Some unpublished results on the research in corrosion of steel in concrete

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The Robert L'Hermite Award 1986 has been bestowed on Dr Carmen Andrade, Acting Director of the Institute Eduardo Torroja, Madrid, for her work on the corrosion of reinforcing steel in concrete, and particularly on the measuring methods of corrosion. On this occasion, in the course of the meeting of the General Council in Bologna, Dr Andrade has reported some results of her recent research work.

Mr President, ladies and gentlemen

Before starting my presentation I would like to give my thanks for having been awarded the Robert L'Hermite Medal.

My interest in RILEMs activities dates back to when I first began my career in research. I was greatly impressed by the superior scientific content of its Journal as well as its other publications and congresses. I especially remember my first reading of the Congress of Prague on durability.

Only since 1981 has it been possible for me to collaborate more actively with RILEM and it was then that I was approached for participation in Committee 60 – corrosion of steel in concrete – whose Chairman is Professor Schiessl. I have learned many things from all my colleagues on this committee.

I am pleased that RILEM has granted its annual prize to a young and as yet unconsecrated scientist. I can say that in my case it provides an unequalled incentive for not leaving direct research. I am aware of my responsibility in ensuring that my future contributions are of high quality to do justice to the merit of this award.

I am grateful for the honor bestowed on my country and my institute by this award. Also, I am proud to have overcome the "sex barrier" and to be the first woman to receive this distinction.

I would like to express my gratitude to the members of RILEM Bureau and juries, who have chosen me among other candidates; and my special thanks to the Italian Group who have organized this meeting with such great efficiency and kindness.

And now not to mention the additional honor of being invited to belong to the TAC committee – I hope not to frustrate all these challenges.

Let me finish these thanks by stating that I have in my heart and mind at this moment – so special for me – those who have contributed in a decisive way to my research activities, namely, my parents and my colleagues, Professors González and Feliú. I am also thinking of my two sons who, at times, have had to share their mother with experiments and the editing of papers. Also present, not only in my heart, but here with me, is my husband, also a RILEM member, whose participation has been crucial. Without his continued encouragement and support I would not have been able to accomplish the work I have carried out up to now. My most heartfelt thanks to all.

And now let me briefly present some considerations and unpublished results of my current research: the corrosion of steel in concrete. A subject very close to RILEM activities and of increasing interest.

I would like to stress that this work is the result of the work of a group, not mine alone. The interdisciplinary aspect is absolutely necessary in this subject.

The three points I will speak about are: carbonation, galvanization and testing techniques.

We have been working during the last eight years on the corrosion of steel in carbonated concrete. We have measured the corrosion parameters during the process of carbonation by means of the polarization resistance method. These types of measurements have informed us about the pH at which depassivation occurs and about other changes in the electrochemical parameters occurring during carbonation. Moreover, we have measured the corrosion rates of the steel embedded in carbonated concrete as a function of variables, such as: the cement type (OPC and blended cements), the amount of cement, the presence of chlorides and the influence of the r.h.

As new and as yet unpublished contributions in this area I present you with the possibility of evaluating the efficiency of different concrete coatings

and the relation between cement carbonation and the SCC phenomenon in pre-stressed steel.

Working together with Dr R. Proctor, UK, we have found that the bicarbonate ions induce the SCC phenomenon in cold-drawn steel wires. In our opinion this is the first step in developing an alternative test to the existing one of the FIP, which uses ammonium sulphocyanate. This new type of testing method could be more reliable from the point of view of the electrolyte (bicarbonates) and the system of testing (slow strain-rate method).

We have been working on the behaviour of galvanized steel in concrete since 1975 and we are publishing extensively to clarify the controversy that exists on this subject.

We have identified three factors that influence the behaviour of the galvanized steel in contact with concrete and which were not taken into account in the past:

(i) the type of cement (alkali content and therefore pH value of the pore solution);

(ii) the characteristics of the galvanized coating (mainly the thickness of the external layer of pure zinc);

(iii) the moisture content of the concrete.

