special attention is needed to reduce these safety risks.

4.1 Limitations of the study

This research does not consider the exposure [worker-hours] to the hazards. The total risk will depend on the magnitude of the exposure [see Equation 3]. The exposure can vary significantly depending on the specific construction project.

$$\text{TOTAL RISK}\left(\text{severity}\right)=\text{Frequency}\left(\frac{\text{accident}}{\text{work-hour}}\right)\text{譙everity}\left(\frac{\text{severity}}{\text{accident}}\right)\text{調 xposure}\left(\text{work-hour}\right)\left(3\right)$$

If the exposure is high but the unit risk is low, then the total risk may be high relative to the other activities. Similarly, if the exposure is low, but the unit risk is high, then the total risk may be low compared to the other activities. In spite of this fact, unit risk is a very important tool to quantify health and safety needs.

The results allow us to compare risk values between different activities, and valuate them in order to prioritize preventive resources. However, as a relative subjective scale, it cannot be said that greater than a specific value the risk is major and under this value the risk is minor.

4.2 Impact on the Industry

The conclusions from this research can be used by construction companies in several ways. Health and Safety managers and supervisors can improve associated risks with specific activities, especially with plumb/level forms activities and risks of falls to lower levels. Project engineers and designers can estimate the exposure time for their specific project and calculate the total risk. This calculation can be made considering the different formwork types and design solutions. Companies can use the results obtained in their occupational safety strategies and in their safety training programmes. The authors encourage further research on the issue and promote future solutions to prevent the risks involved.

ACKNOWLEDGMENTS
This study was financed by the Spanish Government [Ministry of Science and Technology] and FEDER, through the project called Safety from Design in performance of formwork activities in civil works, referenced as BIA2011-27338 in the list of an approved project in the National Plan of Research and Development.
The authors would like to thank the experts from companies such as AZVI, SANDO, ETOSA, IGR and UNIPRESALUD, ULMA, PERI, DOKA, ALSINA, the Town Council of Málaga and the following institutions: the University of Málaga, Loughborough University, University of Granada and Oregon State University. Without the help of their time and suggestions, this study would not have been possible.

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TABLES.

Table 1. Flexible point system for the selection of panel members.

Achievements or experience	**Points**
Master of Science in Occupational Risk Prevention	5
Technical Degree [Architect or Engineer]	4
Years of professional experience	1 per year
Professional registration	2
Author of a book on safety	2 per book
Author of an article on safety in a learned journal	2 per article
Faculty member at an accredited university	3
Ph.D.	4

Table 2. Panel members' scores

Panel Member	Master of Science in Occupational Risk Prevention	Technical Degree	Years of experience	Professional registration	Author of a book on safety	Author of an article on safety in a learned journal	Faculty member at and accredited university	PhD	Total Points	Number of achievement categories
Expert 1	5	4	18	2	32	22	3	4	90	8
Expert 2	5	4	23	0	0	4	3	0	39	5
Expert 3	5	4	12	0	4	12	0	0	37	5
Expert 4	5	4	10	2	4	0	0	0	25	5
Expert 5	5	4	13	2	0	0	0	0	24	5
Expert 6	5	4	0	0	8	0	3	4	24	5
Expert 7	5	4	12	2	0	0	0	0	23	4
Expert 8	5	4	6	2	0	0	0	0	17	4
TOTAL	40	32	94	10	48	38	9	8	279	41
Average	5.0	4.0	11.8	1.3	6.0	4.8	1.1	1.0	34.9	5.1

Table 3.Incident classification

Exposure to harmful substances
Fall to lower level
Fall on the same level
Cutting
Overexertion
Struck against objects in motion
Struck against objects
Caught in or compressed
Repetitive motion
Others

Table 4. Activities

Activity name	Description
Ascend /descend ladder	Ascending or descending ladders to reach the workface at different levels from the ground.
Lift /lower materials	Lifting or lowering materials or equipment from/to ground level.
Nail/screw/drill	Nailing, screwing or drilling formwork components using hammer, nail gun or similar.
Hammer materials	Hammer or drive large objects with tools such as a sledgehammer.
Crane materials and motorized transport	Materials or formwork components are transported by cranes or by vehicles such as trucks, skid steers or scissor lifts. Including loading operations.
Cut materials	Formwork operations where plywood or aluminium is cut on-site.
Inspect/plan	Workers, supervisors and managers of construction planning and inspecting the works.
Manual transport	Transporting equipment and materials.
Static lift	Supporting a portion of formwork while other workers connect components or materials.
Plumb/level forms	Levelling and plumbing forms to shift and adjust a form.
Excavation	Dig or move soil to prepare the ground.
Lubrication/preparation	Formwork lubrication and preparation involving spraying form with oil and/or curing compound and setting and wetting curing blankets and expansion materials.

Table 5. Frequency Scale.

Worker hours per incident	Frequency score
>100 million	1
10-100 million	2
1-10 million	3
100,000-1 million	4
10,000-100,000	5
1000-10,000	6
100-1000	7
10-100	8
1-10	9
0.1-1	10

Table 6. Severity Scale

Subjective severity level	**Severity score**
Negligible	1
Temporary discomfort	2
Persistent discomfort	4
Temporary pain	8
Persistent pain	16
Minor first aid	32
Major first aid	64
Medical case	128
Lost work time	256
Permanent disablement	1,024
Fatality	26,214

Table 7. Consensus of experts

Absolute deviation from the median	
Frequency ratings	Severity ratings
0.89	0.91

Table 8. Risk Scores

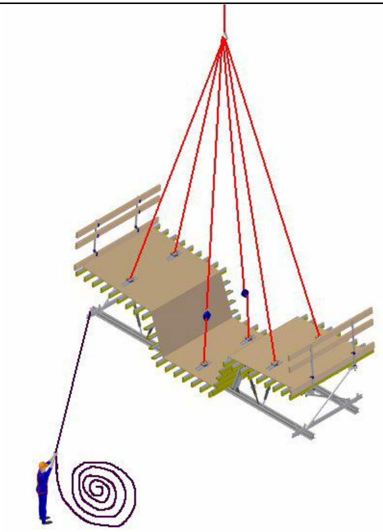
	Exposure to harmful substances	Fall to lower level	Fall on same level	Cutting	Overexertion	Struck against object in motion	Struck against objects	Caught-in	Repetitive motion	Others
Ascend /descend ladder	$2.73 \cdot 10^{-8}$	$1.86 \cdot 10^{-2}$	$1.45 \cdot 10^{-7}$	$2.91 \cdot 10^{-6}$	$2.91 \cdot 10^{-5}$	$2.91 \cdot 10^{-7}$	$2.91 \cdot 10^{-5}$	$5.82 \cdot 10^{-7}$	$2.91 \cdot 10^{-5}$	$1.00 \cdot 10^{-8}$
Lift /lower materials	$1.50 \cdot 10^{-8}$	$1.86 \cdot 10^{-4}$	$2.91 \cdot 10^{-6}$	$1.45 \cdot 10^{-5}$	$2.91 \cdot 10^{-5}$	$7.27 \cdot 10^{-8}$	$1.45 \cdot 10^{-5}$	1.16E-03	$7.27 \cdot 10^{-6}$	$1.00 \cdot 10^{-8}$
Nail/screw/drill	$2.00 \cdot 10^{-8}$	$4.65 \cdot 10^{-3}$	$1.45 \cdot 10^{-6}$	$5.82 \cdot 10^{-4}$	$2.91 \cdot 10^{-3}$	$3.20 \cdot 10^{-7}$	$1.45 \cdot 10^{-5}$	$5.82 \cdot 10^{-6}$	$1.45 \cdot 10^{-3}$	$1.00 \cdot 10^{-8}$
Hammer materials	$1.50 \cdot 10^{-8}$	$4.65 \cdot 10^{-4}$	$2.91 \cdot 10^{-6}$	$2.91 \cdot 10^{-4}$	$2.91 \cdot 10^{-4}$	$3.20 \cdot 10^{-7}$	$1.45 \cdot 10^{-4}$	$5.82 \cdot 10^{-6}$	$1.45 \cdot 10^{-3}$	$1.00 \cdot 10^{-8}$
Crane materials and motorized transport	$1.50 \cdot 10^{-8}$	$1.86 \cdot 10^{-2}$	$2.91 \cdot 10^{-5}$	$2.91 \cdot 10^{-5}$	$7.27 \cdot 10^{-8}$	$5.82 \cdot 10^{-4}$	$7.27 \cdot 10^{-8}$	$1.16 \cdot 10^{-4}$	$7.27 \cdot 10^{-7}$	$1.00 \cdot 10^{-8}$
Cut materials	$1.00 \cdot 10^{-8}$	$1.16 \cdot 10^{-5}$	$2.91 \cdot 10^{-6}$	$5.82 \cdot 10^{-2}$	$2.91 \cdot 10^{-4}$	$3.20 \cdot 10^{-7}$	$1.45\ 10^{-6}$	$2.91 \cdot 10^{-7}$	$7.27 \cdot 10^{-7}$	$1.00 \cdot 10^{-8}$
Inspect/plan	$1.00 \cdot 10^{-8}$	$1.86 \cdot 10^{-4}$	$1.45 \cdot 10^{-6}$	$2.00 \cdot 10^{-8}$	$3.64 \cdot 10^{-8}$	$2.91 \cdot 10^{-7}$	$7.27 \cdot 10^{-7}$	$4.00 \cdot 10^{-8}$	$7.27 \cdot 10^{-8}$	$1.00 \cdot 10^{-8}$
Manual transport	$1.00 \cdot 10^{-8}$	$4.65 \cdot 10^{-4}$	$7.27 \cdot 10^{-8}$	$2.91 \cdot 10^{-7}$	$2.91 \cdot 10^{-3}$	$5.82 \cdot 10^{-7}$	$2.91 \cdot 10^{-5}$	$2.91 \cdot 10^{-7}$	$2.91 \cdot 10^{-4}$	$1.00 \cdot 10^{-8}$
Static lift	$1.00 \cdot 10^{-8}$	$1.86 \cdot 10^{-5}$	$7.27 \cdot 10^{-8}$	$2.91 \cdot 10^{-5}$	$2.91 \cdot 10^{-4}$	$1.45 \cdot 10^{-7}$	$1.45 \cdot 10^{-5}$	$2.91 \cdot 10^{-7}$	$2.91 \cdot 10^{-4}$	$1.00 \cdot 10^{-8}$
Plumb/level forms	$1.82 \cdot 10^{-8}$	$4.77 \cdot 10^{-1}$	$2.91 \cdot 10^{-7}$	$2.91 \cdot 10^{-6}$	$5.82 \cdot 10^{-4}$	$5.82 \cdot 10^{-6}$	$1.45 \cdot 10^{-5}$	$5.82 \cdot 10^{-7}$	$2.91 \cdot 10^{-6}$	$1.00 \cdot 10^{-8}$
Excavation	$1.00 \cdot 10^{-8}$	$4.65 \cdot 10^{-3}$	$5.82 \cdot 10^{-6}$	$1.45 \cdot 10^{-7}$	$2.91 \cdot 10^{-6}$	$2.91 \cdot 10^{-6}$	$1.45 \cdot 10^{-6}$	$2.33 \cdot 10^{-5}$	$7.27 \cdot 10^{-7}$	$1.00 \cdot 10^{-8}$
Lubrication/preparation	$3.64 \cdot 10^{-8}$	$1.86 \cdot 10^{-4}$	$2.91 \cdot 10^{-6}$	$2.91 \cdot 10^{-6}$	$5.82 \cdot 10^{-4}$	$5.82 \cdot 10^{-6}$	$1.45 \cdot 10^{-5}$	$1.16 \cdot 10^{-6}$	$2.91 \cdot 10^{-5}$	$1.00 \cdot 10^{-8}$

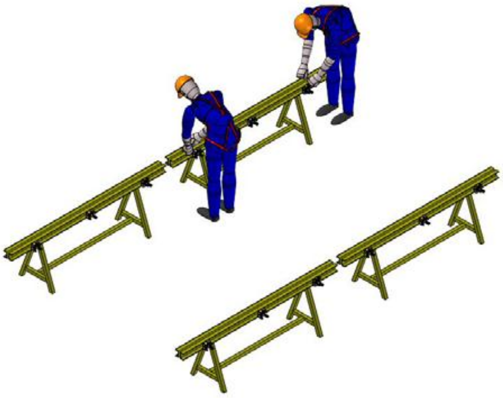
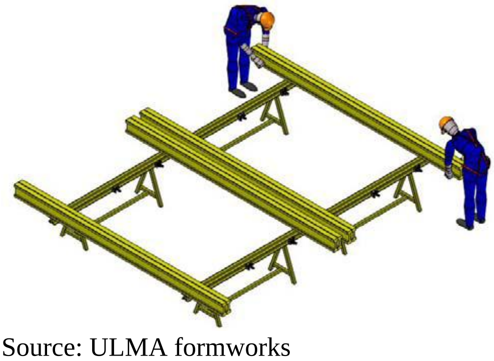
Table 9. Comparison of activity risk values

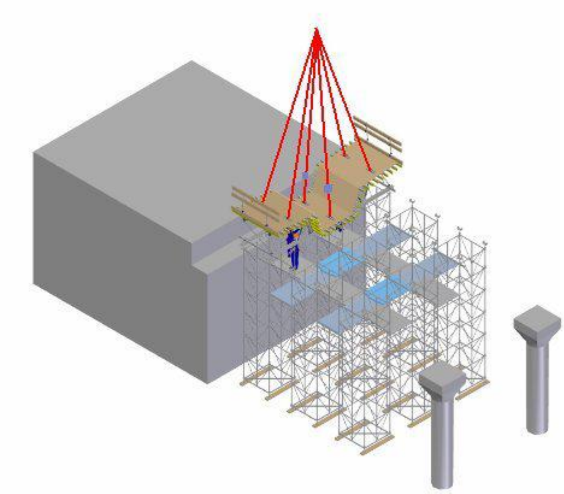
Vertical Formwork civil construction activities	Risk score [S/w-h]
Plumb/level forms	0.4772
Cut material	0.0585
Crane-lift material	0.0194
Ascend/descend ladder	0.0187
Nail/screw/drill	0.0096
Excavation	0.0047
Lift/lower materials	0.0037
Hammer materials	0.0027
Static lift	0.0014
Lubrication/preparation	0.0008
Manual transport	0.0006
Inspect/plan	0.0002
TOTAL	0.5976

Table 10.Comparison of safety risk values.

Safety risk	Risk Score [S/w-h]
Fall to lower level	0.5247
Cutting	0.0591
Overexertion	0.0079
Repetitive motion	0.0036
Caught-in	0.0013
Struck against object in motion	0.0006
Struck against objects	0.0003
Fall on the same level	0.0001
Exposure to harmful substances	0.0000
Others	0.0000
TOTAL	0.5976

Crane materials and motorized transport	 Source: ULMA formworks
Cut materials	 Source: AZVI constructions
Inspect/plan	 Source: AZVI constructions

Inspect/plan	 Source: AZVI constructions
Manual transport	 Source: ULMA formworks
Static lift	 Source: ULMA formworks

Plumb/level forms	 Source: ULMA formworks
Excavation	 Source: AZVI constructions
Lubrication/preparation	 Source: ULMA formworks

5.3 PUBLICATION III. HOW SAFE IS THE CIVIL CONSTRUCTION SECTOR IN SPAIN?. CONTRACTOR´S PERSPECTIVE THROUGH AN EXPERT PANEL.

International Symposium on
Occupational Safety and Hygiene
Feb 14-15, 2013 Guimarães - Portugal

How safe is the civil construction sector in spain? Contractor´s perspective through an expert panel

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1. INTRODUCTION
Construction sector had the worst incident rates per worker in all Europe (Eurostat, 2011). Due that safety at construction has been studied by different authors in many countries like Taiwan (Cheng et al, 2010), Scotland (Cameron et al, 2008), Turquey (Etiler et al, 2004; Mungen&Gurcanli, 2005), Portugal (Macedo&Silva, 2005), or South Korea (Im et al, 2004). However majority of the cited studies are not focused on civil construction, because they are more focused on building and residential construction. There are no specific studies about safety levels in civil construction in Spain based in the point of view of civil contractors, that is the main reason to develop the present study.

2. METHODOLOGY
To achieve the study aim, previously to personal interviews a questionnaire form was developed. Cited questionnaire was checked and improved by 5 different construction professionals. After checking questionnaires experts were selected to be interviewed. Finally 25 experts were selected according some specifics requirements like experience in civil construction or academic background.

3. RESULTS
Results obtained were divided in three different categories: safety risk, activities and preventive measures. Safety risk scores (figure 1) showed that fall to lower was the most important risk considered in civil construction projects. Other risks like cutting, fall to same level, or overexertion were considered important too.

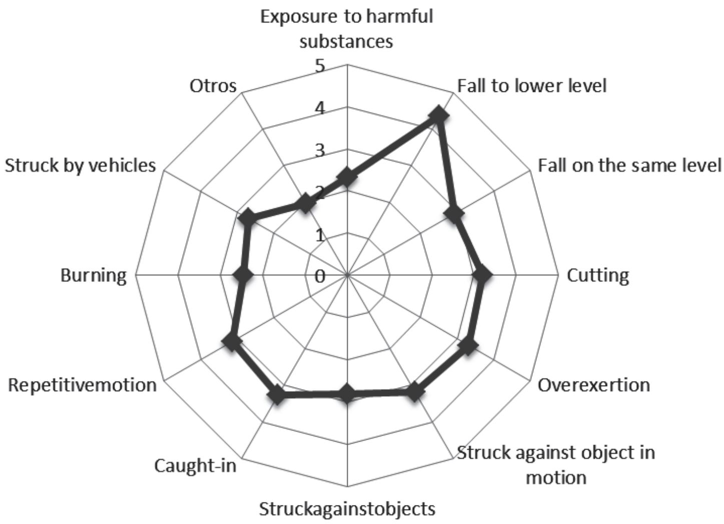

Figure 1- Safety risk score.

With regard to activities results (figure 2), they showed that crane materials was the most dangerous activity in opinion of the interviewed, followed by plumb and level forms, and transport material. Respect to preventive measures they were considerate appropriate but no expert valuated them with the highest possible score, in consequence they can be improved.

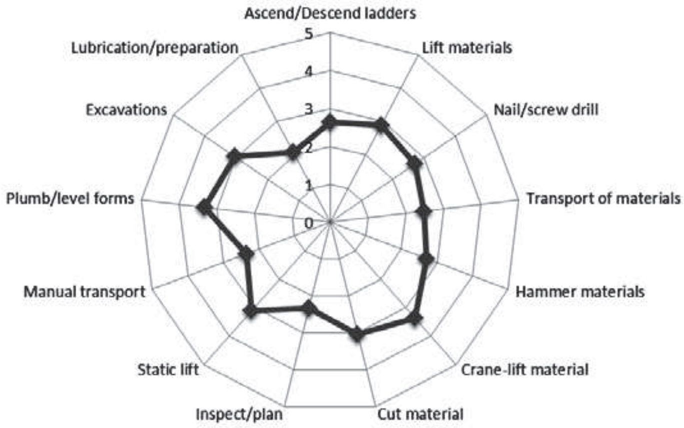

Figure 2- Activities risk score.

4. CONCLUSIONS

In opinion of the experts occupational health and safety issues in civil construction project are not always developed in the best way possible. Lacks of written procedures and low worker´s safety training are present in majority of the projects. Fall to lower must be highlighted as the most important risk, and crane materials and level forms as the most dangerous activities. All this information must be considered from the beginning of the design phase of the project, until the finishing of the works at the construction site, and the adequate preventive measures must be developed according the cited findings.

5. ACKNOWLEDGEMENTS

This study was financed by Ministry of Science and Innovation, in his 2011 call for Research Projects and by Consejería de Empleo de la Junta de Andalucía, and LIMASA III. Authors would like to thank the selected expert´s collaboration. Without their help, this study would not have been possible.

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5.4 PUBLICATION IV. OCCUPATIONAL HEALTH AND SAFETY (OHS) AT CONSTRUCTION PROJECTS. A PERSPECTIVE FROM FORMWORKS& FALSEWORKS COMPANIES.

SHO 14
13::14::february

International Symposium on
Occupational Safety
and Hygiene

Occupational Health and Safety (OHS) at construction projects. A perspective from formworks&falseworks companies.

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ABSTRACT: Construction sector has poor indicators about their Occupational safety levels. In civil construction projects, Occupational Health and Safety in the design and use of formwork/falsework is not properly addressed many times. Aim of current research is to analyze the opinion of the professionals from formwork/falsework manufacturing companies. A Likert-scale survey was distributed between main international manufacturing formwork companies. Questions were divided in three different categories: a) Design phase b) Construction phase and c) Legal issues. Results showed that although safety and final cost are considered during the design of the formwork, customers prefer a cheap product before a safe product. In opinion of the manufacturers, users do not follow instructions about the product frequently. New standards about formwork/falseworks could improve the occupational safety of the civil construction projects.