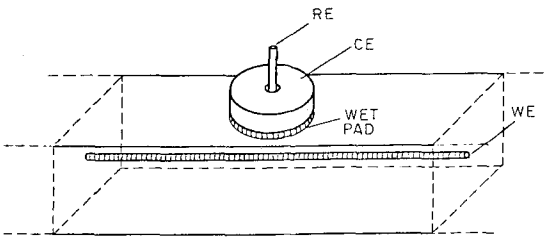
We have also studied the adherence between the galvanized bars and the concrete up to an age of five years. Although a scatter was recorded, all the galvanized bars presented values of bond over the limit considered in the Spanish Standards.

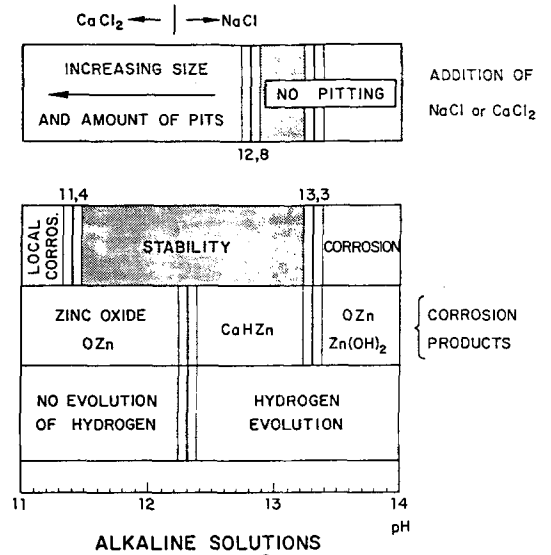
Some unpublished results in this area are those related to the corrosivity of Cl^- and the influence of the nature of the accompanying cation Na^+/K^+ or Ca^{2+}.

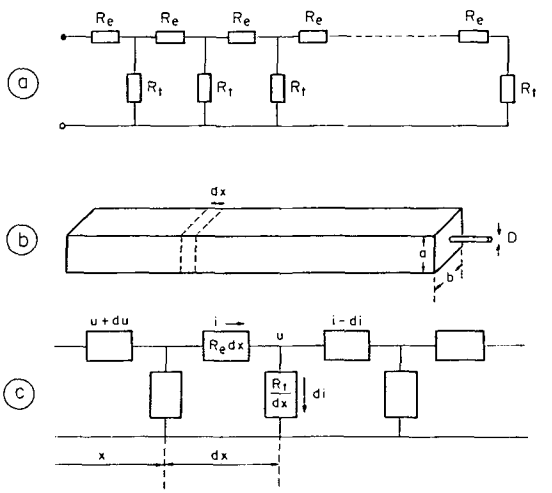
The different pH values which NaCl and $CaCl_2$ induce in the pore solution (which I have tested in collaboration with Dr C. Page, UK) when these admixtures are added to the mix influence decisively the subsequent behaviour.

Thus, $CaCl_2$ reduces the pH of the pore solution and NaCl hardly affects it. $CaCl_2$ induces numerous pits although a lower corrosion rate. NaCl causes a higher corrosion rate, but pits do not appear or are scarce. Therefore, $CaCl_2$ results in more corrosion for galvanized steel in the long term.

Finally, I mention the work on testing techniques, which in my opinion is our most relevant contribution. I have been involved in this work since 1969 and it was the subject of my PhD. For my first work then, I had to prepare about 500 specimens to look at very few variables and I had no other instruments for the measurements than my eyes and an old potentiometer as the most sophisticated one. I decided to look for a non-destructive and reliable testing technique.







The "polarization resistance method", an electrochemical method, has revealed itself as the most appropriate and accurate. In the past we have defined its theoretical basis, the limits of its accuracy and have described how to use it.

We have applied this technique to study the influence of numerous parameters and variables and it was, and it is for us, the key and the most useful tool to improve our knowledge on this subject. Although we have used other electrochemical techniques in hardened concrete, such as a.c. impedance, our conclusion is that the polarization resistance method is the most simple, accurate and reliable.

Now we are trying to apply the polarization resistance method to real structures and I can tell you that we have had success in resolving the theoretical aspects related to the non-homogeneous distribution of the potential or current along the bars.

We have resolved the mathematical equations assuming the model of the transmission line, arriving at very simplified equations. We have found three practical ways to carry out these measurements.

But not only have we resolved the theoretical part of the problem, we have also checked its reliability for big specimens and the results will be presented for publication in *Materials and Structures*. The three practical methods have resulted in similar accuracy for measuring the actual corrosion rate.

Now we are carrying out experiments not only on big specimens but on real bridges which are being repaired because of the problem of de-icing salts. For these experiments we are going to use a portable potentiostat that we have developed. We hope to have success also in this step and we hope to contribute to RILEM in the near future, by presenting this method as a new useful non-destructive testing technique for on-site measurement of the instantaneous corrosion rate of the reinforcements.

Thank you for your attention.

CONFERENCES

CALL FOR PAPERS

Second International RILEM Symposium on Demolition and Reuse of Concrete and Masonry Tokyo, November 7–11, 1988

Organized by the Building Research Institute, Ministry of Construction, Japan, and Nihon University, Tokyo

This symposium is aimed at bringing together all those who are actively engaged in theoretical and practical work on the demolition and reuse of concrete and masonry, and thus provide a forum for the presentation and discussion of research and development in the following areas:

- Demolition techniques for concrete and masonry structures;
- Experiences of demolition of structures, including prestressed concrete structures, nuclear power related structures, off-shore structures, chemical plants and others;
- Reuse, treatment and disposal of demolished concrete, stone and brick;
- The economics of demolition and reuse;
- Health and safety aspects;
- Codes and standards for demolition and reuse.

All sessions will be composed of presentations of accepted papers with appropriate opportunities for discussion.

Prospective authors are asked to submit a one page abstract in English (about 200 words with the title of the paper, and the author's name, affiliation and address) to the Symposium Secretariat before **31 July 1987**. Preliminary acceptance of the paper with instructions describing the final format of the paper and type of presentation expected will be notified by **30 September 1987**. The deadline for acceptance of the final full-length is **30 April 1988**.

The paper should be written in English with a summary in both English and French, and must be a maximum of 10 pages in length including any diagrams or other illustrations. Papers must be in a camera-ready format, typed on A4 paper (210 mm × 297 mm) according to the instructions provided. All papers will be subject to review by the International Scientific Committee of the Symposium before final acceptance.

Address of Secretariat: Susumu FUJIMATSU (Dr Eng.), Symposium Secretariat, Building Research Institute, Ministry of Construction, 1 Tatehara, Oho-machi, Tukuba-gun, Ibaraki-ken, 305 Japan. Telephone: 0298-64-2151. Telefax: 0298-64-2989. Telex: 3652560-BRIMOC J.

ICOSSAR'89

The **5th International Conference on Structural Safety and Reliability** (ICOSSAR'89) will be held in **San Francisco, 8–11 August 1989**. The objective of this Conference is to address societal interest for safety and environmental quality within the constraints of economy. Emphases will be made on methods for assuring and improving safety and reliability as well as applications to specific types of structures. It is concerned with the decision-making process for design, quality control and construction of major structural systems, including aircrafts and aerospace structures, nuclear power plants, bridges, buildings, offshore platforms, ocean vessels and mechanical systems. ICOSSAR'89 is organized by the *International Association for Structural Safety and Reliability* (IASSAR) to provide a forum for project managers, analysis- and design engineers and researchers to discuss new developments as well as state-of-the-art and novel applications of reliability assessments for all types of structures.