1 INTRODUCTION

Studies about Occupational Health and Safety at civil construction are frequently focused on issues such as the impact of the different variables on the severity of the accidents (Sawacha, Naoum and Fong 1999), (Salminen 2004),(Lopez-Arquillos et al., 2012) contributing factors in construction accidents (Haslam et al., 2005) or the occupational safety risk assessment in construction activities (Hallowell and Gambatese 2009).

Researches focused on the concept of design for construction safety also known as Prevention through Design concept (PtD) are also important in the framework of occupational health and safety at construction. Authors like Behm (2005), and Gambatese et al.,(2008) studied the influence of the project design in the construction worker safety. Influence of contractors has been studied by authors like Wang et al., (2006), Saurin et al.,(2008) or Fadier & De la Garza (2006). In others similar researches, influence of the designers or structural engineers has been analyzed by Gambatese and Hinze (1999), Behm (2005), or Gambatese et al.,(2008).
In contrast of cited influence groups, although they are present in majority of civil construction works, literature about influence of the formwork manufacturing companies on the occupational health and safety of construction site has not been found. Among construction tasks, formwork activities are frequently associated with high rates of accidents and injuries. According to Huang and Hinze (2003), 5.83% of falls were attributed to the construction of formwork or to the construction of temporary structures, and around 21% of all accidents involved wood framing or formwork construction.

This study aims to analyze the opinion of the professionals from formwork/falsework manufacturing companies about occupational safety in the design and use of formwork/falsework.

2 METHODOLOGY

A Likert-scale questionnaire (Likert 1932), was designed in order to collect the opinion from the expert selected. Likert scale questionnaire has been demonstrated as a very useful tool in previous papers about occupational health and safety in construction (Ismail et al., 2011, Gittleman et al., 2011, Melia et al., 2008) this is the main reason of the application of this methodology in the present work.

A total number of 70 questionnaires were delivered between the selected formwork/falsework manufacturing companies.

Due to the sensitivity of the data and in order to ensure the understanding of the instructions, in addition of the traditional surveys method as mailing or virtual surveys, possibility of interview was provided to the respondents. Face to face interaction also provided the interviewer with the opportunity to clarify questions about the content of the items.

The questionnaires contained 17 items, grouped in three different categories: a) Design phase, b) Construction phase, and c) Legal issues. The questionnaires were designed to be simple and brief. They were checked previously by five different experts on Occupational Health and Safety in Construction for suitability and quality of the questions. Suggestions of the experts about the language level, comprehensiveness or item content were included in the final version of the questionnaire.

3 RESULTS

Results were divided according to the three different categories of the questionnaire.

3.1 *Design phase*

In the design phase were included items about the design of the project, and the design and manufacturing process of the formwork/falsework as product.
Questions included in the current category are the following:

Q1-The project designer would ask the formwork manufacturing company for advice while they are designing the structure

Q2-The project designer designs the structure without consulting the formwork/falsework manufacturing company. When the design is finished the construction company asks the formwork/falsework manufacturer for constructive solutions to suit the structure as designed.

Q3-The majority of projects do not specify type of the formwork/falsework in the project's documentation. Formwork/falsework selection is up to the construction company.

Q4-When formwork/falsework is being designed safety is considered as a very important design factor.

Q5-When formwork/falsework is being designed productivity is considered as a very important design factor.

Q6-When a formwork/falsework is being designed final cost is considered as a very important design factor.

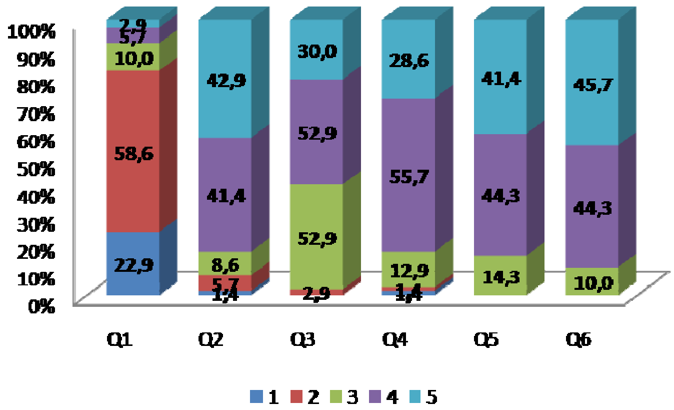

Figure 1. Level of agreement. Items Q1-Q6

Results pointed that the project designer do not use to ask manufacturer about the best formwork solution when he is designing the construction project. It is remarkable that although safety is considered during the design phase of the product, final cost is the most important factor, between both.

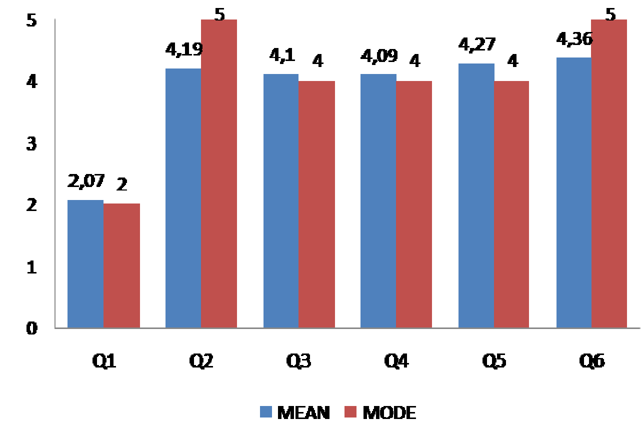

Figure 2. Mean and mode values. Items Q1-Q6

3.2 *Construction phase.*

In this subsection questions about the development of civil construction project on site are included. Items included in this category are:

Q7-The formwork/falsework customer chooses always the safest one.

Q8-The formwork/falsework customer chooses always the cheapest one.

Q9-The user always follows the manufacturer's instructions about the product.

Q10-Technical advice from formwork/falsework companies to users includes advice about safety issues related with use of the formwork/falsework.

Q11-Formwork/falsework suppliers are the same suppliers for the rest of temporary equipment (e.g. scaffolds or hoists)

Q12-Formwork/falsework manufacturers provide training in health and safety to their customers in the use of their products.

Q13-Formwork/falsework manufacturers provide the customer with qualified technicians to erect, use and dismantle the formwork/falsework and their auxiliary equipment.

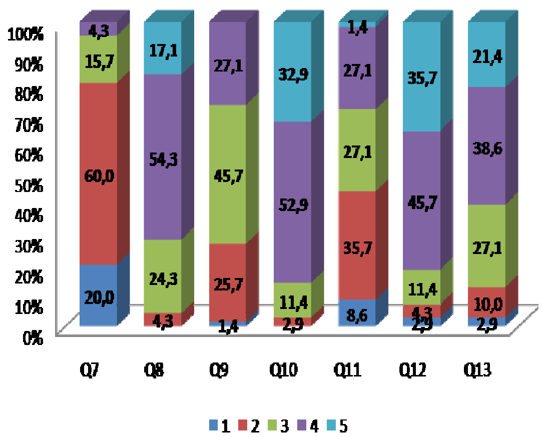

Figure 3. Level of agreement. Items Q7-Q13

It is especially remarkable that in opinion of the experts, customers do not use to choose the safest product, they choose the cheapest one. Item Q10 about the safety advices included in technical advices of the product obtained the higher level of agreement from respondents. In contrast item Q7 about the safety importance when a formwork/falsework is selected obtained the lowest level of agreement

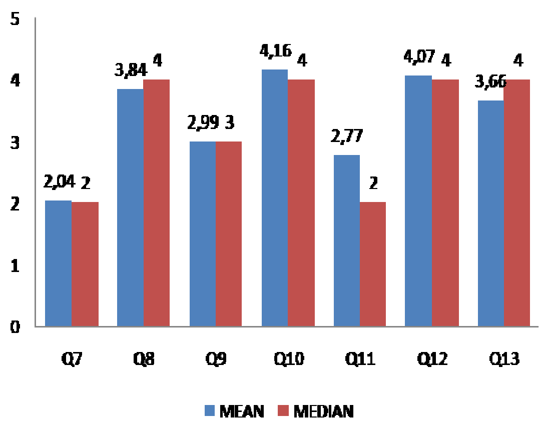

Figure 4. Mean and mode values. Items Q1-Q6.

3.3 *Legal issues*

In the last category of the questionnaire, items about the influence of hypothetical new standards about formwork/falsework and Occupational Health and Safety issues were included:

Q14-A compulsory standard about formwork/falsework design and manufacture would improve health and safety in the final formwork/falsework as a product.

Q15-A non-compulsory specific standard (ISO, BS or similar) about formwork/falsework design and manufacture would improve health and safety in the final formwork/falsework as a product.

Q16-A compulsory standard about formwork/falsework use would improve health and safety for the formwork/falsework workers.

Q17-A non-compulsory specific standard (ISO, BS or similar) about formwork/falsework use would improve health and safety for the formwork/falsework workers.

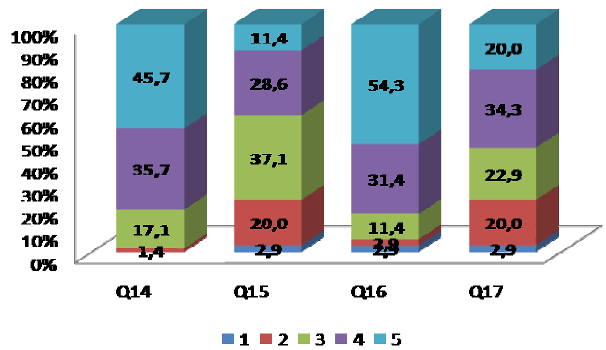

Figure 5. Level of agreement. Items Q14-Q17

It must be highlighted that a big consensus were obtain about the positive influence new standards about manufacturing and use of formworks. Compulsory standards obtained higher values of agreement than non-compulsory standards.

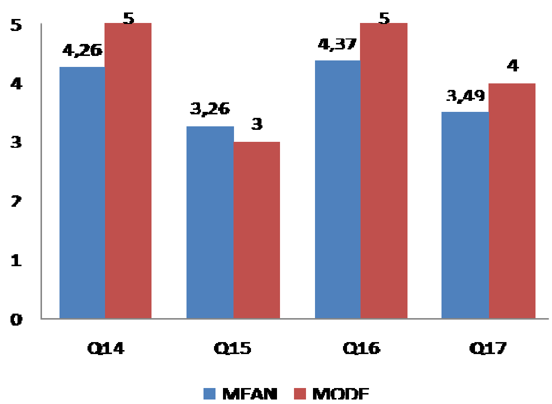

Figure 6. Mean and mode values. Items Q14-Q17.

4 CONCLUSIONS

In the design phase of the construction project, lack of interaction between designers and formworks/falseworks companies was pointed by experts respondents. Regard to the design phase of the formwork/falsework, final cost of the product was considered the most important factor while the product is being designed and productivity factor was considered an important factor too. In contrast safety factor, obtained the lowest score.

In opinion of the manufacturers, users do not follow instructions about the product frequently. In addition new standards about design and use of formwork, would improve health and safety levels.

In future research will be interesting to include in the sample studied other stakeholders as construction companies and project designers in order to contrast opinion from different groups of interest implied in the civil construction process.

5 ACKNOWLEDGEMENTS

This study was financed by Spanish Government [Ministry of Science and Technology] through the project named Safety from Design in performance of formwork activities at civil works, referenced like BIA2011-27338 into the list of approved project in the National Plan of Research and Development.
The authors would like to thank the experts from all companies, but specially from companies such as ULMA, PERI, DOKA, ALSINA.

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5.5 PUBLICATION V. PREVENTION THROUGH DESIGN (PTD) CONCEPT AT UNIVERSITY. ENGINEERING& ARCHITECTURE STUDENTS´ PERSPECTIVE.

Prevention through Design (PtD) concept at university. Engineering& Architecture students´ perspective

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ABSTRACT: Although the importance of the Prevention through Design concept, many accidents still happen because cited concept is not implemented properly in construction projects. Aim of current research is to quantify the integration of Prevention through Design concept at university courses about construction or design of concrete structures at engineering and architecture. Opinions from 246 students were collected using a specific questionnaire. Students were selected from engineering and architecture under/degrees at university of Granada. Results showed different opinions between students from Old degrees and Bologna degrees. Prevention through Design concept had better integration in courses from old degrees. Absence of education and training in Prevention through Design was found in the construction courses studied. Future engineering and architecture syllabi should improve the presence of Prevention through Design concept.

1 INTRODUCTION

Construction sector has the highest incidents rates in many countries. (Eurostat, 2013). Due that, many authors have investigated the problem in countries as different as Taiwan (Cheng et al., 2010), Scotland (Cameron et al., 2008) Turkey (Etiler et al., 2004) (Müngen & Gürcanli, 2005) Portugal (Macedo & Silva, 2005), South Korea (Im et al., 2009). In Spain, accident rates are not better (Camino et al., 2008, López-Arquillos et al., 2012, Martinez-Aires et al., 2010).

Prevention through Design concept (PtD) is especially relevant when accidents in civil construction are studied. The concept definition is available at the web site of the National Institute for Safety and Health (NIOSH, 2013) as:

"Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment".

According to existent literature many accidents could be eliminated or reduced with a correct implementation of PtD during the design phase and the development of the project (Haslam, 2005; Gibb, 2006; Gambatese et al., 2008). In Europe, architects and design engineers are required to implement design for construction safety (ILO, 1985) but unfortunately Prevention through Design concept is often not clearly integrated in engineering and architecture university courses. In consequence many professionals are required to implement a concept little-known or unknown along their academic trajectories. In general, safety contents are not integrated on under/graduate curricula as it could be desirable (HSE, 2009) but this integration is difficult due to the already crowed under/graduate curricula (Culvenor & Else, 1997).

Aim of present research is to quantify the integration of Prevention through Design concept at university courses about construction or design of concrete structures at engineering and architecture.

2 METHODOLOGY

With the aim to collect the opinion from the university students a sample of them were chosen from engineering and architecture courses at Granada University (Spain) focused on the design or construction of concrete structures. It is important to consider that university students can be divided in two groups depending on their academic itinerary. Students from degrees approved before the Bologna process, (Old degrees (OD)) and students from degrees created during the Bologna process in order to achieve the European Higher Education Area (Bologna degrees (BD)). Although now number of students is similar in both, evolution of the distribution of the student is quite different. Old degrees are in an extinction process and the number of students is decreasing on them, at the same time that Bologna degrees are in an implementation process in order to substitute old degrees, and the number of students are increasing.

Criteria of selection were that the course was part of a civil or building construction under/degree and included in its academic programs contents about design or construction of structures. A total of 246 students, from four different under/degrees completed the questionnaire. (62.2% from Old degrees and 37.8% were from Bologna degrees).

A Likert-scale questionnaire (Likert, 1932), was designed in order to collect the opinion from the sample selected. Likert scale questionnaire has been demonstrated as a useful tool in others researches about occupational health and safety in construction (Melia et al., 2008; Gittleman et al., 2010; Ismail et al., 2012). This is the reason of the application of this methodology in the questionnaire form designed. Questionnaire was designed to be simple and brief. It contained 11 items grouped in two categories of questions:

- In the first category, questions were related with their general education and training at Occupational Health and Safety issues.
- In the second category, specific questions about the influence of Prevention through Design concept in the course were included.

Respondent were asked to evaluate each item in a Likert-Scale from 1 [Strongly disagree] to 5 [Strongly agree].

3 RESULTS

Results obtained from questionnaires were divided in two different subsections attending to the category of the item.

3.1 *Occupational Health and Safety issues*

Items related with Occupational Health and Safety issues included in the current subsection are the following:

Q1-Occupational Health and Safety of workers at vertical construction is integrated with the rest of the technical concepts at every lecture of the course

Q2-Occupational Health and Safety of workers at vertical construction is only considered at some lectures of the course

Q3-Workers Occupational Health and safety is often confused with structural safety of the construction

Q4-Workers Occupational Health and safety topic is addressed in other specifics courses of the under/degree

Q5-Knowledge on Occupational Health and safety for workers are evaluated in the course

Results from Old degrees' students, and from Bologna degrees' students are showed in figure 1 and figure 2.

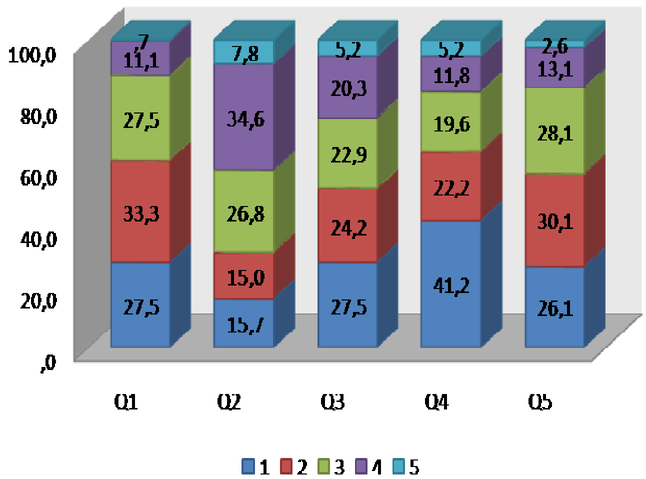

Figure 1. Old degrees respondents. Distribution of results from items Q1-Q5.

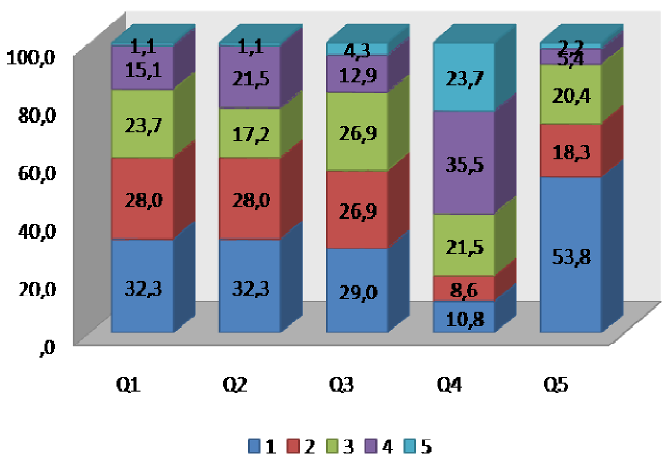

Figure 2. Bologna degrees respondents. Distribution of results from items Q1-Q5.

It is remarkable that integration of the OHS of workers obtained worse results for Bologna degrees, but in contrast OHS issues are addressed in more specific courses in Bologna degrees if we compare them with Old degrees. Values obtained for the item about confusion between.

3.2 *Prevention through Design influence.*

In current subsection items included are related with the influence of PtD concept in courses studied. Questions at this category are:

Q6-I know the meaning of Prevention through Design (PtD) concept

Q7-Worker safety on the design of the construction project is considered along the course

Q8-Prevention through Design (PtD) concept is addressed in many courses like this one

Q9-Prevention through Design (PtD) concept is important to improve workers occupational health and safety in vertical constructions

Q10-Prevention through Design (PtD) concept is not important if compare it with the rest of the course contents.

Q11-Knowledge about Prevention through Design (PtD) concept is evaluated in this course

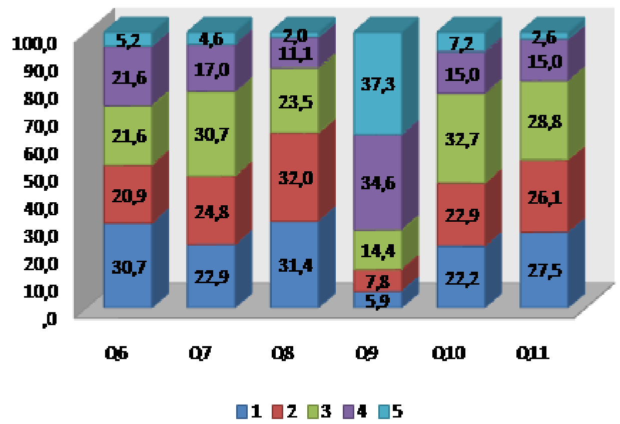

Figure 3. Old degrees respondents. Distribution of results from items Q6-Q11.

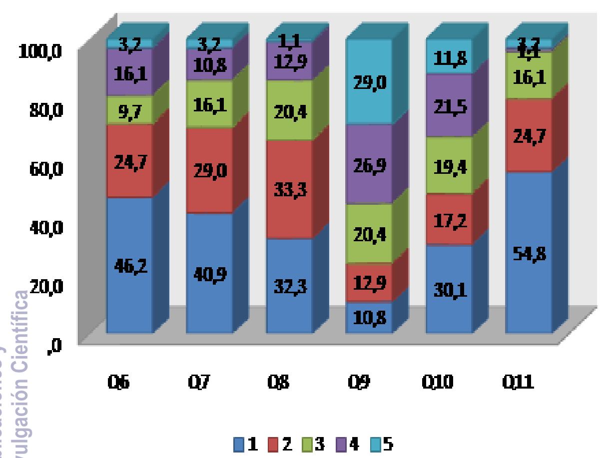

Figure 4. Bologna degrees respondents. Distribution of results from items Q6-Q11.

It is important to note that the knowledge about the meaning of PtD in Old degrees is higher than Bologna degrees. Similarly, the importance of the PtD concept is lower between students from Bologna degrees, than students from Old degrees.

4 CONCLUSIONS

Results obtained in current research from students selected, pointed that level of education and training at Prevention through Design between engineers and architecture students is not as good as could be desirable and a big improvement is required. Comparative study between Old degrees and Bologna degrees are not very positives because the evolution of the contents of construction courses about OHS and PtD has been poor. A lower level of knowledge of PtD concept was found linked to a lower consideration of the importance of PtD concept in construction, in consequence better knowledge of PtD concept would improve the importance of the concept between future professionals from construction sector.

4.1 Future Research

Current analysis should be extended to other universities in order to compare the similarities and differences between the performance and integration of PtD in university construction courses.

5 ACKNOWLEDGEMENTS

This study was financed by Spanish Government [Ministry of Science and Technology] through the project named Safety from Design in performance of formwork activities at civil works, referenced like BIA2011-27338 into the list of approved project in the National Plan of Research and Development.
The authors would like to thank the students from all construction courses studied for their opinion and suggestions. Without their collaboration this study would not had been possible.

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5.6 PUBLICATION VI. ACCIDENT DATA STUDY OF CONCRETE CONSTRUCTION COMPANIES SIMILARITIES AND DIFFERENCES BETWEEN QUALIFIED AND NON QUALIFIED WORKERS IN SPAIN.

**The paper status in the journal is under review. In a second review.*

ACCIDENT DATA STUDY OF CONCRETE CONSTRUCTION COMPANIES SIMILARITIES AND DIFFERENCES BETWEEN QUALIFIED AND NON QUALIFIED WORKERS IN SPAIN

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ABSTRACT:

The aim of this paper is to discuss findings from an analysis of accidents in concrete construction companies in Spain and to compare the accident rates of qualified and non-qualified workers. A total of 125,021 accidents between 2003 and 2008 involving both blue-collar and white-collar workers were analysed, comparing the variables of occupation, age, company staff, length of service, location of the accident, together with the severity of the accidents. Results showed that lack of experience in the first month is more significant in non-qualified workers and experienced supervisors and that head injuries are more likely to lead to fatalities. The most remarkable similarity was that fatal accidents to and from the worksite are a problem common to both groups of workers.

Keywords: Construction, accident, white-collar, blue-collar, qualified worker, Spain

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1. INTRODUCTION.

According to the International Labour Organization (ILO) [1], at least 60,000 people die and many hundreds of thousands more suffer serious injuries and ill-health on construction sites every year. ILO explains that, nevertheless, these estimates are conservative because, in many countries, less than 20% of construction injuries are reported.

According to the Bureau of Labor Statistics (BLS) [2], in 2009 workers in the construction industry incurred the largest number of fatal injuries (816) of any industry in the private sector in the United States. These accidents represented approximately 19% of the "all occupation" deaths from injuries in the US.

Although there are significant differences in the submission of reports and work accident registration procedures in different EU countries, such as those involving the definition of workplace and consideration of traffic accidents [3], it can be observed in Table 1 that European countries such as Spain and the United Kingdom have a higher percentage of these accidents than the US in the construction sector [4].

Table1.Fatal Accidents in Spain and the United Kingdom 2000-2007 [1].

As shown in Figure 1, the percentage of fatal accidents on construction sites compared to all industries in the United Kingdom has fallen significantly. On the other hand, in Spain, even though the total number of fatal accidents decreased significantly, the construction sector numbers did not decrease to the same extent. As a result, the percentage of deaths due to construction accidentscompared to all Spanish industry sectors actually increased from 2000 to 2007.

Figure 1.Percentage of fatal construction accidents in the total number of occupational deaths.

Recent research results show that workplace accidents are influenced by a wide range of factors such as age, [5],[6],[7],[8],[9], company staff [10],[11],[12],[13], length of service in the company [14],[15],[16],[17]. These factors can be quantified easily, but accidents also involve other accompanying factors which are much more difficult to determine in a quantitative and direct way. This is the case, for example, of construction tools and equipment [18],[19],workforce management [20], or the interaction between workers, workplace and material equipment [21]. Results obtained in a study of contributing factors in construction accidents in the UK [22] concluded that problems arising from workers or the work team were presentin 70% of the accidents, workplace issues in 49%, shortcomings with equipment (including PPE) in 56%, suitability and condition of materials in 27% and deficiencies in risk management in 84% of the accidents. However, these studies never dealt with the differences between accidents on construction sites in connection with the occupation and qualification of workers. This paper analyses the impact of a number of variables on the severity of the accidents ofdifferent groups of workers in concrete construction companies.

2. METHODOLOGY

2.1. Data collection

From 2003 the Spanish National Institute for Safety and Hygiene at Work [INSHT; InstitutoNacional de Seguridad e Higiene en el Trabajo] must be notified of all accidents resulting in one or more days off work and this is compulsory by Spanish Law [23]. Notification must be sent through the electronic system DELT@ and involves the filling-in of an Official Workplace Incident Notification Form [Parte Oficial de Accidente de Trabajo]. The Ministry of Labour and Immigration [Ministerio de Trabajo e Inmigración] provided us with the anonymised data of all workplace accidents (as defined by the National Classification of Economic Activities) in the construction sector in Spain during the period 2003-2008. A total of 1,163,178 Notification Forms were supplied andfrom these 125,021 were selected.

The severity level of the accidents analysed is based on medical criteria, as compulsorily diagnosed by the Spanish health authorities in each case. For this purpose the severity of an accident can be classified according to four different levels: *Light accident*, *Serious accident*, *Very serious accident* and *Fatal accident*. The severity level stated in the Official Workplace Incident Notification Form must coincide with the severity level described by a doctor in the Medical Injuries Form [23].

2.2. Selection of Data

According to Hallowell and Gambatese [24], formwork construction is associated with a relatively high frequency of disabling injuries and illnesses, as recorded in the technical literature, BLS data and OHSA fatality reports. An OSHA accident report revealed that 5.83% of falls were attributed to the construction of formwork or to the construction of temporary structures, and 21.2% of all accidents involved framing or formwork construction [16]

The occupation of the workers is stated according to the CNO-94 National Occupation Code. When analysing the accidents in the construction sector in Spain between 2003 and 2008, we found that 8.7% of themaffected workers with a CNO-94 associated with concrete construction and formwork tasks. This percentage increases to 9.23 % in the case of fatal accidents. Table 2 shows the codesassociated with concrete construction which were selected for this study.

Table 2. Accidents selected according to National Occupation Code (CNO-94).

Other codes involving workers not necessarily associated with concrete activities or from other construction activities were excluded from our study. For a comparative analysis, code 701 was considered as a qualified or white-collar worker andcode 712 as a non-qualified or blue-collar worker.

Our study focuses on a sample of 125,021 accidents taken from the total number of accidents reported in the construction sector in Spain between 2003 and 2008.

2.4. Statistical Analysis

Using Camino's methodology [5], contingency tables were made and chi-square values were calculated to test the hypothesis of the independence of each variable from severity. The corrected standardized residuals (csr) were also calculated. In addition, different accident ratios were calculated and expressed in percentage terms.

Rates were obtained by dividing the number of accidents selected in the groups under study by the total number of accidents. The Total Accident Rate (TAR) was obtained by dividing the total number of accidents in the groups under study by the total number of accidents under analysis. The Light Accident Rate (LAR) was obtained by dividing the number of light accidents in the groups under study by the total number of light accidents. The Serious Accident Rate (SAR) was obtained by dividing the number of serious accidents in the groups under study by the total number of serious accidents. The Very Serious Accident Rate (VSAR) was obtained by dividing the number of very serious accidents in the groups under study by the total number of very serious accidents. Finally, the Fatal Accident Rate (FAR) was obtained by dividing the number of fatal accidents in the groups under study by the total number of fatal accidents.

Data were subsequently processed by means of the statistical analysis package SPSS (Statistical Package for the Social Sciences).

3. RESULTS AND DISCUSSION

The study focused on the following variables: *Occupation*, *Age*, *Company staff*, *Length of Service*, *Location of the Accident* and*Injury*.

3.1. Occupation

In order to separate qualified and non-qualified workers, the first variable studied was *Occupation*. Subsequently, all other variables were divided into these two categories.
The results shown in Table 3 reveal that an accident suffered by a white collar worker is more likely to be serious or fatal than an accident suffered by a blue-collar worker.

Table 3.Accident data in relation to occupation and severity.

In the construction of structural works the accidents registered for foremen and management were 18.58% of all the accidents under analysis, a record which increased to 44.04% for total fatal accidents. By contrast, blue-collar workers were involved in 81.42% of the accidents under study. However, this percentage decreased to 55.96% for the total number of fatal accidents. Figure 2 shows an increasing trend in relation to severity for accidents inwhite-collar workers and a decreasing trend for accidents in blue-collar workers.

Figure 2.Distribution of accidents by occupation and severity.
Notes. 701-White-collar,712-Blue-collar.

3.2. Age

Table 4 showsthat as the age of the worker involved in the accident increases the probability that the accident will be more serious than 'light' also increases.

Table 4.Accident data in relation to age and severity.

A comparison of the differences between TAR and FAR for each age group and occupation (Figure 3) reveals that the age group between 50-59 shows the highest increase in fatalities in relation to the total number of accidents (TAR%-FAR%= -8.92% blue-collar; TAR%-FAR%=-6.28% white-collar). By contrast, the probability that the accident will be fatal decreases in the group of workers aged 25-29 (TAR%-FAR%= 11.11% blue-collar; TAR%-FAR%= 9 % white-collar). These values indicate that age is a factor which behaves similarly in all the workers. Nevertheless, the variation of the results obtained from the operation TAR-FAR is a little higher among blue-collar workers.

Figure 3.Difference between TAR-FAR (%) rates in relation to age.
Notes. 701-White-collar,712-Blue-collar.

3.3.Company staff

The variable *Company staff*had no impact on the severity of accidents in the two occupations under study.

Table 5.Accident data in relation to Company staff and Severity.

The data obtained when calculating the difference between TAR and FAR (Figure 4), revealed significant differences as far as the qualification of workers is concerned. A white-collar worker is less likely to suffer a fatal accident when the incident occurs in companies with 11 to 25 employees. However, in the case of blue-collar workers this probability is lower in companies with 101 to 250 employees. On the other hand, companies with less than 5 employees and companies with 11 to 25 employees had the worst results for both white-collar and blue-collar workers. In particular,the results for companies with 11 to 25 employees clearly reveal that records are very different for the two groups.

Figure 4.Difference between TAR-FAR rates in relation to Company staff.
Notes. 701-White-collar,712-Blue-collar.

3.4. Length of service

Many authors mention a short length of service in the company as a relevant causative factor for accidents in the sector [15],[16],[17]. Our analysis reveals that the probability of an accident being fatal is not the same in all the groups under study (Table 6).

Table 6.Accident data in relation to Length of service and Severity.

As Figure 5 shows, a very short length of service can increase the severity of the accident among blue-collar workers. Lack of experience in blue-collar workers is shown to have a high impact on the severity of the accident. In order to reduce fatalities among these workers, special attention must be paid to the first month at work. Efforts to improve safety standards must be focused particularly on this period of time.

On the other hand, white-collar workers present different results as far as this variable is concerned:workers with no experience are not the ones with the worst rates. Figure 5 shows that special attention must be paid to workers with 5-10 years' experience at work. This group of workers presented a difference of 11.27% between TAR and FAR (TAR%-FAR% = -11.27%).

Figure 5.Difference between TAR.-FAR rates in relation to Length of service.

Notes. 701-White-collar,712-Blue-collar.

3.5. Location of the accident

Many authors [9],[25] have considered safety on construction sites, but nowadays not all accidents occurring in the construction sector take placeon construction sites. Results obtained in Table 7 show that, although most accidents took place on the habitual worksite (TAR 82.20%,white collars; TAR 86.95%, blue collars), fatality rates were considerably lower (FAR 57.29%, white-collars; TAR 65.57% blue collars).

Table 7.Accidents data in relation to Location of the accident and Severity.

Differences between TAR and FAR rates were again calculated for each group of workers (Figure 6) and reveal that there are no significant differences between white and blue-collar workers. Both groups presented the highest risk levels in accidents on the way to work or going backhome. This fact must be taken into account, because road traffic accidents going to the work or going back home are considered as occupational accidents in Spain.

Figure 6.Difference between rates TAR-FAR in relation to Location of accidents.
Notes. 701-White-collar,712-Blue-collar.

3.6. Injury.

The distribution of injuries is not the same in all the groups analysed. The highest percentage of blue-collar accidents (43.99 %) is related to wounds and superficial injuries, while the highest percentage of white-collar accidents is linked with dislocations, sprains and strains (45.57 %).

Figure 7.Distribution of accidents in relation to injuries.
Notes. 701-White-collar,712-Blue-collar.

With regard to fatal accident injuries, multiple lesions showed similar results among all workers. They were the main cause of 45.9 % of blue-collar fatalities, and 47.92 % of white collar fatalities. Concussion and internal injuries were the second cause of death for blue-collar workers (22.95 %), while heart attacks, strokes and other non-traumatic diseases were the second cause for white collar workers (17.71%).

Figure 8.Distribution of accidents in relation to fatal injuries.
Notes. 701-White-collar,712-Blue-collar.

4. CONCLUSIONS.

The study confirmed that the variables playing a role in accidents can differ according to the level of qualification of the workers in concrete construction enterprises. Consequently, measures to improve health and safety should be adapted to the similarities and differences found in the study.

Similarities

- Age. Workers between 25-29 years of age are least likely to have a fatal accident while workers between 50-59 years of ageare most likely to have a fatal accident. Consequently, special strategies must be developed in order to reduce the likelihood of fatal accidents for all ages, but, in particular for older workers.

- Location of the accident. Although most of the accidents took place at the habitual worksite, a fatal accident is more likely to occur on the journey to or from work. Workers, companies, and authorities frequently overlook this problem, because they do not consider these incidents as an occupational issue. Whilst some of these issues may be more connected to generic road safety, work-related travel issues such as excessive travel or travel after long stressful work hours should be addressed.

- Injuries. Multiple lesions were the main cause of death in the accidents studied. This result should encourage occupational health and safety and health stakeholders to identify the circumstances involved in accidents with these injuries and to promote preventive measures concerning the relevant factors. There should be further research on this type of injury.

Differences

- Occupation. Whilst white collar workers have less accidents, an accident involving a white-collar worker would probably have more severe consequences than an accident involving a blue-collar worker. Qualification is not necessarily tantamount to safety. In many cases the technical skills of workers are not related to education in risk prevention at work. In Spain university programs do not always include compulsory courses on specific issues regarding occupational safety which could be an issue.

- Company size. This variable presents a very heterogeneous tendency without a clear applicable pattern. It cannot be said that safety increases or decreases according to company size for any of the groups under study. However, the likelihood that a white-collar worker will have a fatal accident is low in companies with 11 to 25 workers. However, companies with 101 to 250 workers had the best rates for blue-collar workers. The need for more efficient preventive measures in a company differs in relation to the number and qualification of their employees.

- Length of service. Lack of experience is an important in fatal accidents in blue-collar workers, especially during the first monthof work. On the other hand,white-collar workers with 5 to 10 years of experience had the worst fatality rates. A similar conclusion can be drawn in relation toworkers' age. Special strategies must be developed in order to improve these results. Particular attention must be paid to the first month at work of blue-collar workers. White-collar workers should have further formation on safety standards after 5 to 10 years of work experience.

- Injuries. The second cause of death among blue-collar workers was "concussion and internal injuries", while among white-collar workersthe second cause was "heart attacks, strokes and other non-traumatic diseases". For proper prevention, accidents that could lead to these injuries should be given more attention in future studies.

4.1.Impact on Industry

The conclusions we have drawn in this paper shouldmake safety stakeholders more aware of the problem of accidents at work andencourage them to promote training plans, preventive measures, and safety strategies to reduce the number and consequences of accidents in concrete construction companies.

ACKNOWLEDEGEMENTS.

This study was financed by Spanish Government [Ministry of Science and Technology] through the project named Safety from Design in performance of formwork activities at civil works, referenced like BIA2011-27338 into the list of approved project in the National Plan of Research and Development.

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FIGURES LEGEND.

Figure 1.Percentage of fatal construction accidents in the total number of occupational deaths.

Figure 2.Distribution of accidents by occupation and severity.
Notes. 701-White-collar,712-Blue-collar.

Figure 3.Difference between TAR-FAR (%) rates in relation to age.
Notes. 701-White-collar,712-Blue-collar.

Figure 4.Difference between TAR-FAR rates in relation to Company staff.
Notes. 701-White-collar,712-Blue-collar.

Figure 5.Difference between TAR.-FAR rates in relation to Length of service.
Notes. 701-White-collar,712-Blue-collar.

Figure 6.Difference between rates TAR-FAR in relation to Location of accidents.
Notes. 701-White-collar,712-Blue-collar.

Figure 7.Distribution of accidents in relation to injuries.
Notes. 701-White-collar,712-Blue-collar.

Figure 8.Distribution of accidents in relation to fatal injuries.
Notes. 701-White-collar,712-Blue-collar.

TABLES.

Table1. Fatal Accidents in Spain and the United Kingdom 2000-2007 (Eurostat, 2011).

	Spain			United Kingdom		
	All sectors	Only Construction		All sectors	Only Construction	
Year	Number	Number	(%)	Number	Number	(%)
2000	803	229	**28.52**	280	105	**37.50**
2001	739	226	**30.58**	233	80	**34.33**
2002	805	246	**30.56**	219	70	**31.96**
2003	722	247	**34.21**	224	71	**31.70**
2004	695	217	**31.22**	215	68	**31.63**
2005	662	248	**37.46**	209	60	**28.71**
2006	680	235	**34.56**	237	77	**32.49**
2007	572	219	**38.29**	230	72	**31.30**

Table 2. Accidents selected according to National Occupation Code (CNO-94).

CNO-94	Code Description	Type of worker
701	Foreman, head in construction structural works	White-collar
712	Workers in concrete, structural iron or similar	Blue-collar

Table 3.Accident data in relation to occupation and severity.

Chi-Squared	1820.92									
	d.f = 27	Sig=0.000								
	Total Accidents		**Light Accidents**		**Serious Accidents**		**Very Serious Accidents**		**Fatalities**	
	TAR (%)		LAR (%)		SAR (%)		VSAR (%)		FAR (%)	
CNO-94	**701**	**712**	**701**	**712**	**701**	**712**	**701**	**712**	**701**	**712**
Percentages	18.58	81.42	18.43	82.57	24.44	75.56	37.50	62.50	44.04	55.96

Table 4.Accident data in relation to age and severity.

CNO-701	N= 23233	Chi-Squared	58.0	d.f= 27	Sig=0.000
CNO-712	N=101788	Chi-Squared	160.6	d.f= 27	Sig=0.000

	Total Accidents TAR (%)		Light Accidents LAR (%)		Serious Accidents SAR (%)		Very Serious Accidents VSAR (%)		Fatalities FAR (%)	
Age (years)	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**
<16	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16-19	0.28	2.79	0.28	2.81	0.00	1.97	0.00	0.00	0.00	3.28
20-24	2.79	13.49	2.84	13.58	1.22	8.20	0.00	10.91	1.04	10.66
25-29	9.00	19.31	9.03	19.38	9.74	15.94	9.09	16.36	0.00	8.20
30-39	28.15	33.76	28.36	33.79	19.68	31.82	21.21	32.73	25.00	33.61
40-49	29.17	19.90	29.13	19.82	29.82	24.54	42.42	23.64	31.25	24.59
50-59	22.89	9.11	22.74	9.00	28.80	15.42	21.21	14.55	29.17	18.03
60-65	7.52	1.61	7.44	1.61	10.34	2.03	6.06	1.82	12.50	1.64
65-70	0.16	0.02	0.15	0.02	0.41	0.07	0.00	0.00	1.04	0.00
>70	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 5.Accident data in relation to *Company staff* and *Severity*.

CNO-701	N= 23233	Chi-Squared	19.4	d.f= 21	Sig=0.000	
CNO-712	N=101788	Chi-Squared	72.0	d.f= 21	Sig=0.000	

	Total Accidents TAR (%)		Light Accidents LAR (%)		Serious Accidents SAR (%)		Very Serious Accidents VSAR (%)		Fatalities FAR (%)	
Company staff	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**
< 5 workers	17.57	9.20	17.51	9.19	19.27	10.24	27.27	7.27	19.79	6.56
from 5 to 10	13.05	8.09	12.96	8.05	16.43	10.63	18.18	12.73	14.58	10.66
from 11 to 25	20.76	18.18	20.78	18.11	20.89	22.44	15.15	21.82	17.71	22.13
from 26 to 50	17.51	21.19	17.57	21.19	15.21	21.13	18.18	18.18	14.58	23.77
from 51 to 100	14.13	20.64	14.11	20.68	15.01	18.24	12.12	12.73	15.63	20.49
from 101 to 250	10.96	15.88	11.00	15.92	9.13	13.45	9.09	20.00	10.42	12.30
from 251 to 500	3.59	5.15	3.61	5.18	2.43	3.15	0.00	7.27	5.21	3.28
over than 500	2.44	1.68	2.46	1.69	1.62	0.72	0.00	0.00	2.08	0.82
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 6.Accident data in relation to *Length of service* and *Severity*.