IN LABORATORIIS

University of Leeds, Department of Civil Engineering

Civil Engineering Materials Research

Concrete: The main research area is the study of cement substitutes (pfa, slag, microsilica, trass, and red tropical soils) and admixtures (plasticizers and superplasticizers) on the properties of fresh and hardened concrete, cured and stored in environments ranging from adiabatic conditions to tropical wet to arid-dry conditions. Durability, short-term and long-term stress–strain behaviour under various types of loading, and performance functions are being evaluated.

Instruments for measuring gas-permeability chloride diffusion have been developed for hardened concrete, while a turning-tube viscometer and shear-rate apparatus have been developed for measuring rheology of fresh concrete. Other studies include the reaction modelling between lime and pozzolanic materials using thermal analysis.

Masonry: Current research projects are assessing the use of pfa clay bricks for brickwork, the fundamental causes of moisture expansion in clay bricks and brickwork, and composite models for time-dependent properties of brickwork and blockwork.

Bituminous materials: A new method of assessing the workability of these materials has been developed, together with a design procedure for evaluating the parameters: filler type, quantity and filler/bitumen ratio on permeability and long-term deformation of mixes for road and airfield pavements.

A RILEM Titular Member
TECNOMARE, Italy

Tecnomare is an applied research and engineering company whose primary objective is the research, development and industrial application of innovative marine technologies: the operating formula of the company calls for the direct transfer of the results of research to industrial application: from the conceptual design through its full operating life.

Tecnomare carries out self-sponsored research within its own budget as well as research and development for its shareholders and to third parties: some 35% of the activities of the company are devoted to applied research and innovative projects. In addition the company carries out design and engineering of offshore structures and facilities, and the design and operation of underwater equipment and vehicles.

Tecnomare's general scope of activities includes research, development, engineering, consulting, technical assistance and project management services of complete marine systems, fixed, compliant and floating structures, mooring points, subsea storage tanks and production equipment, underwater machinery and remote control systems: from the conceptual design to the fabrication, installation and operation.

The sophisticated know-how and capabilities developed are the result of the combination of the continuous development of research projects and performance of engineering services.

Tecnomare's key personnel have acquired over the years significant professional experience and expertise in offshore research, design, construction and operations providing services for oil operators and companies throughout the world.

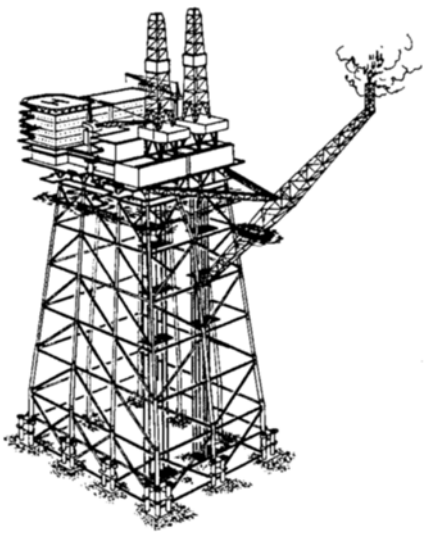


Fig. 1 Jacket structure for Bouri field.

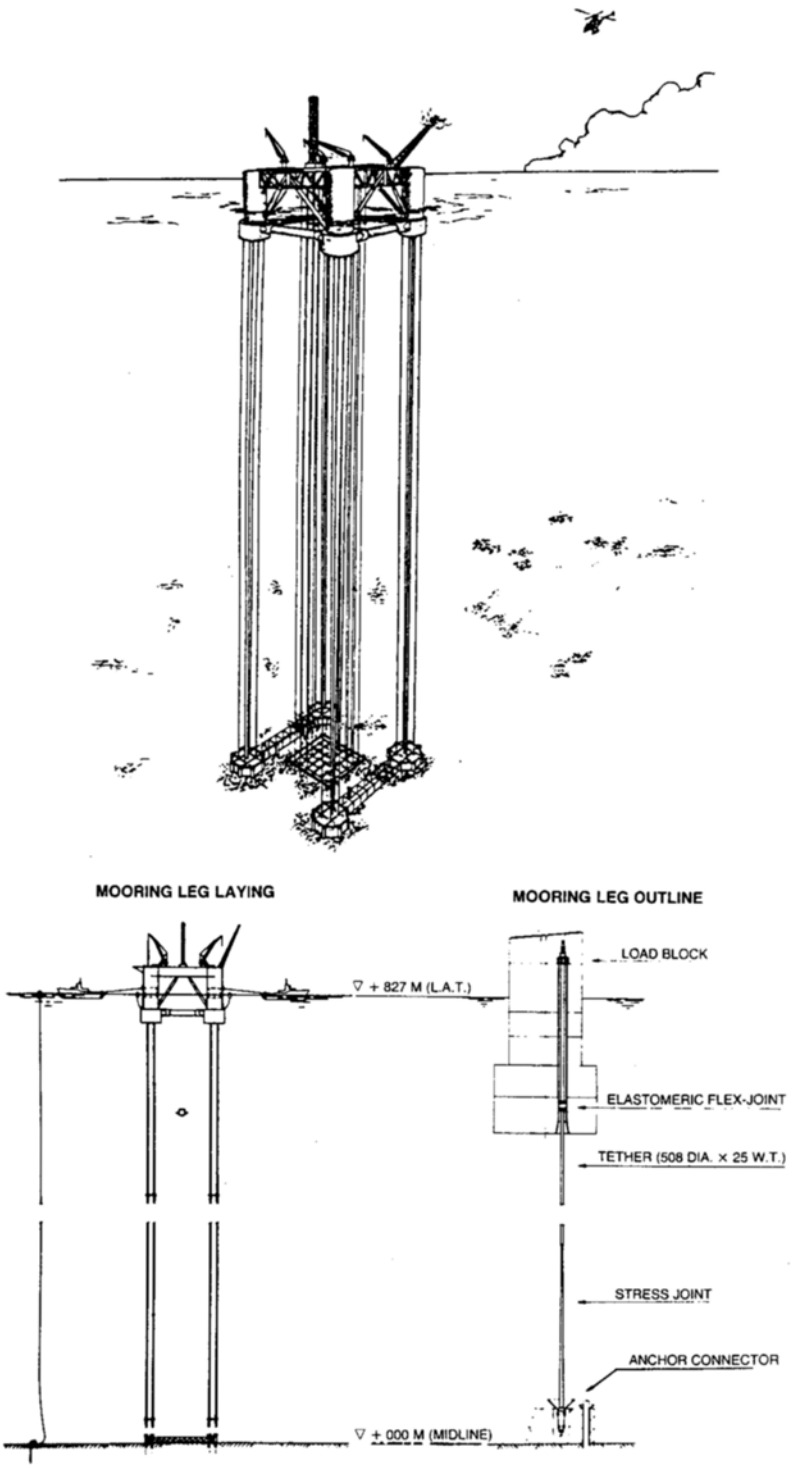


Fig. 2 Tecnomare TLP for the Aquila field.

Internal disciplines include structural, naval, geotechnical metallurgical, mechanical, electrical, instrumentation and electronic engineering, physics and applied mathematics. Fabrication, installation and operative experts support the engineers.

A very close technological relationship and exchange with highly specialized bodies such as universities, laboratories and research institutes, and a continuous updating process through internal and external education programmes keep Tecnomare's people updated and informed on state-of-art technologies.

In the field of offshore structures, to date Tecnomare has completed over 40 platforms designs for the most varied offshore scenarios in water depth ranging from 25 m to 172 m, including the two jackets for Libya's Bouri oilfield: the largest offshore structures of the Mediterranean Sea.

To a certain extent all the projects performed by Tecnomare incorporate innovative concept configurations, cost cutting design principles, advanced design criteria for the engineering, construction and installation phases as a result of the extensive research and development activities as well as the expertise acquired in the past.