CNO-701	N= 23233	Chi-Squared	64.4	d.f= 21	Sig=0.000	
CNO-712	N=101788	Chi-Squared	35.5	d.f= 21	Sig=0.000	

	Total Accidents TAR (%)		**Light Accidents** LAR (%)		**Serious Accidents** SAR (%)		**Very Serious Accidents** VSAR (%)		**Fatalities** FAR (%)	
Length of service	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**
< 1 month	10.54	25.69	10.50	25.61	12.17	29.59	9.09	27.27	10.42	39.34
1 -3 months	9.10	19.12	9.10	19.15	9.53	17.98	12.12	5.45	6.25	14.75
4-12 months	24.37	33.42	24.43	33.47	23.94	30.51	9.09	34.55	18.75	20.49
1-2 years	15.63	11.70	15.64	11.70	16.23	11.55	18.18	18.18	9.38	13.11
3-4 years	14.74	6.24	14.78	6.24	12.98	6.36	12.12	5.45	15.63	6.56
5-10 years	18.94	3.32	18.90	3.32	18.26	3.67	24.24	9.09	30.21	3.28
11-30 years	5.75	0.46	5.74	0.46	5.68	0.33	15.15	0.00	5.21	1.64
>30 years	0.92	0.05	0.90	0.05	1.22	0.00	0.00	0.00	4.17	0.82
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 7.Accidents data in relation to *Location of the accident* and *Severity*.

CNO-701	N= 23233	Chi-Squared	235.5	d.f= 9	Sig=0.000
CNO-712	N=101788	Chi-Squared	309.5	d.f= 9	Sig=0.000

	Total Accidents TAR (%)		**Light Accidents** LAR (%)		**Serious Accidents** SAR (%)		**Very Serious Accidents** VSAR (%)		**Fatalities** FAR (%)	
Location of the accident	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**	**CNO-701**	**CNO-712**
Habitual worksite	82.20	86.95	82.67	87.16	67.34	75.59	54.55	67.27	57.29	65.57
On the way from worksite to worksite	2.82	0.50	2.69	0.49	4.87	0.92	27.27	3.64	14.58	2.46
Going to worksite or going home	5.47	2.86	5.26	2.79	12.37	6.43	12.12	7.27	15.63	16.39
Non-habitual worksite	9.51	9.69	9.38	9.57	15.42	17.06	6.06	21.82	12.50	15.57
TOTAL	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

FIGURES

Figure 1. Percentage of fatal construction accidents in the total number of occupational deaths.

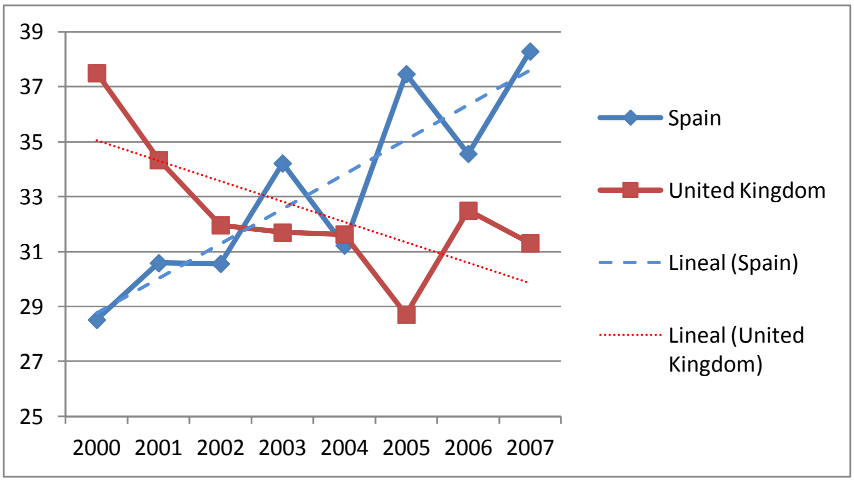

Figure 2. Distribution of accidents by occupation and severity

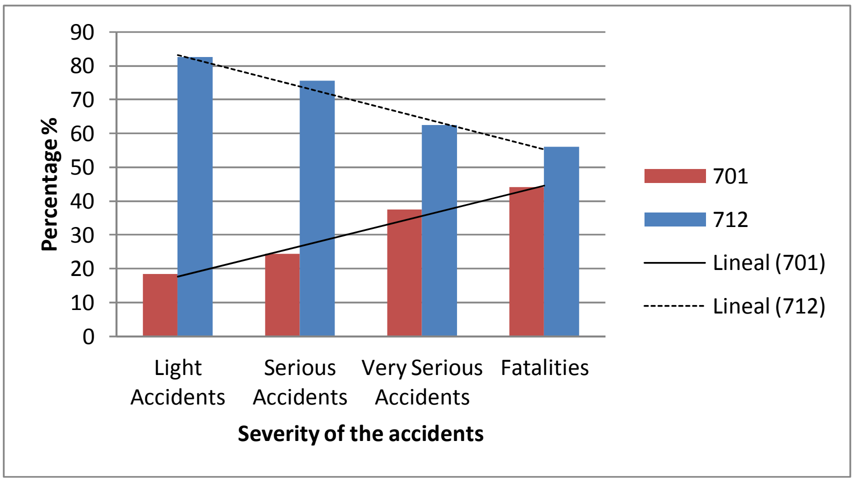

Figure 3. Difference between TAR-FAR (%) rates in relation to age.

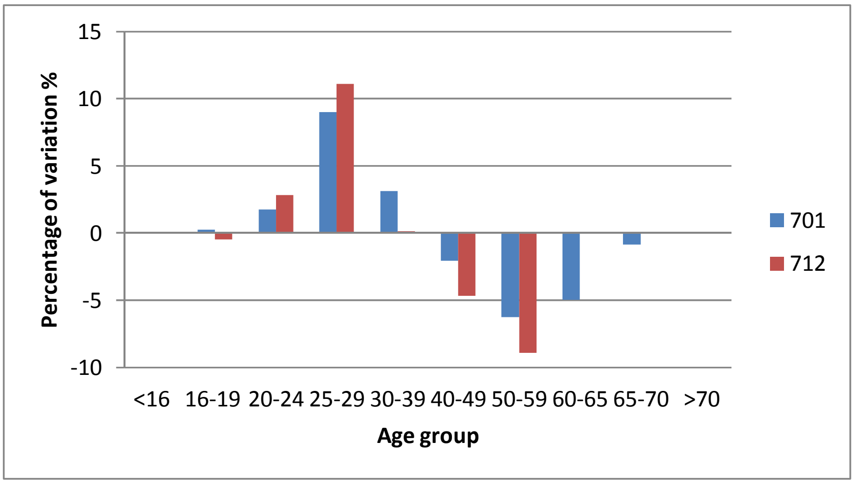

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Figure 4. Difference between TAR-FAR rates in relation to Company staff.

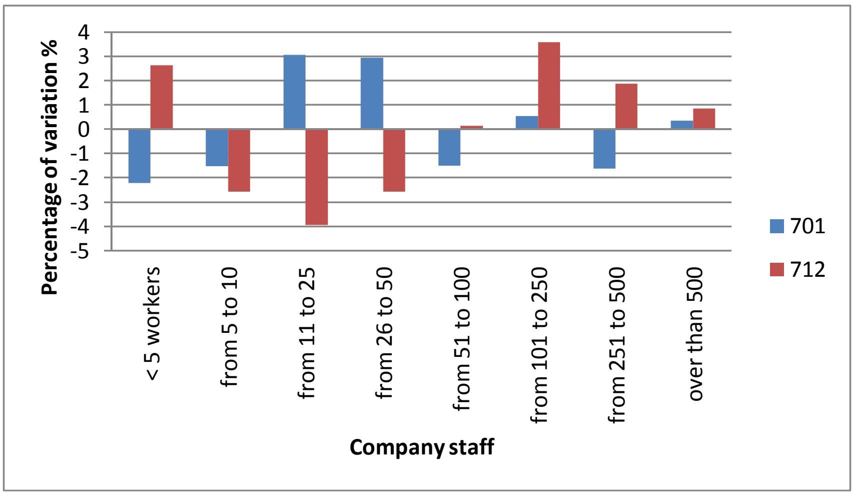


Figure 5. Difference between TAR.-FAR rates in relation to Length of service.

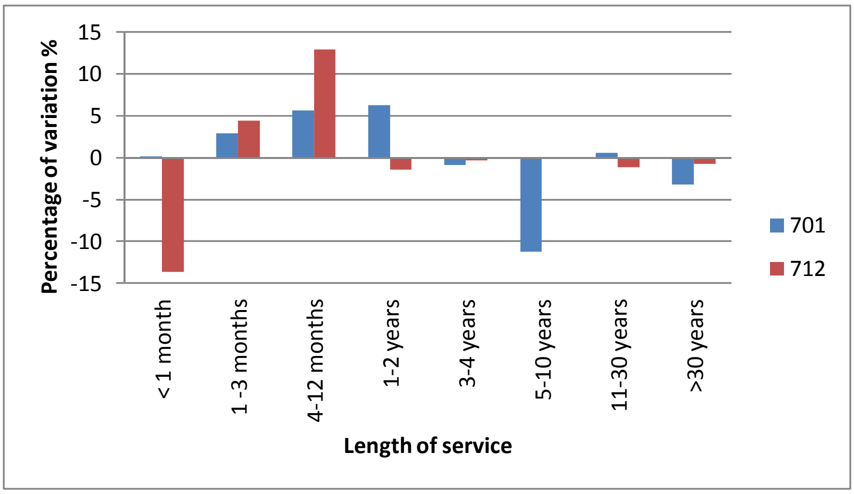


Figure 6.Difference between rates TAR-FAR in relation to Location of accidents

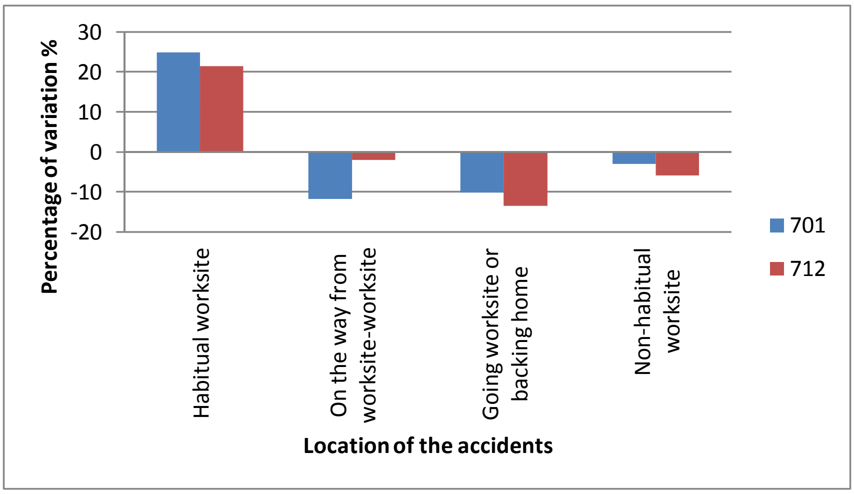


Figure 7. Distribution of accidents in relation to injuries

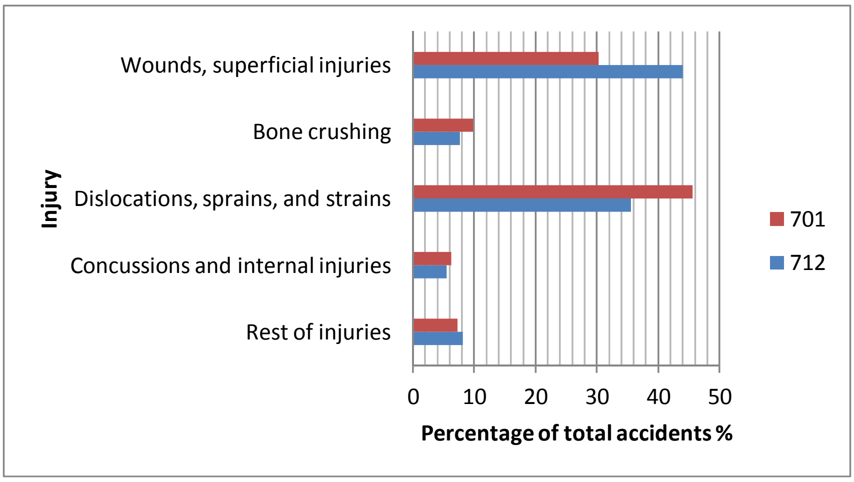
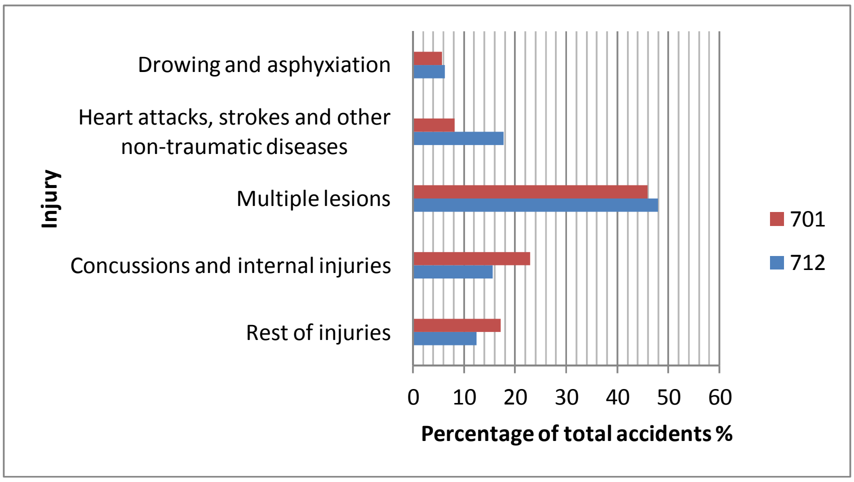


Figure 8. Distribution of accidents in relation to fatal injuries.



5.7 PUBLICATION VII. PREVENTION THROUGH DESIGN (PTD) THE IMPORTANCE OF THE CONCEPT IN ENGINEERING & ARCHITECTURE UNIVERSITY COURSES.

**The paper status in the journal is under review*

PREVENTION THROUGH DESIGN (PtD).
THE IMPORTANCE OF THE CONCEPT IN
ENGINEERING & ARCHITECTURE UNIVERSITY COURSES

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Abstract

Background: Although the concept of Prevention through Design (PtD) is not new, many accidents still occur at construction sites due to the fact that it is poorly implemented or not implemented at all in construction projects run by engineers and architects who have graduated from universities.

Objective: To quantify how Prevention through Design is taught in university design or construction courses offered as part of Engineering and Architecture under/degrees in Spain, which focus on the construction of concrete structures.

Methodology: Objective and subjective methodologies were used to compare courses from the under/degrees from the previous system (Old) and those under the Bologna process. A survey of 454 Engineering and Architecture students was taken. In addition, lecturers of the courses were interviewed and an objective analysis of the contents of the syllabi and the rest of courses in the under/degrees was conducted.

Results: Occupational Health and Safety had a greater presence and importance in the courses under the Old degrees than those created to comply with the Bologna process. Similarly, Prevention through Design was more fully integrated in the courses from Old degrees. Similar results in both groups were obtained with regard to the value of Prevention through Design in the labour market. Analysis of the contents included in the syllabi showed that although the integration of occupational prevention decreased in construction courses in the Bologna degrees, the number of courses dealing with OHS topics increased, but they did not necessarily include the topic of Prevention through Design.

Conclusions: Lack of education and training in Prevention through Design was found in courses on the construction of concrete structures that were included in the study. The Bologna

degrees have not been an improvement in this respect. An enormous effort is necessary to improve the understanding and implementation of the Prevention through Design concept.

Impact on the industry: The results of this research indicate that Occupational Health and Safety and Prevention through Design need to be enhanced in future Engineering and Architecture syllabi.

Keywords: Prevention through Design, course, Occupational Health and Safety, degree, Bologna, construction, structure.

1. Introduction

Construction accident rates are an international cause for concern because the sector presents the highest casualty rates in many countries (Camino López *et al.*, 2008; Eurostat, 2013). Consequently, the problem has been investigated by researchers in countries as different as Taiwan (Cheng *et al.*, 2010), Scotland (Cameron *et al.*, 2008) Turkey (Etiler *et al.*, 2004) (Müngen & Gürcanli, 2005) Portugal (Macedo & Silva, 2005), or South Korea (Im *et al.*, 2009). In Spain, accident rates are equally high (Camino *et al.*, 2008, López-Arquillos *et al.*, 2012, Martinez-Aires *et al.*, 2010).

In addition, Prevention through Design (PtD) is especially relevant when accidents in civil construction are studied. The definition of the concept is available on the National Institute for Safety and Health (NIOSH, 2013) website:

"Addressing occupational safety and health needs in the design process to prevent or minimize the work-related hazards and risks associated with the construction, manufacture, use, maintenance, and disposal of facilities, materials, and equipment".

There are many studies of PtD which conclude that a large percentage of construction accidents could have been avoided or reduced if occupational safety had been considered in the design phase and during the project itself (Weinstein *et al.*, 2005; Behm, 2005; Haslam, 2005; Gibb, 2006; Gambatese *et al.*, 2008). Authors such as Behm (2005) and Gambatese *et al.* (2008) studied the influence of project design on construction worker safety. Their studies analyzed connections between construction fatalities and construction safety design and found that 42% of the fatalities reviewed were linked to this concept.

In Europe, architects and design engineers are required to implement design for construction safety (ILO, 1985) but unfortunately Prevention through Design is often forgotten or not clearly integrated in university Engineering and Architecture courses. Consequently, many professionals are required to implement a concept that they have not studied at all or only briefly during their academic careers. This is only a part of a bigger problem because, in general, safety contents are not integrated in the under/graduate curricula as it should be (HSE, 2009). Changing this is difficult since the under/graduate curricula is already crowded (Culvenor & Else, 1997).

Studies of occupational health and safety courses (OHS) at universities do exist in the literature (Heinrich, 1956; Nolan, 1991; Grossel, 1992; Senkbeil, 1994; Phoon,1997; Hill & Nelson, 2005; Arezes & Swuste, 2012; Cortés *et al.*, 2012), but specific studies on the presence of PtD in courses and attempts to quantify their impact on design and construction of concrete structures in Engineering and Architecture programs have not been found.

The aim of the current study is to quantify how the Prevention through Design concept is taught in university under/graduate design or construction courses offered in Engineering and Architecture under/degrees in Spain, which focus on the construction of concrete structures. Opinions from students and lecturers and an analysis of academic programs will be used for this purpose.

2. Material and methods

The study was divided into three stages.

- 1) Identify and select a sample of the Engineering and Architecture courses that focus on the design or construction of concrete structures.
- 2) Use a questionnaire to collect and analyze the perception of the students taking the university courses selected previously in stage 1.
- 3) Analyze the safety-related content in the syllabi from the courses selected, and the safety issues discussed in the rest of courses that make up the under/degree.

2.1 Data collection

During the 2010-2011 academic year a total of 212,466 university students were enrolled in one of the 718 Engineering or Architecture under/degrees available in Spain (MEC, 2013; INE, 2013). It is important to note, that the European Higher Education Area was launched in 2010 as part of the Bologna process. More competitive and more attractive under/degrees were created for both Europeans and students and scholars from other continents under this more compatible and comparable framework.

Nowadays, university students can be divided into two groups depending on their academic itinerary. Students studying degrees approved before the Bologna process, (Old degrees (OD)) and those whose degrees were created during the Bologna process in order to achieve the European Higher Education Area (Bologna degrees (BD)). Although the number of students in both is currently similar, the future distribution of the students will be quite different. The Old degrees are in the process of being phased out and the number of students is therefore declining. At the same time the Bologna degrees are being rolled out to substitute the Old degrees and the number of students is thus on the rise.

In the same period, 50,996 students concluded their under/degrees and of those 39 per cent (20,086) were building or civil construction under/degrees [Architecture, Civil Engineering, Building Engineering, and Industrial Engineering] (MEC, 2013). In order to obtain the opinion of future construction professionals, 12 courses related to design or construction of concrete structures from 8 different under/degrees at three different universities were selected (6 courses from four different Old degrees, and 6 courses from four different Bologna degrees). The selection criteria used was that the course be part of a civil or building construction under/degree and that the syllabus must include the design or construction of structures.

From the selected construction courses 454 students were surveyed in-situ using a questionnaire during a lecture on theory. 432 students correctly completed all of the items on the questionnaire and thus the response rate was 95.15%. Distribution of the answers is provided in table 1.

Table 1. Distribution of the courses studied

	University	Under/degree	Course	Respondents
Old Degrees (Total respondents = 213)	University of Granada	Architect degree	Construction III	47
			Prefabrication	8
		Architect undergraduate degree	Construction II	26
			Projects	21
		Civil Engineer	Construction procedures	77
	Univ of Malaga	Architect Degree	Structures VI	34

Bologna Degrees (Total respondents =219)	University of Granada	Building engineer	Construction IV	47
			Structures III	46
		Civil Engineer	Mechanics for engineers	41
		Architect Degree	Construction I	32
	University of Sevilla	Building engineer	Structures III	24
			Construction II	29

Based on the population studied and the sample collected the results obtained from the questionnaires had a confidence level higher than 95%, and a margin of error under 5%.

2.2 Questionnaire design

A Likert-scale questionnaire (Likert, 1932) was designed to collect the opinions of the students in the sample since these scales have been shown to be a very useful tool in previous papers on occupational health and safety in construction (Melia *et al*., 2008; Gittleman *et al*., 2010; Ismail *et al*., 2012). The questionnaire was designed to be simple and short. It contained 15 items grouped into three categories:

- 1) Questions related to the student’s general education and training on Occupational Health and Safety issues.
- 2) Specific questions regarding the influence of Prevention through Design in the courses.
- 3) Questions about the present value of occupational safety and Prevention through Design in the labour market.

Respondent were asked to evaluate each item from 1 [Strongly disagree] to 5 [Strongly agree].

2.3 Statistical tools

A variety of statistical tools were used on the academic programs and questionnaire results. For the academic programs the frequencies of specific keywords related to construction projects and safety were analyzed. Statistical tools such as the median test and the Kruskal-Wallis test were applied to the questionnaire results to test specific hypotheses. The statistical results were obtained using SPSS 20.

3. Results and discussion

Results were analyzed for the three categories. The mean, median, mode and variance were calculated for all answers. In addition, Kruskal-Wallis and median tests were carried out in order to test the medians and distributions between answers from different groups with a confidence level of 95%.

3.1 Questionnaires

3.1.1 Occupational Health and Safety Training

Results from this section (Table 2) showed that the integration of workers' occupational health and safety with the rest of the technical concepts obtained very poor results. Although the means were similar, the mode in the Bologna results obtained the lowest possible value.

Different results were found in the case of OHS-specific courses. OHS is studied in specific courses more often in Bologna degrees than in Old Degrees, although these courses are not necessarily related to construction courses.

Table 2. Results from OHS items

	QUESTION	UNDER/DEGREE	MEAN	MEDIAN	MODE	VARIANCE
Q1	Workers' Occupational Health and Safety at vertical construction sites is integrated with the rest of the technical concepts in every lecture of the course	Old (OD)	2.17	2	2	1.00
		Bologna (BD)	2.13	2	1	1.07
Q2	Workers' Occupational Health and Safety at vertical construction sites is only considered in some lectures of the course	Old (OD)	2.86	3	4	1.48
		Bologna (BD)	2.26	2	1	1.30
Q3	Workers' Occupational Health and Safety is often confused with the structural safety of the construction	Old (OD)	2.60	3	1	1.61
		Bologna (BD)	2.50	3	3	1.25
Q4	Workers' Occupational Health and Safety is addressed in other specifics courses of the under/degree	Old (OD)	2.30	2	1	1.95
		Bologna (BD)	3.49	4	4	1.55
Q5	Knowledge of Workers' Occupational Health and Safety is evaluated in the course	Old (OD)	2.24	2	1	1.34
		Bologna (BD)	1.90	2	1	0.98

3.1.2 The Influence of Prevention through Design

The survey showed that Students' knowledge of Prevention through Design was poor in both groups but worse results were obtained for Bologna degrees than for Old degrees (Table 3). It is important to note that the lowest mode value for both groups of respondents was obtained for question 6 regarding knowledge of PtD. Ignorance with regard to PtD is not properly detected because the majority of the respondents agree that this knowledge is not evaluated during the course.

In the previous section, the results indicated that OHS-related topics were addressed in other specific courses dealing with this issue, but this is no guarantee that students will have a better grasp or understanding of OHS concepts.

Despite the lack of training in PtD, student respondents considered it to be an important concept for improving workers' occupational health and safety in vertical constructions, with students studying Old degrees assigning a greater importance to PtD. A correspondence exists between a deeper understanding of PtD by respondents and the greater importance they gave to the influence of the concept in the occupational safety of the workers.

Table 3. Results from PtD influence items

	QUESTION	UNDER/DEGREE	MEAN	MEDIAN	MODE	VARIANCE
Q6	I know what Prevention through Design (PtD) is	Old (OD)	2.47	2	1	1.71
		Bologna (BD)	2.25	2	1	1.52
Q7	Worker safety when designing a construction project is taken into account during the course	Old (OD)	2.47	2	1	1.71
		Bologna (BD)	2.13	2	1	1.12
Q8	The concept of Prevention through Design (PtD) is addressed in many courses such as this one	Old (OD)	2.20	2	1	1.28
		Bologna (BD)	2.47	2	2	1.38
Q9	The concept of Prevention through Design (PtD) is important for improving workers' occupational health and safety in vertical constructions	Old (OD)	3.93	4	5	1.35
		Bologna (BD)	3.59	4	4	1.47
Q10	The concept of Prevention through Design (PtD) is not important when compared to the rest of the course content.	Old (OD)	2.67	3	3	1.51
		Bologna (BD)	2.78	3	3	1.72
Q11	Knowledge of Prevention through Design (PtD) is evaluated in this course	Old (OD)	2.24	2	1	1.29
		Bologna (BD)	1.89	2	1	1.06

3.1.3 Value of occupational safety and PtD in the labour market

There was a high degree of consensus among respondents in this section (Table 4). The majority considered OHS and PtD to be very important and the items from this section obtained the highest level of agreement. The differences in the answers from both groups were very small, and distribution of the answers can be considered similar in all items from this category.

Table 4. Results from value of PtD in the labour market

	QUESTION	UNDER/DEGREE	MEAN	MEDIAN	MODE	VARIANCE
Q12	Training in OHS increases the value of the professional curricula	Old (OD)	3.69	4	4	1.10
		Bologna(BD)	3.79	4	4	1.23
Q13	Independent of its real value the labour market views training in OHS very positively	Old (OD)	3.31	3	3	0.90
		Bologna (BD)	3.30	3	3	1.23
Q14	Training in PtD increases the value of the professional curricula	Old (OD)	3.42	3	3	1.07
		Bologna (BD)	3.39	3	3	1.14
Q15	Independent of its real value, the labour market views training in PtD very positively	Old (OD)	3.21	3	3	0.93
		Bologna (BD)	3.16	3	3	1.08

3.2 Statistical test

Quantitative statistical tools were used to test the following hypotheses:

*Hypothesis 1 (**H1**): The median of the items is the same in the two respondent categories: Old degrees and Bologna degrees.*

*Hypothesis 2 (**H2**): The distribution of the items is the same in the two respondent categories: Old degrees and Bologna degrees.*

Hypothesis 1 was validated using the median test, Hypothesis 2 was validated using the Kruskal-Wallis test. Results from these tests are shown in table 8. Results were obtained with a significance level of 0.05, with a confidence interval of 95%.

Table 5. Statistical test results.

Issues	**Item**	**Median test (H1)**		**Kruskal-Wallis test (H2)**	
		Sig	**Decision**	**Sig**	**Decision**
Occupational Health and Safety Training	**Q1**	0.771	Accepted	0.600	Accepted
	Q2	0.000	Rejected	0.000	Rejected
	Q3	0.051	Accepted	0.484	Accepted
	Q4	0.000	Rejected	0.000	Rejected
	Q5	0.008	Rejected	0.002	Rejected
The influence of Prevention through Design	**Q6**	0.107	Accepted	0.093	Accepted
	Q7	0.007	Rejected	0.002	Rejected
	Q8	0.046	Rejected	0.013	Rejected
	Q9	0.004	Rejected	0.041	Rejected
	Q10	0.190	Accepted	0.431	Accepted
	Q11	0.003	Rejected	0.001	Rejected
Value of occupational safety and PtD in labour market	**Q12**	0.014	Rejected	0.235	Accepted
	Q13	0.359	Accepted	0.801	Accepted
	Q14	0.991	Accepted	0.817	Accepted
	Q15	0.936	Accepted	0.814	Accepted

Statistical tests showed that in 7 of the 15 items there were no significant differences when comparing the medians of both groups of respondents. Similarly, the distribution of the answers was the same in the two groups for 8 of the 15 item on the questionnaire.

3.3 Lecturers' interviews

In order to contrast the results obtained from the student questionnaire in the previous section, a survey was conducted of the lecturers who teach the courses analyzed. In the interview they completed the questionnaire and provided comments on some of the items, based on their own experience. Obviously, there are fewer lecturers than students, but their experience and academic background is higher. 11 lecturers from the courses included in the study were interviewed. They represent a total of 223 years of experience. The main results from the interview and comments by the lecturers are shown in table 6. The statistical comparison of results is not as accurate as we would like because the sizes of the student and lecturer samples are very different, but the results can provide us with an idea of the lecturers' opinion.

Most of lecturers interviewed felt that it would be difficult to include OHS and PtD because time is limited and the curricula is already quite crowded. This is in line with results from previous studies (Culvenor & Else, 1997). These concepts are not included in the specific course content and as a result they are not considered a priority. Although lecturers were aware of PtD, many of them they did not study the concept when they were students.

It is interesting to note that a high level of consensus existed around the idea that training in OHS and PtD increases the value of professional curricula, but the labour market does not seem to value this to.

Table 6. Results and comments from lecturers

	QUESTION	MEAN	MODE	NOTEWORTHY COMMENTS
Occupational Health and Safety Training				
Q1	Workers' Occupational Health and Safety at vertical construction sites is integrated with the rest of the technical concepts in every lecture of the course	2,45	1	*" Including OHS is difficult because there are other many other concepts in the courses and time is limited"* *"If I included OHS I would need to exclude other concepts because there just isn't time for everything"*
Q2	Workers' Occupational Health and Safety at vertical construction sites is only considered in some lectures of the course	2,00	1	*"OHS concepts are not formally included in the course"* *" OHS is not a specific aim of the course"* *"OHS is a transversal concept"*
Q3	Workers' Occupational Health and Safety is often confused with the structural safety of the construction	3,09	3	*"Many time the difference is not clear because structural failures are linked to accidents "* *"This is easily and frequently confused"*

Q4	Workers' Occupational Health and Safety is addressed in other specifics courses of the under/degree	3,45	5	*"OHS for workers is a priority on other courses"*
Q5	Knowledge of Workers' Occupational Health and Safety is evaluated in the course	2,91	1	*"Other concepts are evaluated in more detail"*
Prevention through Design influence				
Q6	I know what Prevention through Design (PtD) is	4,27	5	*"I am familiar with the concept, but I did not study this when I was student"*
Q7	Worker safety when designing a construction project is taken into account during the course	2,91	4	*"Worker safety is not considered during the course. It is not an objective here"*
Q8	The concept of Prevention through Design (PtD) is addressed in many courses such as this one	3,09	3	*"I am not sure what the contents of the rest of the courses are"*
Q9	The concept of Prevention through Design (PtD) is important for improving workers' occupational health and safety in vertical constructions	4,82	5	*"The importance of the concept is not reflected in its presence on syllabi"*
Q10	The concept of Prevention through Design (PtD) is not important when compared to the rest of the course content.	2,09	1	*"Design of the course contents is pre-established on the syllabi"*
Q11	Knowledge of Prevention through Design (PtD) is evaluated in this course	2,18	1	*"I cannot evaluate, concepts that I have no time to explain properly"*
Value of occupational safety and PtD in the labour market				
Q12	Training in OHS increases the value of the professional curricula	4,45	5	*"It is important, especially for future OHS managers, coordinators, etc."*
Q13	Independent of its real value the labour market views training in OHS very positively	3,36	5	*"The market focuses on productivity tools and OHS is not usually placed in this category"*
Q14	Training in PtD increases the value of the professional curricula	3,91	4	*"PtD increases the value of the curricula, but is not the most important aspect of a good engineer"*
Q15	Independent of its real value, the labour market views training in PtD very positively	3,18	4	*"PtD is important but is not a priority for the market"*

3.4 Analysis of syllabi

In this section the syllabi from the 12 courses studied in the previous section were analyzed for the frequency of specific keywords related to construction and occupational safety. The keywords included: structure, construction, calculation, design, prevention, economy, costs. The syllabi were divided into five different subsections: a) Title, b) Aims, c) Contents, d) Evaluation, and e) Bibliography. Statistics were generated based on the presence of each keyword in the different subsections of each syllabus. The results for the Old degree courses can be found in Figure 1 and those for Bologna degrees are in Figure 2.

Figure 1. Frequency of keywords in syllabi for courses from the Old degrees

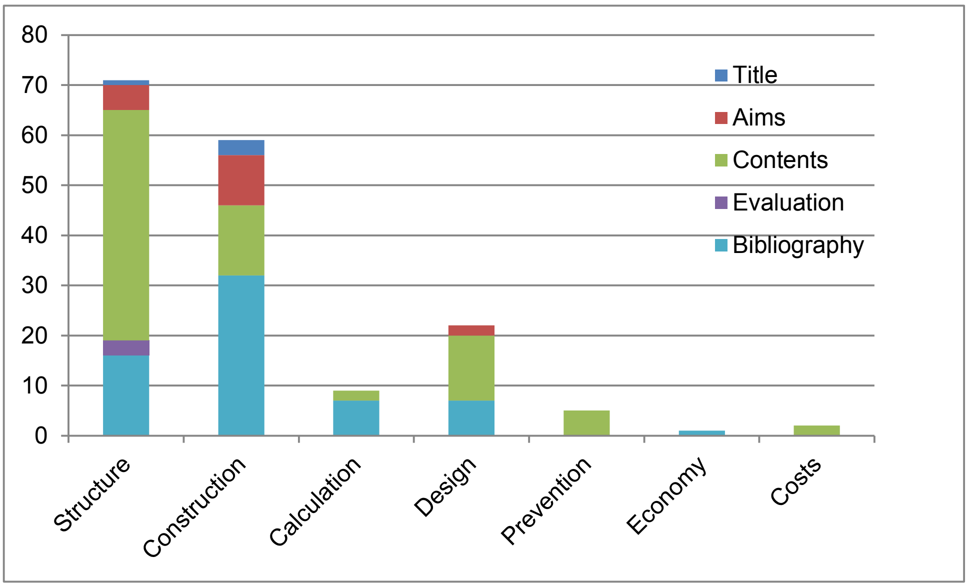
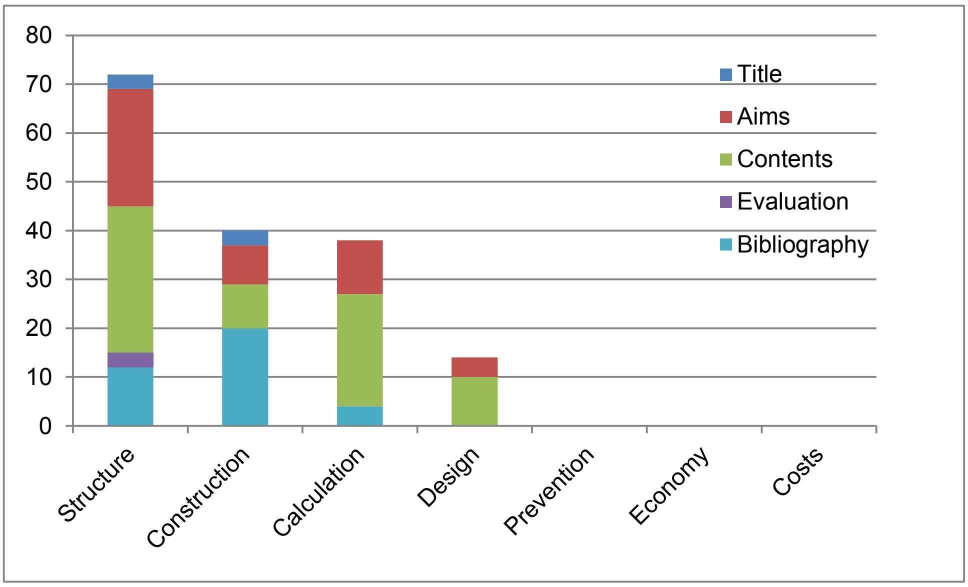


Figure 2. Frequency of keywords in syllabi for courses from Bologna degrees.



No significant differences can be found in the presence and distribution of keywords such as “structure”, and “construction”. However the frequency of the term “calculation” increased in the Bologna degrees compared to the Old degrees while the word “design” decreased. It is interesting to note that the term “design” was found in relation to “construction” or “structure” but not “prevention”. It is significant that although the presence in Old degrees of the term “prevention” is especially low in comparison with keywords such as construction, or structure,

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in the Bologna degrees this keyword was completely absent from all of the syllabi studied. “Economy” and “costs” were also absent.

Table 7. Results from Old degrees and Bologna degrees

Keywords		Structure	Construction	Calculation	Design	Prevention	Economy	Costs
Old degrees	Total appearances	71	59	9	22	5	1	2
	Mean per course	11.8	9.8	1.5	3.6	0.8	0.1	0.3
New degrees	Total appearances	73	39	38	14	0	0	0
	Mean per course	14.6	7.8	7.6	2.8	0	0	0

The absence of the concept of prevention in the new syllabi of the courses bodes negatively for the inclusion of OHS in the studies of future construction professionals. This is partially mitigated by the fact that specific courses on OHS have increased slightly in the global under/degree curricula. In addition, new courses are compulsory whereas in the old under/degrees the only course found on this subject was optional. Students could skip them and finish their university studies without any OHS background whatsoever (Table 7).

Tabla8. The presence of Occupational Health and Safety-related courses in the degrees studied.

	University	Degree	Number of courses related to OHS topics	Course credits	Compulsory Course	Degree Credits	Percentage of course credits of the total degree credits
Old degrees	University of Granada	Architect degree	0	0	NO	400	0.0
		Architect under degree	1	6	NO	307	1.95
		Civil Engineer	0	0	NO	400	0.0
	University of Málaga	Architect	0	0	NO	398	0.0
Bologna Degrees	University of Granada	Building engineer	1	6	YES	240	2.50
		Architect degree	0	0	NO	240	0
	University of Sevilla	Civil Engineer	1	3	YES	240	1.25
		Building engineer	1	9	YES	240	3.75

Although the contents of the OHS-specific courses are not part of the design or construction courses, an increase in the number of OHS courses can improve Architecture students' knowledge of the subject and provide them with some useful tools. However, as previously was pointed out, including this is difficult due to the already crowded curricula (Culvenor & Else, 1997).

Table 9. Average presence of OHS courses in degrees studied

	Average of credits of OHS contents (credits)	**Classification of the courses**	**Percentage of OHS courses credits in the total degree credits (%)**
Old degrees	1.5	Optional	0.40
Bologna degrees	4.5	Compulsory	1.87

4. Conclusions.

The results of the current study show that training in Prevention through Design for Engineering and Architecture students is not especially good and significant improvements are required. The results, when comparing Old degrees and Bologna degrees, are not very positive since the number of construction courses that include.

A higher level of understanding of PtD corresponded to a higher consideration of the importance of PtD in construction. Although the inclusion of PtD in construction courses from Bologna degrees is lower than courses from Old degrees, the total amount of OHS-specific courses identified in the Bologna degrees was greater when compared to the Old degrees. In addition, the new courses included in new academic itineraries were compulsory and not optional, which assures that students cannot finish their degrees without some OHS training. However, the focus on OHS is still insufficient and is not as well integrated as it should be in Engineering and Architecture under/degrees. Results from the surveys given to lecturers showed that PtD and OHS are not priority subjects in the construction courses examined in this study. It is assumed that future professional will be qualified in OHS and PtD, but current education and training are insufficient to achieve this.

The absence of PtD in many construction degrees could be solved in two ways.

- By including PtD concepts with the rest of the technical concepts.
- By creating specific OHS courses that focus on construction issues.

Although this would require an extra effort in the already crowded engineering and architecture curricula, this occupational education and training would prevent many accidents in the future.

4.1 Impact on the industry

The results of this study should be taken into account when creating current and future Engineering and Architecture syllabi in Spain to improve the curricula design for future construction professionals. The literature shows that a correct implementation of PtD can avoid accidents in the construction industry, and the first step should be taken at the university.

4.2 Limitations of the study

The current research is limited to under/degree courses and students in Spain. Engineering and Architecture syllabi and the contents of construction courses can differ in other countries.

4.3 Future Research

This analysis should be extended to other countries to compare the similarities and differences of how PtD is included and taught in university construction courses.

Acknowledgements

This study was financed by the Spanish Government [Ministry of Science and Technology] through project BIA2011-27338 “Safety from Design in performance of formwork activities at civil works”, approved as part of the National Plan for Research and Development.

The authors would like to thank the lecturers and students from all construction courses studied at the different universities for their opinion and suggestions. Without their collaboration this study would not have been possible.

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APPENDIX

6.1 APPENDIX I. QUESTIONNAIRE CIVIL CONSTRUCTION ACTIVITIES RISK ASSESSMENT

CIVIL CONSTRUCTION ACTIVITIES RISK ASSESSMENT

YOUR PROFILE

Master of Science in Occupational Risk Prevention (Yes/No)	Technical Degree (Yes/No)	Years of experience (Number)	Professional registration (Yes/No)	Author of a book on safety (Number)	Author of an article on safety in a learned journal (Number)	Faculty member at and accredited university (Yes/No)	PhD (Yes/No)

YOUR VIEWS

Evaluate each selected safety risk in civil construction with a value of risk from 1 [Low] to 5 [High], considering the frequency of the risk and the severity in case of accident. Answers must be based on the own experience of the respondent and they were not based on the safest case scenario.