For example the development of the concept and the structural configuration, the design, the assistance during construction, installation and operation of the first Steel Gravity Platform (TSG) for the Maureen field in the North Sea demonstrate the range of activities in which the company have been successfully involved.

Tecnomare is involved in the design of a tension leg platform for an oilfield in the Adriatic Sea. Besides the design water depth of 827 m, Tecnomare's TLP differs from other concepts in that its tubular legs will be welded and rigidly fixed without flexible joints at the bottom. The legs will be fitted into a stress joint clamped tight into a unique and patented anchor connector held in a foundation piled into the seabed. To assure high quality welds for the tether assembling, Tecnomare has developed and tested within the same project a prototype of a fully automatic multi-headed welding machine.

Tecnomare has developed an underwater production system for application in up to 1000 m water depth: the design envisages production equipment housed in two composite (concrete-steel) cylindrical vessels held in place by a foundation structure on the seabed. They are "sandwiched" together and incorporate an access chamber. The production vessel will be permanently linked to the surface by means of a slender tensioned Monopile structure.

The monopile structure consists of a slender steel column tensioned by a submerged buoyancy chamber and anchored on the seabed to a foundation structure. For the same structural concept and for application such as mooring point and lightweight topsides support Tecnomare is developing application of composite material (GRP) as constructing material.

Tecnomare has designed, built, tested and operated a number of underwater vehicles for pipe and cable trenching. The latest in the line of subsea trenchers designed and built by Tecnomare since the early seventies is the TM 702, a shallow water remote controlled vehicle capable of burying pipelines or cables in very soft soil conditions.

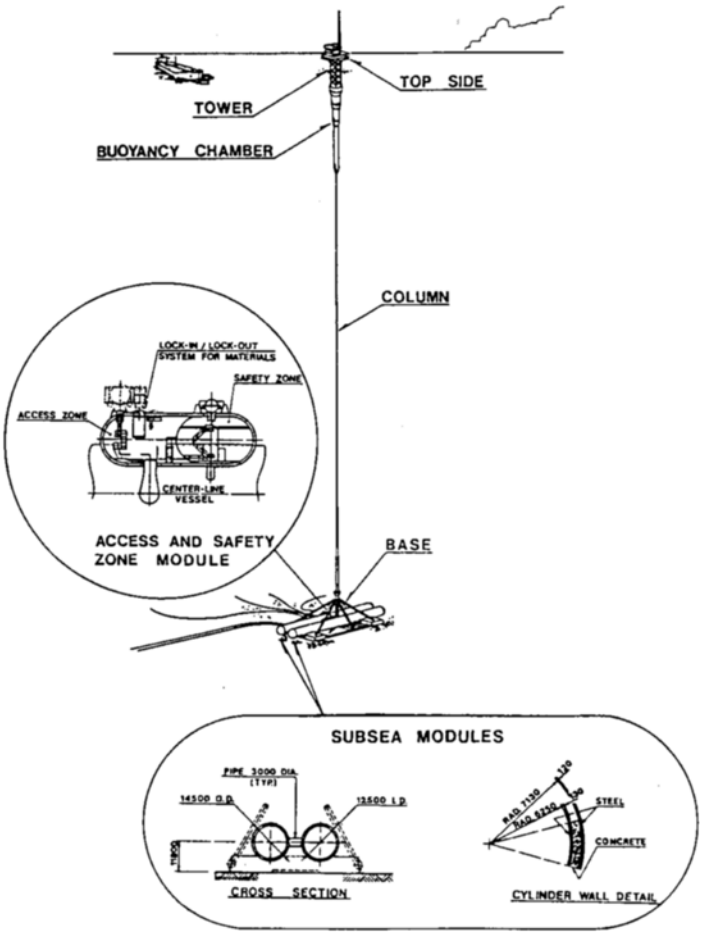


Fig. 3 Tecnomare underwater production system.