SAFETY RISK	VALUE
Exposure to harmful substances	
Fall to lower level	
Fall on the same level	
Cutting	
Overexertion	
Struck against objects in motion	
Struck against objects	
Caught in or compressed	
Repetitive motion	
Others	

Evaluate global risk of each activity having in consideration frequency and severity of the all possible risks during the development of the activity. Range of possible score values were established from 1 [Low] to 5 [High].

ACTIVITY NAME	GLOBAL RISK
Ascend /descend ladder	
Lift /lower materials	
Nail/screw/drill	
Hammer materials	
Crane materials and motorized transport	
Cut materials	
Inspect/plan	
Manual transport	
Static lift	
Plumb/level forms	
Excavation	
Lubrication/preparation	

Thank you for your collaboration

6.2 APPENDIX II. QUESTIONNAIRE PREVENTION THROUGH DESIGN IN FORMWORK AND FALSEWORK ACTIVITIES IN THE CIVIL ENGINEERING SECTOR.

"PREVENTION THROUGH DESIGN IN FORMWORK AND FALSEWORK ACTIVITIES IN THE CIVIL ENGINEERING SECTOR"

Thank you for your assistance with this questionnaire which is part of a collaborative research project between Loughborough University and the University of Malaga (Spain). The same survey has been carried out in similar Spanish companies in order to contrast the opinion between the two countries.

The questionnaire has two different parts:
The first includes questions to determine the respondent's profile. The second includes questions where the expert can express their opinion about different issues.

Answering all the questions should only take around ten minutes.

YOUR PROFILE

Please tick all that apply

DESIGN COMPANY ☐		**CONSTRUCTION COMPANY MANAGEMENT /SUPERVISION** ☐	**FORMWORK COMPANY TECHNICIAN** ☐
		MALE ☐	FEMALE ☐
ACADEMIC BACKGROUND	ENGINEERING MSc☐ ARCHITECT BSc/BA ☐ OTHER QUALIFICATION ☐	ENGINEERING BEng/BSc☐ OTHER TECHNICAL DEGREE ☐	ARCHITECT MSc ☐ OTHER DEGREE ☐
TRAINING IN HEALTH AND SAFETY (H&S)	MASTER IN H&S☐ INDUSTRY H&S COURSES ☐	UNIVERSITY H&S COURSES☐ OTHER H&S COURSES ☐	NO TRAINING IN H&S ☐
JOB	PROJECT-BASED MANAGEMENT ☐ OFFICE BASED MANAGEMENT ☐ PROJECT DESIGN ☐ R&D ☐ TRAINING& EDUCATION ☐ COMMERCIAL TECHNICIAN ☐	PRODUCT DESIGNER SALES ☐ TRAINING& EDUCATION ☐	PROJECT-BASED ENGINEERING ☐ OFFICE BASED ENGINEERING ☐ PRODUCT DESIGN ☐ AFTERSALES ☐
YEARS EXPERIENCE IN CONSTRUCTION			

YOUR VIEWS

Evaluate the next sentences expressing your degree of agreement or disagreement in accordance with your personal experience and your technical point of view.

Do you agree or disagree with the statements?				
1 STRONGLY DISAGREE	**2** DISAGREE	**3** NEITHER AGREE NOR DISAGREE	**4** AGREE	**5** STRONGLY AGREE

		1 to 5
A	The project designer would ask the formwork manufacturing company for advice while they are designing the structure	
B	The project designer designs the structure without consulting the formwork/falsework manufacturing company. When the design is finished the construction company asks the formwork/falsework manufacturer for constructive solutions to suit the structure as designed.	
C	The majority of projects do not specify type of the formwork/falsework in the project´s documentation. Formwork/falsework selection is up to the construction company.	
D	When formwork/falsework is being designed safety is considered as a very important design factor.	
E	When formwork/falsework is being designed productivity is considered as a very important design factor.	
F	When a formwork/falsework is being designed final cost is considered as a very important design factor.	
G	The formwork/falsework customer chooses always the safest one.	
H	The formwork/falsework customer chooses always the cheapest one.	
I	The user always follows the manufacturer's instructions about the product.	
J	Technical advice from formwork/falsework companies to users includes advice about safety issues related with use of the formwork/falsework.	
K	Formwork/falsework suppliers are the same suppliers for the rest of temporary equipment (e.g. scaffolds or hoists)	
L	Formwork/falsework manufacturers provide training in health and safety to their customers in the use of their products	
M	Formwork/falsework manufacturers provide the customer with qualified technicians to erect, use and dismantle the formwork/falsework and their auxiliary equipment.	
N	A compulsory standard about formwork/falsework design and manufacture would improve health and safety in the final formwork/falsework as a product.	
O	A non-compulsory specific standard (ISO, BS or similar) would improve health and safety in the final formwork/falsework as a product.	
P	A compulsory standard about formwork/falsework use would improve health and safety for the formwork/falsework workers.	
Q	A non-compulsory specific standard (ISO, BS or similar) would improve health and safety for the formwork/falsework workers.	

Thank you for your collaboration

6.3 APPENDIX III. QUESTIONNAIRE PREVENTION THROUGH DESIGN IN ENGINEERING & ARCHITECTURE UNIVERSITY COURSES

“PREVENTION THROUGH DESIGN IN ENGINEERING & ARCHITECTURE UNIVERSITY COURSES”

The current questionnaire is a part of a research project developed by University of Málaga and University of Granada. The aim is to collect opinions from students and lecturers about courses related with vertical concrete structures construction.

Evaluate the next sentences expressing your degree of agreement or disagreement in accordance with your personal experience and your technical point of view.

YOUR PROFILE

AGE:	**MALE ☐ FEMALE ☐**
UNIVERSITY:	**DEGREE:**
COURSE:	
YEAR OF THE COURSE:	
EXPERIENCE IN CONSTRUCTION (years):	

YOUR VIEWS

Do you agree or disagree with the statements?				
1 STRONGLY DISAGREE	**2** DISAGREE	**3** NEITHER AGREE NOR DISAGREE	**4** AGREE	**5** STRONGLY AGREE

			De 1 a 5
OCCUPATIONAL HEALTH AND SAFETY TRAINING	Q1	Workers' Occupational Health and Safety at vertical construction sites is integrated with the rest of the technical concepts in every lecture of the course	
	Q2	Workers' Occupational Health and Safety at vertical construction sites is only considered in some lectures of the course	
	Q3	Workers' Occupational Health and Safety is often confused with the structural safety of the construction	
	Q4	Workers' Occupational Health and Safety is addressed in other specifics courses of the under/degree	
	Q5	Knowledge of Workers' Occupational Health and Safety is evaluated in the course	
THE INFLUENCE OF PREVENTION THROUGH DESIGN	Q6	I know what Prevention through Design (PtD) is	
	Q7	Worker safety when designing a construction project is taken into account during the course	
	Q8	The concept of Prevention through Design (PtD) is addressed in many courses such as this one	
	Q9	The concept of Prevention through Design (PtD) is important for improving workers' occupational health and safety in vertical constructions	
	Q10	The concept of Prevention through Design (PtD) is not important when compared to the rest of the course content.	
	Q11	Knowledge of Prevention through Design (PtD) is evaluated in this course	
VALUE OF OCCUPATIONAL SAFETY AND PTD IN THE LABOUR MARKET	Q12	Training in OHS increases the value of the professional curricula	
	Q13	Independent of its real value the labour market views training in OHS very positively	
	Q14	Training in PtD increases the value of the professional curricula	
	Q15	Independent of its real value, the labour market views training in PtD very positively	

Thank you for your collaboration

EXECUTIVE SUMMARY (in Spanish)

RESUMEN

7. SUMMARY (in Spanish).

En este apartado se incluye una descripción de los motivos para desarrollar la presente tesis doctoral con el propósito de obtener el doctorado internacional en la Universidad de Málaga. Del mismo modo, se incluyen también los objetivos y las metodologías aplicadas

7.1 MOTIVACIÓN.

Según cifras de la International Labour Organization (ILO, 2013),321.000 personas mueren en el mundo como consecuencia de un accidente laboral mortal. A estos datos tan negativos debemos de sumarles los 317 millones de accidentes laborales no mortales que occuren cada año en todo el planeta. Estas cifras tan alarmantes son una clara evidencia de que los accidentes laborales son un serio problema a nivel mundial.

Los accidentes laborales se encuentran ligados a multitud de costes (económico, humano, organizacional, financiero, etc). La mayoría de esos costes no son cuantificables por ser indirectos o estar ocultos tras otros factores (Betastren-Belloví, 2001). Sin embargo, su impacto negativo en las empresas, los trabajadores, y la sociedad en su conjunto no puede ser negado (Heinrich, 1959, Bird, 1975).

La siniestralidad laboral afecta a todos los sectores productivos de todos los países, pero el sector de la construcción es el que presenta las peores tasas de accidentes en multitud de países (Eurostat, 2011, Bureau of Labor Statistics, 2010, Camino *et al*., 2008). Un ejemplo del problema lo encontramos en los Estados Unidos de América, donde en el año 2009, los trabajadores de la industria de la construcción sufrieron el mayor número de accidentes mortales (816) de cualquier industria en el sector privado dentro de los Estados Unidos (Bureau of Labor Statistics, 2010). Estos accidentes representaron aproximadamente el 19% de las muertes laborales, de entre todos los sectores en los EE.UU.

En la Unión Europea el problema es similar. Tan solo en los 15 Estados miembros originales de la UE, cerca de 1.300 trabajadores de la construcción mueren cada año, otras 800.000 resultan heridas, y muchos más sufren problemas de salud debido a su trabajo (Eurostat, 2011). En países como España y el Reino Unido, las tasas no son mejores que en los EE.UU. Ambos países tienen un mayor porcentaje de estos accidentes que los EE.UU en el sector de la construcción (Eurostat, 2011), aunque hay diferencias significativas en cuanto a la presentación de informes y los procedimientos de registro de accidentes de trabajo en diferentes países, tales como la definición de un accidente de trabajo y la consideración de los accidentes de tráfico

(Martínez-Aires, Rubio, y Gibb, 2010). La armonización de los datos de Eurostat permite una comparación de los resultados de los Estados miembros de la UE, pero es importante tener en cuenta que estas comparaciones entre países aún no son completamente fiables (Martínez-Aires, Rubio, y Gibb, 2010). A pesar de todo lo expuesto, la mayor parte de los autores consideran que las tasas de incidencia en España son aproximadamente el doble de los de la media europea.

La manifiesta peligrosidad del sector, así como las malas cifras de siniestralidad en España en comparación con el resto de países Europeos, despertaron en el doctorando el interés por abordar esta temática. ¿A qué se deben estás malas cifras en un sector económico tan importante?

Con el fin de identificar soluciones para los accidentes en la construcción, muchos investigadores han estudiado los diferentes factores de influencia del problema. Los factores que contribuyen en los accidentes de construcción pueden clasificarse en dos categorías (Haslam *et al* 2005). Por un lado las circunstancias inmediatas y factores de forma que determinan el accidente (Trabajador, equipo de trabajo, lugar de trabajo, materiales y equipos, etc) y por el otro los problemas de origen. (Diseño de la construcción y de procesos, gestión de proyectos, gestión de riesgos, etc.). Dentro de estos dos grupos principales, los factores clasificados como problemas de origen, especialmente insuficiencias con la gestión de riesgos, se consideran que han estado presentes en el 94% de los accidentes (Haslam *et al* 2005).

Una de las herramientas más importantes para la gestión de riesgos en los proyectos de construcción desde el origen es el concepto de la Prevención a través del Diseño (PtD). La importancia de la consideración de la seguridad y salud en el trabajo desde el diseño y el proyecto en la construcción, también denominado PtD, ha sido estudiada por autores como Gambatese (1997), Behm (2005), o Fadier (2006). En este sentido, Gambatese, Behm, y Rajendran (2008) han estudiado el rol que ocupa el diseño en la prevención de accidentes.La facilidad en la implantación y la efectividad de la mejora de la seguridad a través del diseño depende en gran medida de los vínculos existentes entre el diseño y los riesgos. Dicho estudio concluyó que a pesar de que el diseño resulta efectivo eliminando y reduciendo riesgos no es una panacea, ya que la reducción de riesgos es una compleja tarea que consta de diversas facetas. Por tanto la prevención desde el diseño debe de formar parte de una metodología integral para reducir los riesgos y mejorar la seguridad en la construcción. Varios de los autores anteriormente citados, en concreto Gambatese y Hinze (1999) estudiaron el diseño, considerándolo como una fase clave en la que incorporar las consideraciones necesarias para la seguridad del trabajador de la construcción. Uno de los principales problemas encontrados fue la falta de consciencia real por parte del diseñador de su influencia en la seguridad, así como unos conocimientos limitados en cuanto a la seguridad y salud en el trabajo. Para solucionar este problema, consideraron fundamental apostar por una mayor formación en seguridad de los diseñadores, un mayor asesoramiento por parte de los expertos en esta materia, así como tener en cuenta las consideraciones de los propios trabajadores. Todas estas soluciones solo serían efectivas si se cambiase la mentalidad tradicional de los diseñadores en la que la seguridad ocupaba un lugar secundario, hacia una nueva mentalidad en la que la seguridad sea unos de los principales factores a tener en cuenta. A pesar de todo lo anterior, la PtD sigue siendo una herramienta preventiva infrautilizada en demasiadas ocasiones.

A la importancia del problema tratado, se une la inquietud profesional del doctorando en cuanto a la prevención de riesgos laborales se refiere. Su trayectoria tanto académica como profesional ha estado ligada a la seguridad y salud laboral. Durante sus estudios de ingeniería el candidato configuró su expediente académico incluyendo asignaturas como Seguridad Industrial o Gestión de la Calidad. Al finalizar Ingeniería Industrial, fue admitido en un Master Universitario Oficial de Prevención de Riesgos Laborales. En sus inicios profesionales, su labor en una fábrica de mármol le permitió su primer contacto con los riesgos ligados tanto a la fabricación como a la colocación en obra, de piedra natural. Su posterior trabajo en la Cátedra de Prevención y Responsabilidad Social Corporativa de la Universidad de Málaga, le brindó la posibilidad de seguir formándose, y a la vez desarrollar tareas de investigación dentro del ámbito de la prevención en el sector de la construcción, en proyectos de ámbito nacional financiados por organismos de reconocido prestigio tales como el Centro para el Desarrollo Tecnológico Industrial (CDTI), o el Ministerio de Ciencia y Tecnología a través del proyecto de plan nacional titulado "Seguridad desde el diseño en las actividades de ejecución de estructuras mediante encofrados en obra", el cual está muy ligado a la presente tesis.

En base a lo expuesto, a modo de resumen se puede decir que los motivos que han justificado la elección de esta temática para la elaboración del presente trabajo de investigación por que se opta al grado de Doctor Internacional por la Universidad de Málaga son los siguientes:

- Las acciones destinadas a la mejora de la seguridad y salud laboral resultan clave a la hora de proteger la integridad física y mental de los trabajadores.
- El sector de la construcción en España presenta unas cifras especialmente preocupantes en cuanto a seguridad y salud laboral.
- La gestión de la prevención con herramientas tan útiles como la prevención a través del diseño (PtD), se descuida en demasiadas ocasiones, hecho que aumenta la frecuencia y

severidad de accidentes directamente evitables, si se hubiera llevado a cabo la gestión adecuada de la prevención de riesgos laborales.

- El interés del doctorando por los aspectos relacionados con la gestión de la prevención, unido a la experiencia profesional previa en el sector de la construcción, han sido motivos convergentes que se han unido en el planteamiento de este trabajo.

7.2 OBJETIVOS Y METODOLOGÍAS.

Las motivaciones previamente expuestas muestran la importancia de la temática a estudiar. A ello se debe de añadir los diversos grupos de interés a los que afecta la gestión de la prevención: diseñadores de proyectos, contratistas, subcontratistas, trabajadores, sindicatos, etc. El análisis estadístico de la siniestralidad unido a la opinión de los expertos de distintos grupos de interés pueden resultar de gran utilidad a la hora de identificar las principales causas de los accidentes y contribuir a su prevención.

Por tanto, habiendo establecido como temática de estudio la gestión de la prevención en la seguridad y salud laboral en la construcción junto con la importancia de la Prevención a través del Diseño (PtD), se procedió a centrar la investigación tratando de dar respuesta a las siguientes cuestiones.

- ¿Cuales son las causas de los accidentes de la construcción en España?
- En dichos accidentes ¿Qué trabajadores son mas susceptibles de sufrir accidentes mortales?
- ¿Existen diferencias, en cuanto a siniestralidad se refiere, entre los trabajadores de ejecución de estructuras de hormigón, y otros trabajadores del sector?
- ¿Cuáles son las semejanzas y diferencias entrs los accidentes que afectaron a trabajadores cualificados, y los no cualificados en la construcción de estructuras de hormigón?
- ¿Cuál es la opinión de las compañías de construcción respecto a los problemas de seguridad en el sector de obra civil en España?
- ¿Cuáles son los niveles de riesgo en las actividades de construcción?
- ¿Son evaluados correctamente los riesgos en el sector?
- ¿Se identifican adecuadamente los peligros durante la ejecución de estructuras verticales?
- ¿Cuáles son los principales riesgos de seguridad en la ejecución de estructuras verticales?
- ¿ Se implementa adecuadamente la PtD en la obra civil?

- La importancia de la PtD en los proyectos de construcción de obra civil ¿está en consonancia con la importancia que le otorgan a la PtD los expertos en la materia?
- ¿Es adecuada la formación en PtD de los profesionales del sector?
- ¿Cómo de importante es la PtD en los planes de estudios universitarios?

En línea con estas interrogantes, para el desarrollo de esta investigación se definió un objetivo global de la tesis, en torno al cual se formularon una serie de objetivos parciales, que se dividieron a su vez en diferentes objetivos específicos, con el propósito de poder alcanzar dicho objetivo global mediante la consecución secuencial de los diferentes objetivos específicos.

En base a lo expuesto, los objetivos del presente trabajo son los siguientes:

❖ OBJETIVO GLOBAL.

Obtener una nueva visión ampliada y actualizada tanto de los riesgos en la construcción de estructuras verticales de obra civil como de la gestión de la seguridad laboral a través de la PtD en las citadas estructuras.

- OBJETIVO PARCIAL.
  a) Analizar los accidentes en el sector de la construcción basándonos en estadísticas oficiales de siniestralidad.

  OBJETIVOS ESPECÍFICOS

  a.1) Conocer los factores presentes en los accidentes producidos en el sector de la construcción.

  a.2) Comparar factores de siniestralidad entre trabajadores cualificados y no cualificados en la construcción de estructuras de hormigón.
- OBJETIVO PARCIAL.
  b) Identificar y valorar los riesgos en tareas constructivas de encofrado en obra civil.

  OBJETIVO ESPECÍFICO

  b.1) Evaluar riesgos en actividades constructivas de encofrado en estructuras verticales.
- OBJETIVO PARCIAL.
  c) Conocer la percepción de las necesidades de seguridad en el diseño y ejecución de los proyectos de obra civil con actividades de encofrado.

  OBJETIVOS ESPECÍFICOS

  c.1) Conocer la opinión de los constructores respecto a la seguridad y salud de los proyectos de obra civil.

c.2) Conocer las opiniones y modos de interacción respecto a las necesidades de seguridad en un proyecto de obra civil, de los profesionales responsables: Proyectistas, contratistas, y fabricantes de encofrados.

- OBJETIVO PARCIAL.

  d) Cuantificar la presencia del concepto Prevención a través del Diseño entre los profesionales del sector.

  OBJETIVO ESPECÍFICO

  d.1) Evaluar el grado de implementación de la PtD en la formación universitaria en las titulaciones ligadas a la construcción de estructuras verticales de hormigón.

Una vez definidos los objetivos de la tesis se procede a exponer las metodologías utilizadas para alcanzar las metas propuestas. Las metodologías aplicadas para lograr los distintos objetivos de la presente tesis doctoral se pueden dividir en dos grupos principales atendiendo a si dichas metodologías se basan en técnicas cuantitativas objetivas, o en técnicas cualitativas subjetivas. Las metodologías objetivas más utilizadas están ligadas a herramientas estadísticas que se han implementado durante el desarrollo de análisis estadísticos de siniestralidad en el sector basados en datos oficiales de accidentes, mientras que las metodologías subjetivas se encuentran unidas a la búsqueda de la opinión de los profesionales del sector a través de distintas técnicas de encuesta y mediante paneles de expertos.

Atendiendo a esta clasificación, las metodologías utilizadas en el presente trabajo fueron las siguientes:

METODOLOGÍAS CUANTITATIVAS - ANÁLISIS DE ACCIDENTES.

En primer lugar, se llevo a cabo una revisión bibliográfica exhaustiva de la literatura acerca de la seguridad y salud ocupacional en construcción civil. La revisión bibliográfica se centró en palabras clave como accidente, construcción, obra civil, estructuras de hormigón, seguridad y salud, prevención, PtD, integración de la PtD, formación universitaria, etc.