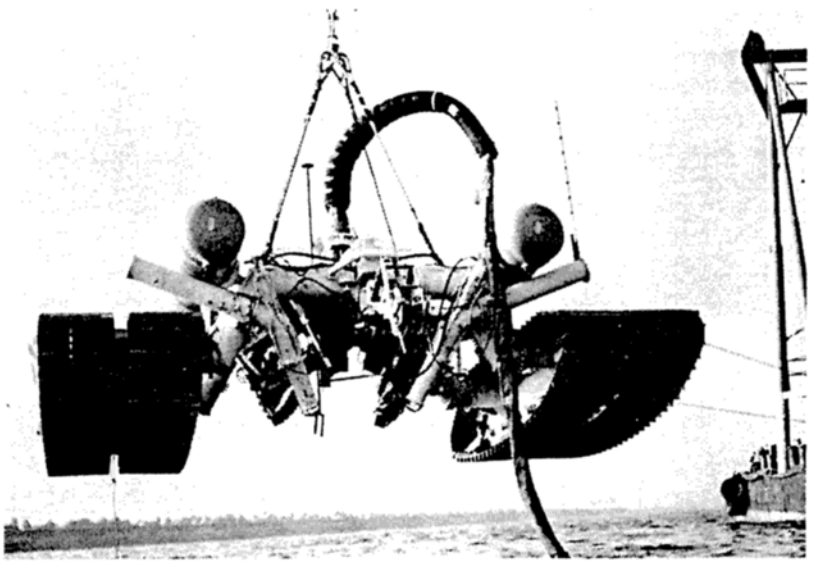


Fig. 4 TM 702 – Pipe trenching vehicle.