En segundo lugar, se desarrolló un análisis estadístico basado en un total de 1.163.178 partes de accidentes de trabajo suministrados por el Ministerio de Trabajo. El diseño de este análisis se basó en el estudio previo llevado a cabo por Camino *et al* (2008). Las variables a estudiar fueron categorizadas en grupos para evaluar la relación entre cada una de las variables respecto a la severidad resultante para cada uno de los accidentes. En una primera aproximación, se elaboraron tablas de contingencia analizando las 57 variables incluidas en el Parte de Notificación de Accidentes (PAT). Sin emabargo para algunas variables, la mayoría de los valores obtenidos en las tablas de contingencia no alcanzaron una significación estadística mayor o igual al 95%, por lo que no se pudo confirmar la independencia entre variables y en consecuencia no se pudo asegurar la existencia de una influencia real entre variables más allá de la aleatoria. En base a esta primera aproximación, la mayoría de las 57 variables fueron rechazadas. Finalmente se escogieron 10 variables cuya significación estadística fue mayor o igual del 95%. Una vez escogidas, se elaboraron tablas de contingencia y los valores de chi-cuadrado fueron calculados para probar las hipótesis de la independencia de cada variable con respecto a la gravedad. Para el desarrollo del análisis se utilizó el paquete estadístico SPSS (Statistical Package for the Social Sciences).

En tercer lugar, se desarrolló un análisis estadístico basado en un total de 125.021 partes de accidentes de trabajo procedentes de compañías de ejecución de estructuras de hormigón. En dicho análisis se llevó a cabo la comparación de los índices de siniestralidad de este tipo de compañías con el resto de compañías del sector. Además, se elaborón una comparativa entre los trabajadores cualificados (white-collar) y trabajadores no cualificados (blue-collar). De nuevo, se elaboraron tablas de contingencia y los valores de chi-cuadrado se calcularon para probar las hipótesis de la independencia de cada variable con respecto a la gravedad.

METODOLOGÍAS CUALITATIVAS - OPINIÓN DE LOS PROFESIONALES.

En cuarto lugar, haciendo uso de la metodología denominada “staticized groups” propuesta por Hallowell and Gambatese (2009) se llevó a cabo el análisis de las doce actividades más frecuentes en la construcción y de los diez riesgos de seguridad, que fueron identificados y validados por expertos. Cada riesgo para la seguridad identificado de esta manera se cuantificó para cada actividad utilizando la metodología binaria de acuerdo con la frecuencia y escalas de gravedad desarrollados en investigaciones previas. Los autores contactaron con 15 empresas de construcción y 10 universidades. Tras revisar la disponibilidad y el perfil profesional del los posibles candidatos 12 expertos fueron seleccionados de 7 grandes constructoras y 5 escuelas de ingeniería de acuerdo con la citada metodología “staticized groups”.

En quinto lugar se seleccionó un nuevo grupo de expertos de 8 constructoras con actividad en España para ser entrevistados, y recabar su opinión respecto a diversas cuestiones relacionadas con los nieveles de seguridad y salud del sector en nuestro país. Un total de 25 expertos fueron seleccionados de acuerdo con una serie de requisitos mínimos establecidos previamente.

En sexto lugar, se elaboró una encuesta con escala Likert a los diseñadores de proyectos, empresas constructoras y empresas de encofrado de fabricación con el fin de identificar las necesidades en la fase de diseño, en la fase de construcción, así como en cuestiones normativas. Se distribuyeron un total de 206 cuestionarios de los cuales 160 se obtuvo contestación. Los profesionales que contestaron acumularon en total 2.122 años de experiencia con una medía de 13.26 años por profesional. El 88.1% fueron hombres y el 11.9% mujeres. Resulta destacable que el 90% de los profesionales tenía formación en seguridad y salud. Los cuestionarios fueron diseñados para ser claros, concisos y concretos. Una vez diseñados fueron revisados por 8 expertos que aportaron sugerencias y mejoreas acerca del lenguaje y el contenido de los ítems. Con el propósito de probar la validez de diferentes hipótesis se utilizaron herramientas estadísticas tales como el test de la mediana, test de Kruskall-wallis, y la U de Mann-Whitney.

En septimo lugar, se desarrolló una encuesta basada en la escala Likert que fue contestada tanto por alumnos como personal docente de 8 titulaciones distintas pertenecientes a 6 universidades españolas, con el fin de evaluar el grado de implantación de la Prevención a través del Diseño (PtD) en la formación universitaria de los futuros profesionales del sector de la construcción, ligados a la construcción de estructuras de hormigón. Un total de 454 alumnos participaron en la encuesta, obteniendo una tasa de respuestas del 95%, gracias a los 432 alumnos que completaron correctamente el cuestionario.

7.3 DOCUMENTACIÓN Y FUENTES DE INFORMACIÓN.

Las fuentes utilizadas para el desarrollo del presente trabajo se han clasificado conforme a la clasificación propuesta por la UNESCO.

FUENTES FORMALES

Las principales palabras clave que se introdujeron en las diferentes búsquedas estaban estrechamente relacionadas con las condiciones de seguridad y salud laboral en construcciones de obra civil así como con la prevención a través del diseño en los proyectos de las citadas tipologías de obra. Un ejemplo de palabras clave utilizadas lo encontramos en términos como: prevención, seguridad y salud laboral, accidentes, construcción, estructuras, estructuras verticales, encofrados, obra civil, PtD, siniestralidad laboral, riesgo, diseño, formación, educación, universidad, profesional, ingeniero civil, etc.

La búsqueda se realizó en las siguientes bases de datos, catálogos electrónicos y buscadores:

- *Bases de Datos del Consejo de Universidades.*
- *BNE (Bibliografía Nacional Española, recoge referencias de los libros*
- *CICA (Bussiness elite).*
- *Ciencia y Tecnología del CSIC.*
- *CINDOC, Catálogo de revistas.*
- *CIRBIC-Libro. Catálogo colectivo de libros del CSIC.*
- *CIRBIC-Revistas. Catálogo colectivo de revistas del CSIC.*
- *depositados en la Biblioteca Nacional. De temática multidisciplinar).*
- *EBSCOHOST*
- *Google Scholar*
- *ICYT. Base de datos del Instituto de Información y Documentación en*
- *ISBN. Información bibliográfica de libros editados en España.*
- *ISI web of Knowledge*
- *ISOC. Base de datos del Instituto de Información y Documentación en Ciencias Sociales y Humanidades del CSIC. Cubre las áreas temáticas de Economía, Sociología, Ciencias Políticas, Ciencias Jurídicas, etc.*
- *PUBMED.*
- *REBIUN. Catálogo colectivo de libros y revistas de bibliotecas universitarias. − Etc.*
- *ScienceDirect*
- *SCOPUS*

- *TESEO. Base de datos del Ministerio de Educación y Cultura donde se encuentran todas las tesis doctorales leídas en España.*

De las búsquedas planteadas, cabe destacar las revistas electrónicas donde se abordaban temáticas de interés para el presente trabajo, entre las que podemos enumerar las siguientes:

- *Accident Analysis& Prevention*
- *Applied Ergonomics*
- *Capital Humano*
- *Dyna Ingenieria e Industria*
- *Ergonomics*
- *Health and Safety Executive Bulletin*
- *Health Promotion International*
- *Human Factors*
- *Industrial Relations Journal*
- *Informes de la construcción*
- *International Journal of Health Services*
- *International Journal of occupational Safety and Ergonomics*
- *International Labour Review*
- *Journal of Cleaner Production*
- *Journal of Construction Engineering and Management*
- *Journal of Occupational Rehabilitation*
- *Journal of Safety Research*
- *Journal of the Institute Occupational Safety and Health*
- *NOHSAC TechnicalReport*
- *NZ Centre for SME Research*
- *Occupational Safety and Health*
- *Prevención*
- *Prevención Express*
- *Prevención, Trabajo y Salud*
- *Professional Safety*
- *Revista de la economía pública, social y cooperativa*
- *Revista de la construcción*
- *Safety Science*
- *Work: A journal of prevention,assessment &rehabilitation, etc*

También resultaron de interés las páginas webs de las siguientes instituciones, la mayoría de ellas relacionadas con la seguridad y salud laboral:

- *Instituto Andaluz de Tecnología (IAT).*
- *Instituto Nacional Americano de Normalización (ANSI).*
- *Instituto Nacional de Riesgo y Seguridad (INRS)*
- *Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT).*
- *Instituto Nacional de Salud y Seguridad Ocupacional (NIOSH).*
- *Instituto de Seguridad y Salud Británico (HSE)*
- *Observatorio Estatal de Condiciones de Trabajo (OECT)*
- *Organización Mundial de la Salud (OMS-WHO).*
- *Organización Internacional del Trabajo (OIT).*
- *Administración Americana de Seguridad y Salud (OSHA).*
- *Agencia Europea para la Seguridad y Salud en el Trabajo.*
- *Asociación Española para la Calidad (AEC).*
- *Asociación Internacional de la Seguridad Social.*
- *CIB. International Council of building.*
- *NSC. National Safety Council.*

También resulta de relevante la información obtenida en los siguientes eventos:

- International Symposium on Occupational Safety and Hygiene-SHO2014. Guimaraes, Portugal, February 2014.
- 5ª Jornada Anual de Prevención de Riesgos Laborales y Responsabilidad Social Corporativa. Seguridad Vial y Movilidad Sostenible. April 2013.
- International Symposium on Occupational Safety and Hygiene-SHO2013. Guimaraes, Portugal, February 2013.
- 6th International Conference on Industrial Engineering and Industrial Management. Vigo. June 2012.
- 11 International Conference Occupational Risk Prevention ORP 2012. Bilbao, May 2012.
- International Symposium on Occupational Safety and Hygiene-SHO2012. Guimaraes, Portugal, February 2012.
- Tertulia-taller sobre “Investigación sobre soluciones preventivas ante el riesgo de vuelco de maquinaria”. Cátedra de Prevención y Responsabilidad Social Corporativa de la Universidad de Málaga. February 2012.
- Tertulia-taller sobre “Principales cambios en el Reglamento de los Servicios de Prevención”. Cátedra de Prevención y Responsabilidad Social Corporativa de la Universidad de Málaga. February 2010.
- Tertulia-taller sobre “Claves de la coordinación de actividades empresariales en grandes organizaciones donde se produce la concurrencia de numerosas empresas”. Cátedra de

Prevención y Responsabilidad Social Corporativa de la Universidad de Málaga. February 2010.

Por ultimo pero no por ello menos importante el candidato quisiera destacar las estancias realizadas durante el desarrollo de las investigaciones.

- Estancia de investigación en Loughborough University. June-September 2012.
- Estancia de investigación en al Universidad de Granada. April-June 2013.

FUENTES TABULARES

En este caso la información de carácter estadístico o numérico se ha obtenido por diferentes vías. Por un lado los datos solicitados al Ministerio de Trabajo y Asuntos Sociales, y por otro lado los diferentes cuestionarios diseñados específicamente para la investigación.

7.4 ESTADO ACTUAL DE LA INVESTIGACIÓN.

Del análisis de la bibliografía consultada durante el desarrollo del presente trabajo es importante resaltar las investigaciones similares previas realizadas en el mismo ámbito de estudio.

Multitud de autores consideraron que el éxito de de la gestión de la seguridad y salud ocupacional se basa en el correcto conocimiento de las causas de accidentes e incidentes (Williamson and Feyer, 1998) .Solo con el adecuado conociemiento de las casuas de los accidentes e incidentes laborales será posible establecer estrategias preventivas y prevenir hechos similares (Bird, 1990, Gatfield, 1999, Thompson *et al*.,1998)

El análisis de los índices de siniestralidad en un sector específico puede ser muy útil a la hora de establecer las directrices adecuadas para la formación en prevención, los métodos de trabajo y equipos (Camino *et al*., 2008, Rikhardsson and Impgaard, 2004) o la organización de los turnos de trabajo (Lilley *et al*., 2002).

En este sentido, determinados sectores e industrias han sido estudiados en profundidad debido a sus características particulares, sus índices de incidencia, o la gravedad de sus accidentes. El sector eléctrico (Cawley and Homce, 2003), la minería (Sanmiquel *et al*., 2010) y la construcción (Cattledge *et al*.,1996; and Haslam et al., 2005) son ejemplo de este tipo de industrias.

La industria de la construcción presenta unas altas cifras de siniestralidad en Europa (Eurostat, 2011), pero el problema no se limita a nuestro continente. En los Estados Unidos de América, de acuerdo con la Bureau of Labor and Statistics (BLS, 2010) el índice de accidentes mortales por trabajadores empleados en la construcción es el triple que en el resto de sectores en su conjunto. En el resto del mundo, las cifras en los accidentes del sector no son mejores (ILO, 2013). En base a estas cifras, la investigación en seguridad y salud ocupacional en el sector de la construcción es una clara prioridad.

Con el fin de identificar soluciones para los accidentes en la construcción, diferentes investigadores han estudiado el problema en multitud de países. Ejemplos de estos estudios incluyen países tan diversos como Taiwán (Cheng, Leu, y Lin Fan, 2010), Escocia (Cameron, Hare & Davies, 2008), Turquía (Etiler *et al* 2004) (Mungen y Gürcanli, 2005), Portugal (Macedo y Silva, 2005), o Corea del Sur (Lim *et al* 1998).

Basándonos en investigaciones anteriores, se puede afirmar que cuando se analiza un accidente, muchas variables y factores están presentes. Una investigación significativa en el Reino Unido (Brace *et al*, 2009) identificó que los factores subyacentes de los accidentes mortales e incidentes de alto potencial se pueden agrupar en tres categorías: factores macro, en relación con las partes interesadas, como la sociedad, la educación, la industria, la organización empresarial y los sindicatos, los factores mezzo, en referencia a aspectos tales como la gestión de proyectos, la organización y la contratación y los factores micro, cuestiones referentes al trabajador, el lugar de trabajo y el supervisor.

Otro importante ejemplo de este tipo de investigaciones es el estudio sobre los factores de accidentes de la construcción en el Reino Unido llevado a cabo por Haslam *et al*, (2005) en el que se concluyó que los problemas derivados de los trabajadores o el equipo de trabajo estaban presentes en el 70% de los accidentes, problemas laborales en un 49%, las deficiencias con el equipo (incluyendo EPIS) en el 56%, problemas con la idoneidad y el estado de los materiales (27%) y las deficiencias con la gestión del riesgo en el 84% de los accidentes.

Además de este tipo de estudios citados, también debe tenerse en cuenta la influencia de las variables en la gravedad de las lesiones. Hay una gran cantidad de estudios de investigación en esta dirección. Por ejemplo, Sawacha, Naoum y Fong (1999) demostraron que los operarios entre las edades de 16 a 20 años eran más propensos a tener accidentes que los demás. Un análisis más detallado de los datos en el mismo documento sugiere que el nivel de accidentes tiende a disminuir rápidamente después de los 28 años para llegar a un punto bajo en los cuarenta años. De una manera similar, Salminen (2004) concluyó que los trabajadores jóvenes tenían una tasa de lesiones más alto que los trabajadores de mayor edad, sin embargo, se informó de las lesiones de los trabajadores jóvenes son menos a menudo fatales en comparación con las de los trabajadores de mayor edad.

En otros estucios como el llevado a cabo por Chau *et al* (2004) se mostró que los riesgos de lesiones para cada trabajador dependen de la edad, índice de masa corporal, trastornos, trastornos del sueño, y actividades deportivas, niveles de audición. Si el trabajador es joven, o con sobrepeso, o tiene cualquier audiencia o trastorno del sueño y no realiza actividades deportivas, entonces su riesgo es más alto que otras personas sin estos factores de riesgo. Sin embargo, es necesario no olvidar que los accidentes en la construcción surgen mayoritariamente de un fallo en la interacción entre los trabajadores, de su lugar de trabajo y los materiales y equipo que están usando (Haslam *et al*, 2003).

La mayoría de variables citadas como pueden ser los trabajadores, las empresas, el equipamiento, los materiales o el lugar de trabajo son identificados y tenidos en cuenta con relativa frecuencia por parte de las compañías constructoras en su día en la fase constructiva del proyecto, sin embargo las condiciones de seguridad deberían de ser descritas antes en la fase de diseño (Hallowell & Gambatese, 2008). La consideración específica, por parte de los arquitectos e ingenieros, de la seguridad en la construcción es conocida como el diseño para la seguridad en la construcción.

Por otro lado, las investigaciones centradas en la influencia del concepto de diseño para la seguridad en la construcción también conocida como la prevención a través del diseño (PtD) son especialmente relevantes cuando se estudian los accidentes en la construcción civil. El concepto es definido por el Instituto Nacional de Seguridad y Salud de Estados Unidos (NIOSH, 2013) como:

> Responder a las necesidades de seguridad y salud en el proceso de diseño para evitar o reducir al mínimo los riesgos y peligros relacionados con el trabajo asociados a la construcción, la fabricación, uso, mantenimiento y disposición de instalaciones, materiales y equipos.

Hay muchos estudios basados en el citado concepto, que concluyeron que un gran porcentaje de los accidentes en la construcción podría ser eliminado o reducido si la seguridad hubiese sido considerada en la fase de diseño y desarrollo del proyecto (HSE, 2003, Weinstein, Gambatese, y Hecker, 2005, Behm, 2005, Gambatese, Behm, Rajendran, 2008, Gibb 2001, Haslam 2005). Autores como Behm (2005), y Gambatese *et al*., (2008) estudiaron la influencia del diseño del proyecto, en la seguridad de los trabajadores de la construcción. En sus estudios se analizaron los vínculos entre muertes en la construcción y el diseño para el concepto de seguridad en la construcción. Sus resultados mostraron que el 42% de las muertes estaban vinculadas al citado concepto.

La adecuada implmentación de la PtD durante la construcción del proyecto no es responsabilidad de una única persona o grupo. Diferentes grupos de influencia están presentes en la seguridad y salud de los empleados en obras de construcción desde que el diseño del proyecto se inicia. Aunque cada uno de los distintos grupos esta ligado a distintas responsabilidades dentro del proyecto, sus niveles de influencia no son las únicas razones para estudiar más de un único grupo de interés. La literatura existente (Borman 1997;. Brutus *et al*, London & Wohlers, 1991) recomienda que para una mejor y una comprensión más exacta de los niveles de seguridad en el trabajo, la retroalimentación debe buscarse a partir de múltiples fuentes. La retroalimentación de múltiples fuentes proporciona información única desde diferentes perspectivas, añadiendo validez a la investigación (Borman, 1997). En esta investigación, se esperaba que los comentarios de los diferentes grupos de interés pudieran ser distintos y que cada grupo proporcionara una perspectiva única para mejorar el cambio necesario.

La influencia de los contratistas ha sido estudiada por autores como Wang *et al*., (2006), Saurin *et al*., (2008) o Fadier y De la Garza (2006). En otras investigaciones similares, la influencia de los diseñadores o ingenieros estructurales ha sido analizada por Gambatese y Hinze (1999), Behm (2005), Frijters y Swuste (2008) Gangolells *et al*., (2010) o Gambatese *et al*., (2008). La metodología desarrollada por Gangolells *et al*., (2010) resulta que especial interés para los diseñadores, ya que le permiten comparar diferentes técnicas y sistemas constructivos durante la fase de proyecto y determinar los correspondientes niveles de seguridad sin restringir el talento creativo del diseñador.

En el caso de las empresas de encofrado, y a diferencia de los grupos de influencia citados, aunque están presentes en la mayoría de las obras de construcción civil, no se ha encontrado literatura sobre la influencia de las citadas empresas de fabricación de encofrados en la salud y la seguridad en el lugar de construcción. Sin embargo, entre las tareas de construcción, las actividades relacionadas con encofrados se asocian frecuentemente con altas tasas de accidentes y lesiones. De acuerdo con Huang y Hinze (2003), 5,83% de las caídas se atribuye a la construcción de encofrado o para la construcción de estructuras temporales, y alrededor de 21% de todos los accidentes involucrado bastidor de madera o construcción de encofrados.

Con el objeto de alcanzar un mayor conocimiento acerca de las singularidades de los diseñadores como grupo de interés, existen ciertos aspectos que deben ser tenidos en cuenta.

En este sentido cabe señalar que a nivel europeo, a los arquitectos e ingenieros civiles se les exige que implementen el diseño para la seguridad en la construcción (ILO, 1985), pero desafortunadamente la prevención a través del diseño no se integra de un modo claro y adecuado en las carreras de arquitectura e ingeniería. Como consecuencia de ello, a muchos profesionales se les exige que implementen un concepto en su ejercicio profesional que no han estudiado, o que en el mejor de los casos han conocido de un modo muy breve y superficial. Esto es solo una parte de un problema mayor, ya que en general, los contenidos sobre seguridad y salud ocupacional no se encuentran integrados en las titulaciones de ingeniería y arquitectura de un modo adecuado (HSE, 2009). Esta inadecuada integración es difícil de cambiar debido a los ya de por si saturados planes de estudios de este tipo de titulaciones (Culvenor & Else, 1997).

Existen diversos trabajos acerca de la importancia de los contenidos de seguridad y salud ocupacional en diferentes niveles y estudios universitarios (Heinrich, 1956; Nolan, 1991; Grossel, 1992; Senkbeil, 1994; Phoon,1997; Hill & Nelson, 2005; Arezes & Swuste, 2012; Cortés *et al.*, 2012), sin embargo no se han encontrado estudios específicos acerca de la presencia de la PtD en los estudios universitarios de arquitectura e ingeniería, y su impacto en el diseño y construcción de las estructuras de hormigón.

Por todo lo anterior, y aun a pesar del gran valor científico de los trabajos desarrollados hasta el momento, los accidentes se siguen produciendo, lo cual es muestra inequívoca de la necesidad de mejora de las condiciones de seguridad y salud en el sector de la construcción. Mediante trabajos como el actual se pretende aportar posibles acciones y estrategias preventivas, en especial aquellas que tienen en cuenta la PtD, que ayuden a mejorar los niveles de seguridad y salud y contribuyan a la disminución de las altas tasas de siniestralidad en el sector, y más concretamente en la construcción de estructuras verticales.

7.5 RESUMEN DE LOS PRINCIPALES RESULTADOS.

Los principales resultados de la investigación nos muestran una serie de aspectos claves a tener en cuenta a la hora de llevar a cabo mejoras de los niveles de seguridad y salud en los proyectos de construcción.

a) Resultados del análisis de accidentes en el sector.

En este apartado se muestran los principales resultados del análisis de siniestralidad llevado a cabo sobre el total de accidentes del sector. Los citados resultados mostraron que una vez ocurrido un accidente la probabilidad de que éste sea severo se incrementa con la edad del trabajador. Este hecho es especialmente significativo en los trabajadores entre 60 y 65 años que obtuvieron los peores ratios de accidentes mortales por accidente producidos.

Otro factor que influye en la gravedad del accidente una vez producido es la antigüedad del trabajador en el puesto de trabajo. Los trabajadores de entre 4 y 12 meses de experiencia obtuvieron los ratios de accidentes mortales más bajos respecto al total de accidentes producidos en su grupo mientras que los trabajadores con una experiencia de entre 5 y 10 años obtuvieron los peores. No se encontró una relación lineal proporcional entre antigüedad y gravedad del accidente una vez producida, sino que esa relación variaba entre grupos de edades asemejándose la representación gráfica a una función senoidal.

Respecto a las desviaciones presentes en los accidentes, la pérdida de control de maquinaria y las caídas produjeron un tercio del total de accidentes, si bien este porcentaje se incrementó a más de la mitad si consideramos solamente los accidentes mortales.

b) Resultados del análisis de accidentes en empresas de construcción de estructuras de hormigón.

Una vez analizada la influencia de las diferentes variables en el sector en su conjunto, se analizó la influencia de variables similares para el supuesto específico trabajadores pertenecientes a empresas de construcción de estructuras de hormigón.

Los resultados en el citado análisis mostraron semejanzas y diferencias entre los dos tipos de trabajadores estudiados trabajadores, es decir, entre los trabajadores cualificados, también denominados “white-collar”, y los no cualificados también denominados “blue-collars.

La principal semejanza se encontró en la variable edad del accidentado, cuyos resultados mostraron que el grupo de edad con mayor probabilidad de que una vez producido el accidente éste sea mortal, es de trabajadores entre 50 y 59 años de edad, no habiendo diferencias en este sentido entre los cualificados y los no cualificados.

La principal diferencia entre los trabajadores cualificados y no cualificados radicó en que a pesar de los trabajadores más cualificados sufrieron tan solo el 18.58% del total de accidentes, esta porcentaje se incrementó hasta el 44.04% para el caso de los accidentes mortales, lo cual parece indicar que un alto grado de cualificación, no le exime al trabajador de la posibilidad de sufrir un accidente mortal.

c) Resultados de la evaluación de riesgos en actividades de encofrado de estructuras mediante panel de expertos.

Como fruto de la evaluación de las diferentes actividades constructivas ligadas a la construcción de estructuras verticales mediante la utilización de encofrados, cabe destacar que la actividad que obtuvo un mayor índice de riesgo fue la colocación y nivelación de los encofrados, seguida por el corte de materiales, y el uso de grúas.

En lo que respecta a los riesgos presentes en las actividades, el riesgo caída a distinta nivel, el de corte y los sobreesfuerzos, son los que obtuvieron una mayor puntuación global, en cuanto a su frecuencia y severidad durante el desarrollo de las distintas actividades.

d) Resultados de los agentes implicados en el uso, diseño y fabricación de los encofrados.

Los resultados de este apartado son el reflejo de la opinión de los diferentes grupos de interés afectados por el uso, diseño y fabricación de los encofrados que se utilizan durante todo proyecto de obra civil cuyo objeto es la construcción de una estructura vertical de hormigón. Los principales grupos de interés que se identificaron fueron: diseñadores o proyectistas, contratistas, y fabricantes de encofrados. La opinión de los citados grupos obtuvo un elevado consenso respecto a las siguientes afirmaciones:
El diseñador o proyectista no pide asesoramiento alguno al fabricante de encofrados mientras está proyectando, y es una vez terminado el diseño cuando se le piden soluciones constructivas al fabricante de encofrados.

Si bien la seguridad es un factor a tener en cuenta en el diseño de un encofrado por parte del fabricante, el factor determinante para la elección de un encofrado es su precio, y no su seguridad.

El desarrollo de nuevos estándares o normas en torno a la fabricación y uso de los encofrados mejoraría la seguridad tanto del producto en sí, como la seguridad de los trabajadores durante su uso. En opinión de los expertos, esta mejora sería mayor si los nuevos estándares fuesen de obligado cumplimiento en lugar de normas voluntarias.

e) Resultados de la importancia de la PtD en las titulaciones técnicas relacionadas con la construcción de estructuras de hormigón.

A pesar de la gran importancia de la prevención a través del diseño como herramienta de gestión de la seguridad y salud laboral, su presencia en las titulaciones técnicas estudiadas, relacionadas con las estructuras verticales de hormigón, es escasa en base a los resultados obtenidos. Si bien las antiguas titulaciones anteriores al Plan Bolonia obtuvieron unos resultados poco positivos en cuanto a la presencia e importancia de la PtD en las mismas, las nuevas titulaciones de grado no obtuvieron mejores resultados, llegando incluso a ser peores en algunos ítems.

Si bien la implementación del concepto de la PtD en las diferentes asignaturas de construcción de estructuras de hormigón en muchas ocasiones no tiene lugar debido a los ya de por si saturados planes de estudio, los resultados no ofrecieron duda acerca de la importancia de este concepto en el mercado laboral y en el currículo del técnico.

Resulta destacable que cuanto mayor es el grado de conocimiento acerca de la PtD, mayor es el grado de importancia que le otorga el alumno y el docente a ese concepto. Los principales obstáculos que encuentran los docentes a la hora de enseñar este concepto son diversos: falta de tiempo, la no inclusión de la PtD como contenido en los programas académicos, o simplemente que la seguridad y salud laboral no se considere como objetivo en los diferentes métodos de diseño de la estructura.

7.6 RESUMEN DE LAS PRINCIPALES CONCLUSIONES.

Del mismo modo que se plantearon los objetivos al inicio del presente trabajo de investigación y considerando el mismo criterio, las conclusiones obtenidas en este estudio, se pueden clasificar en conclusiones globales y conclusiones parciales y específicas

CONCLUSIONES GLOBALES

Las conclusiones globales que a continuación se exponen, muestran una visión amplia y actual de los principales riesgos en la construcción de estructuras verticales de obra civil, así como de los niveles de uso y conocimiento de la Prevención a través del Diseño en el sector.

PRIMERA CONCLUSIÓN

La influencia de las diferentes variables presentes en los accidentes que se producen en el sector de la construcción, queda patente en la severidad de los accidentes registrados en España. Factores como la edad del trabajador, el tamaño de la empresa, el lugar del accidente, o la desviación que produjo el accidente, reflejaron una influencia significativa en el más de un millón de casos analizados, y en consecuencia un mayor conocimiento de estos factores, pueden servir de gran ayuda a la hora de planificar medidas preventivas que reduzcan los altos índices de siniestralidad del sector, en especial los de los accidentes de mayor gravedad.

SEGUNDA CONCLUSIÓN

La formación del trabajador es un factor presente en los accidentes que merece especial mención, debido a que en la comparativa realizada entre trabajadores de empresas de construcción de estructuras de hormigón se encontraron más diferencias que similitudes entre los trabajadores cualificados y no cualificados.

TERCERA CONCLUSIÓN

La valoración de los riesgos en las diferentes tareas constructivas de encofrados en obra civil en base a la opinión de los profesionales del sector, resultó bastante homogénea con unos niveles consenso bastante elevados, lo cual parece indicar que el nivel de conocimiento de los riesgos es similar entre los profesionales de la construcción.

CUARTA CONCLUSIÓN

La percepción de las necesidades en cuanto a seguridad y salud laboral, de los principales grupos de interés con capacidad de influencia en la implementación de la prevención a través del diseño, durante el desarrollo de un proyecto de construcción, difiere dependiendo del grupo de interés (Proyectista, contratista, fabricante de encofrados). La presencia de la prevención a través del diseño en los proyectos constructivos no es lo suficientemente habitual e importante como para que su eficacia como herramienta preventiva sea acorde con su potencial. Esta falta de presencia es debida tanto al desconocimiento como a la falta de comunicación entre los participantes en un proyecto. Este hecho hace necesario una mayor comunicación entre las diferentes partes implicadas para la mejora de la Seguridad y Salud en los proyectos constructivos desde el inicio de la fase de proyecto hasta el final de la fase de ejecución.

QUINTA CONCLUSIÓN

Por último, pero no menos importante, cabe destacar a modo de conclusión global los bajos niveles de integración de la Prevención a través del Diseño, en los contenidos académicos de las diferentes titulaciones universitarias estudiadas. Este hecho negativo, hace que los futuros profesionales de la construcción desarrollen su labor profesional con carencias de base en el conocimiento de la PtD. Dichas carencias formativas resultan un importante escollo a la hora de mejorar tanto los niveles de seguridad laboral como los índices de siniestralidad.

CONCLUSIONES PARCIALES Y ESPECÍFICAS

Una vez expuestas las conclusiones globales de la investigación se procede a detallar los aspectos más significativos de las conclusiones parciales y específicas en las que se basan las citadas conclusiones globales.

a) Conclusiones del análisis de accidentes

En Conclusiones del análisis de accidentes se detallan las conclusiones del análisis de datos de accidentes, y se dividen en las conclusiones generales sobre el sector de la construcción en España y las conclusiones específicas sobre los trabajadores calificados y no calificados en las empresas de la construcción de hormigón.

El análisis de todo el sector de la construcción en España mostró que la gravedad de los accidentes está relacionada con diversas variables estudiadas. Las conclusiones para cada variable se pueden resumir de la siguiente manera:

Con respecto a la variable edad, el análisis de los datos no muestra si la tasa de accidentes varía con la edad, sino que la consecuencia probable de un accidente una vez este se ha producido varía con la edad. Un accidente con un trabajador de mayor edad involucrado, probablemente tendría consecuencias más graves que si el trabajador involucrado fuera de entre 20 y 24 años. Es por ello que se deberán de considerar planes especiales de formación para los trabajadores de más edad y aptitud para los regímenes de trabajo establecidos.

En cuanto a la variable antigüedad en la empresa, comparando la TAR de los accidentes ocurridos, se puede concluir que los accidentes sufridos por los trabajadores con 5-10 años de experiencia tuvieron los peores resultados. Por otro lado, los trabajadores con experiencia de 4 a 12 meses, tuvieron las mejores tasas de accidentes fatales. Los trabajadores experimentados deben estar especialmente capacitados con programas específicos de acuerdo a sus necesidades.

Respecto a la desviación que produjo el accidente, el análisis de los datos mostró que la pérdida de control de la maquinaria y la caída desde la altura causaron casi un tercio de los accidentes leves. La adición de ambas desviaciones, causó más de la mitad del resto de accidentes.

El estudio específico de los accidentes sufridos por trabajadores empleados en la construcción de estructuras de hormigón en España, confirmó que las variables que intervienen en los accidentes pueden variar en función del nivel de cualificación de los trabajadores. Por consiguiente, las medidas para mejorar la salud y la seguridad deberían de adaptarse a las similitudes y diferencias encontradas en el estudio.

La principal similitud se produjo en la variable edad. Los trabajadores de 25 a 29 años de edad obtienen los índices más seguros en relación con los accidentes mortales, mientras que los trabajadores de entre 50-59 años de edad obtuvieron los peores registros. En consecuencia, las estrategias especiales deben desarrollarse con el fin de mejorar los resultados de las personas más mayores.

En contraste con la edad como principal semejanza, se detectó la variable ocupación como principal diferencia. Un accidente de un trabajador cualificado (en adelante “cuello-blanco”) probablemente tendría consecuencias más graves que un accidente de un trabajador no cualificado (en adelante “cuello azul”), por tanto el nivel de cualificación no es necesariamente equivalente al nivel de seguridad. En muchos casos, las habilidades técnicas de los trabajadores no están relacionadas con la educación preventiva, en el trabajo. En los programas universitarios de España no siempre se incluyen cursos obligatorios sobre cuestiones concretas relativas a la seguridad.

b) Conclusiones de los profesionales del sector en base a la percepción de las partes interesadas o grupos de interés.

Los resultados de este parte del estudio pueden ser utilizados como una herramienta importante para la evaluación del riesgo cuando se programe una tarea de encofrado vertical. Cada proyecto de construcción implica cuestiones de seguridad específicas porque cada uno tiene diferentes circunstancias y entornos. Sin embargo, los temas de seguridad generales que se describen en esta investigación pueden utilizarse como herramienta de partida en cada proyecto.

En cuanto a las medidas preventivas, los recursos siempre son limitados y deben ser manejados de manera eficiente. Los profesionales de construcción deben primero identificar las actividades más peligrosas y los mayores riesgos de seguridad. Este es el primer paso para dar prioridad a las medidas preventivas de acuerdo con una escala adecuada de las necesidades.

c) Conclusiones sobre los grupos de interés en el mercado de encofrados.

En la fase de diseño del proyecto de construcción, la falta de interacción entre diseñadores y empresas de encofrados, fue detectada por todos los interesados. Además, la ausencia de especificación del tipo del encofrado en los proyectos se señaló también como una práctica habitual. En lo que respecta a la fase de diseño del encofrado, el costo final del producto era considerado el factor más importante, mientras que el producto se está diseñando. La productividad se considera un factor importante por todos los grupos encuestados, en contraste con el factor de seguridad, que obtiene la puntuación más baja. Estos resultados fueron corroborados por los resultados obtenidos en la fase de construcción en la que los usuarios prefirieron el encofrado más barato antes que el más seguro.

Se debe prestar especial atención a la formación en materia de salud y seguridad para los usuarios de encofrado, y la provisión de técnicos cualificados por los fabricantes. La ausencia de formación en seguridad y salud de los usuarios, por parte de los fabricantes se señaló de ambos grupos como una práctica habitual en el desarrollo actual de las obras de construcción. El mayor consenso se obtuvo para las cuestiones normativas estudiadas. Todos los grupos consideraron que las normas sobre el diseño y el uso de encofrados, podrían mejorar los niveles de salud y seguridad.

d) Conclusiones sobre la integración de la PtD en las titulaciones universitarias ligadas a la construcción de estructuras de hormigón.

A la vista de los resultados del presente estudio se puede concluir que la formación en el concepto de prevención a través del diseño no es la adecuada en las titulaciones de ingeniería y arquitectura estudiadas, y que por tanto requieren un esfuerzo en su mejora. En este sentido cabe destacar que las nuevas titulaciones de grado no han presentado apenas mejoras si las comparamos con las antiguas titulaciones en proceso de extinción.
Los alumnos con un mayor nivel de conocimiento de la PtD, le otorgan una mayor importancia a este concepto como herramienta preventiva. Resulta también reseñable que en opinión de los propios profesores, los contenidos cobre PtD y seguridad y salud ocupacional no son prioritarios en las asignaturas de construcción estudiadas.

A pesar del esfuerzo que supone el integrar estos contenidos en los ya de por si extensas programaciones académicas, no se debe olvidar que una formación adecuada al respecto resulta crucial a la hora de prevenir accidentes.

7.7 IMPACTO EN EL SECTOR DE LA CONSTRUCCIÓN DE OBRA CIVIL.

La identificación de las principales variables presentes en los accidentes de la construcción es el primer paso para minimizar y reducir los accidentes y sus consecuencias. Las conclusiones de este trabajo pueden ser utilizadas por las empresas en sus estrategias de seguridad en el trabajo y en sus programas de formación en seguridad. La formación específica puede ser diseñada teniendo en cuenta las necesidades específicas de cada grupo de trabajadores y para cada tipo de empresa. Se debe prestar especial atención al colectivo de trabajadores con experiencia de 5 a 10 años. Con demasiada frecuencia, sus riesgos son mal juzgados en las obras. Sus gerentes, supervisores, y ellos mismos tienden a confiar en su experiencia y habilidad, pero la experiencia no es un protector de la vida que nunca falla, y puede ser un arma de doble filo, que conduce a una mayor aceptación de riesgos. Se debe de realizar un esfuerzo en todas las empresas, en relación a su tamaño y la ubicación de cada trabajador, especialmente cuando no están en su lugar habitual de trabajo. Los resultados de esta investigación están basados en los datos disponibles de los formularios oficiales de notificación de accidentes. Se podría obtener un mayor conocimiento de este tipo de estudios, si los datos de los accidentes fueran más completos y específicos, como pueden ser los factores propuestos por Haslam *et al*. (2005). Sin embargo, la mayoría de autores reconocen los retos asociados a esta propuesta y es necesario seguir trabajando para establecer las estrategias adecuadas.

Respecto al estudio de riesgo de la actividad, los resultados de este manuscrito pueden ser utilizados por parte de las empresas de construcción cuando se están diseñando sistemas de seguridad, y advertirles sobre los riesgos de seguridad y las actividades más peligrosas para que puedan tenerlos en cuenta cuando se están elaborando los planes de seguridad en el trabajo. Además, estos resultados se pueden utilizar para dar prioridad a los elementos de seguridad más eficaces para los proyectos de construcción con el fin de controlar el riesgo de seguridad en la construcción. Esta información estratégica puede ser especialmente útil cuando los recursos en los proyectos son pequeños y limitados, ya que puede ser utilizada para seleccionar las medidas más eficaces.

La implementación de las conclusiones de esta investigación puede ser llevada a cabo por las empresas de construcción de varias maneras. Gerentes y supervisores de salud y seguridad pueden mejorar los riesgos asociados a actividades específicas, sobre todo con actividades nivelación y colocación de encofrados y riesgos de caídas a niveles inferiores. Los ingenieros y diseñadores de proyectos pueden estimar el tiempo de exposición para su proyecto específico y calcular el riesgo total. Este cálculo se puede hacer teniendo en cuenta los diferentes tipos de encofrado y soluciones de diseño. Las empresas pueden utilizar los resultados obtenidos en sus estrategias de seguridad en el trabajo y en sus programas de formación en seguridad. Los autores creen que se debe de seguir investigando sobre el tema y promover soluciones de futuro para evitar los riesgos descritos.

Además de lo anterior, la identificación de las necesidades del sector de actividad a través de la opinión de los principales participantes en el comercio de encofrado es otro paso importante para mejorar los niveles de salud y seguridad. La mejora de la percepción de la opinión de los distintos participantes en el sector de la construcción tendrá un impacto positivo en cada organización implicada. El conocimiento de las percepciones de los otros participantes podría facilitar la comunicación y la interacción entre las partes. Con todo ello se trata de generar una cooperación positiva entre los grupos con el fin de mejorar los niveles de salud y seguridad desde el principio de la construcción en la fase de diseño.

Por último pero no menos importante, los resultados obtenidos respecto de la integración de la PtD en las titulaciones universitarias deben de servir para mejorar los contenidos académicos al respecto.

7.8 FUTURAS LINEAS DE INVESTIGACIÓN.

Algunas variables estudiadas en los análisis de siniestralidad merecen ser estudiadas de un modo más profundo en futuros estudios para obtener una estimación más exacta acerca de su influencia en los índices de siniestralidad. Un ejemplo de ello lo encontramos en la variable zona climática, ya que no se establecieron diferencias significativas que explicaran las razones existentes para la exsitencia de ciertas diferencias entre los índices de siniestralidad de la zona mediterránea y las zonas continentales.

Diferentes estrategias preventivas deberían de ser investigadas para desarrollar y mejorar la efectividad en la formación de los trabajadores experimentados. Las tareas fuera del lugar habitual de trabajo deberían de ser mejor diseñadas, y los procedimientos y medidas de seguridad correctamente implementadas.

Se deberían de llevar a cabo evaluaciones de riesgos mediante paneles de expertos de otras actividades más alla de las actividades de encofrado y desencofrado estudiadas en el presente trabajo.

Los canales de comunicación entre los diferentes grupos de interés podría ser una importante futura línea de investigación.

Del mismo modo la evolución de los contenidos sobre educación y formación en PtD así como su impacto en los índices de siniestralidad deberían de seguir siendo objeto de estudio en los próximos años.