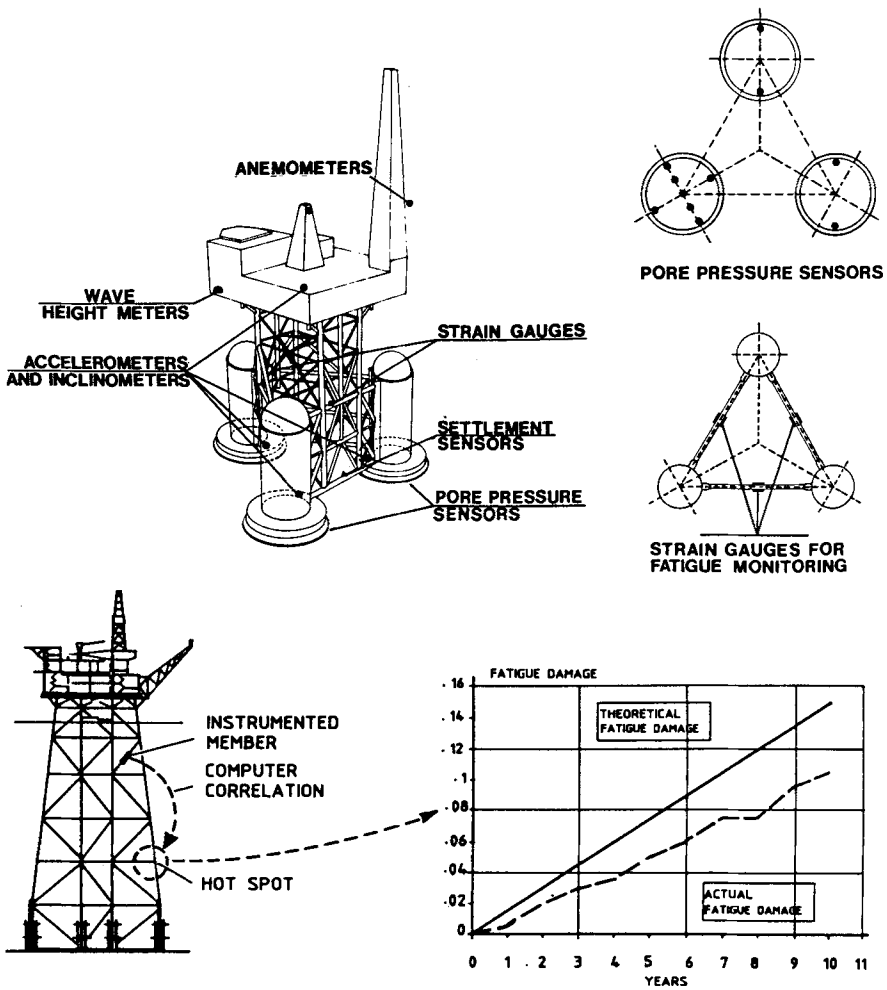


Fig. 5 (a) Tecnomare monitoring system for Maureen platform; (b) Tecnomare monitoring system.

During the past ten years Tecnomare has developed monitoring techniques to check the integrity of offshore structure by early detection of fatigue signs and crack growth. The system is based on the principle that an elastic wave propagating along a structure is partially reflected when it reaches a discontinuity. Such a system has been installed in the unmanned Barbara platform in the Adriatic, sending data on the structural behaviour of the platform to a control room onshore. A sophisticated monitoring system has also been installed on the Maureen TSG platform to keep a check of all the nodes.

Tecnomare is now involved in a joint stock company, Moser, with Norway's Veritec to perform various monitoring services throughout the offshore world.

DESIGN AND ENGINEERING OF OFFSHORE STRUCTURES AND FACILITIES

- platform structures of the fixed, floating and compliant types
- platform facilities and ancillary systems
- mooring and loading points/ terminals
- monitoring of structures and systems
- sealine connections and repair systems
- underwater storage tanks

UNDERWATER AUTOMATED MACHINERY DESIGN AND OPERATION

- remote controlled trenching machinery
- remote controlled systems for subsea wellheads
- remote controlled systems for seabed sampling
- subsea production equipment
- assembly of mechanical and electronic subsea equipment

TECHNICAL ASSISTANCE AND OPERATIONAL SUPPORT ENGINEERING

- during fabrication
- during tow, transportation and installation of marine systems
- during start-up, commissioning and early stages of operation
- structural monitoring and diagnostic services
- project services control
- project management
- quality assurance

RESEARCH AND DEVELOPMENT OF INNOVATIVE PROJECTS

- complete marine systems
- deep water and arctic structural configurations
- concepts for mooring and loading points
- structural diagnostic methods
- subsea robotics, communications and electronics
- development of new computer procedures
- environmental mechanics and risk/ reliability studies
- application of new materials
- offshore business analyses
- field development schemes
- feasibility studies

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Sème Symposium International des Routes en Béton, Aix-la-Chapelle, Juin 1986

Cette importante conférence, organisée par Cembureau en étroite coopération avec l'Association Internationale Permanente des Congrès de la Route (AIPCR) et l'Association Fédérale de l'Industrie Cimentière Allemande (BDZ), a donné lieu à la publication de 5 volumes représentant au total quelque 900 pages. Le prix des 5 volumes est de 1 250 F.F., port compris, payable par chèque libellé en Francs Français, sur une banque en France, à l'ordre de: Cembureau, 2, rue Saint-Charles, F-75740 Paris Cedex 15, France.

Les 4 premiers volumes contiennent le texte de 88 contributions présentées dans la langue de l'auteur avec résumé dans les trois langues du Symposium (allemand, anglais et français); chaque volume correspond à un thème principal, à savoir:

A: Conception et comportement à long terme des chaussées en béton

B: Construction des chaussées en béton

C: Entretien et réhabilitation des chaussées en béton

D: Thèmes spécifiques

Le cinquième volume E rassemble le texte des allocutions d'ouverture et de clôture, des 15 rapports généraux, de quelques contributions complémentaires et des exposés présentés au cours d'un Séminaire consacré aux "Stratégies pour l'entretien et la réhabilitation des revêtements en béton".