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The introduction of prestressed concrete in Portugal: Teixeira Rêgo

C. Pimenta do Vale
Universidade do Porto, Porto, Portugal

M.L. Sampaio
Universidade Nova de Lisboa, Lisbon, Portugal

R.F. Póvoas
Universidade do Porto, Porto, Portugal

ABSTRACT: This paper addresses the professional career of António Teixeira Rêgo, Portuguese engineer, born in 1906, died in 1967. Professor at the Faculty of Engineering, he combined teaching and research activities with intense professional practice, working with the most important northern architects and being connected to some of the most notable works of the city of Porto, such as the Passos Manuel garage, the Coliseu do Porto, or the Casa de Serralves. He was responsible for the introduction of prestressed and light prefabrication technology in Portugal, discussing his experiences in international forums.

1 INTRODUCTION

The history of architecture, and the history of the construction of the city of Porto, in the 20th century, have been the target of an increasing number of studies in recent years, the result of greater academic research. The studies are generally focused on the work and professional careers of architects, analysis of the transformation of areas of the city, or certain types of buildings. An important gap identified is the lack of an equivalent investment in research that focuses on the professional career of civil engineers, the processes of introducing structural calculations into the licensing permits, their role in the implementation or dissemination of new materials and constructive systems, and their impact on the industrialization of construction processes. We can point to research on the teaching of engineering (Matos & Sampaio 2019), the careers of some engineers (Sampaio 2019), on calculations and regulations (Póvoas & Vale 2018), and on the history of engineering (AA.VV. 2002; Viseu, 1993), among others.

One of the least studied engineers who developed a fruitful professional life between the 30s and 60s, participating in significant projects of the city of Porto such as Garagem Passos Manuel, Coliseu do Porto, or Casa de Serralves, is António Augusto Guimarães Teixeira Rêgo, professor at the Faculty of Engineering. Along with theoretical and scientific production parallel to his activity as a designer, he would participate in international circles of technical knowledge transfer, namely in congresses and conferences, and would be responsible for the introduction of prestressed technology in Portugal. As Viseu (1993, 151) states, in Portugal Teixeira Rêgo "was for prestressed concrete as (…) the engineer Moreira de Sá was for reinforced concrete (Hennebique system)". His professional practice followed a period of change in construction systems, and consolidation of the use of reinforced concrete in Portugal, being active at the start of the industrialization process and prefabrication of construction in the 50s. Research has revealed his importance in the construction panorama and in the introduction and systematic use of new materials such as reinforced and prestressed concrete. This article is the first presentation of ongoing research.

2 ANTÓNIO TEIXEIRA RÊGO, ENGINEER AND PROFESSOR

António Augusto Guimarães Teixeira Rêgo, born in Matosinhos in May 1906 (d. Oct. 1967), graduated in civil engineering at the University of Porto where he finished his course in 1935, with his final internships at the Port of Leixões (5 July 1932); Anglo Doutels Engineering and Harbor Works, in Leixões (14 November 1934) and finally the Water and Sanitation Service of the Porto City Hall (17 January 1935) (FEUP. Arquivo, 1932–5). During his student days, between 1932 and 33, he was the editor delegate of Porto for the magazine *Academia Portuguesa* (S:N. 1933, 2).

In 1936 he began his career as a teacher. By order of the Rectory on 29 May 1936 he was appointed

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for three years to the position of assistant of the 3rd Group (Hydraulics) of the Faculty of Engineering, beginning on 14 June (Universidade do Porto 1926–1988, 1). He was finally permanently employed in August 1942. From 1940, he assumed responsibility for the subject "Industrial Hygiene", which the following year was renamed "Industrial Hygiene and Safety of Workers", and in 1942 he took over the subject "General Hydraulics – Hydraulic Machinery". In 1956, he ceased as head of "Industrial Hygiene and Safety of Workers", to become head of "Aerodynamics", a position that would continue until his death in 1967 (Universidade do Porto, 1926–1988).

In 1944 he presented his PhD thesis entitled "*Da Hidráulica: uma Ciência Experimental e Teórica* [Hydraulics: An Experimental and Theoretical Science]" (Rêgo 1944) which allowed him to be appointed to the position of 1st Assistant in March 1945, since he had already become an Assistant in 1936 (Universidade do Porto, 1926–1988). In his PhD, he defended the use of physical theories as necessary to knowledge acquisition of hydro-dynamics, the use of experimental data, which should be based on laboratory work using scale models, to confirm abstract knowledge. Most significantly, he defended the application of the principles of similarity that allowed models to be used to analyze hydraulic behavior (Rêgo 1944). It should be mentioned that in 1939 he advocated the "theory of similarity" in an article published in the *Journal of the Faculty of Engineering* (Rêgo 1939).

In 1942 he participated, in Porto, in the 4th Congress of the Portuguese Association for the Progress of Sciences, publishing the article "*Um método prático para a construção de tetos de grandes salas de espectáculos* [A practical method for the construction of ceilings for large concert halls]" using his experience in the works of the Coliseu do Porto (Rêgo 1942).

Between 1944 and 1952 he held "the position of member of the Higher Council of Public Works, (which he) exercised with the greatest competence and zeal the functions he was charged with" and was appointed again in August 1952 (Universidade do Porto 1953; Universidade do Porto 1926–1988).

His studies in Hydraulics, and his internship in Leixões Port, led him to an interest in the work of Eugene Freyssinet (1879–1962) the pioneer of prestressed concrete in 1931; an interest that would define his contribution to the national construction industry. From the end of World War Two, we find the application of this process in hydraulic works, such as the construction of the Rivières sur le Tarn dam which started in 1946, and the Orleans water tanks, also from 1946. The application of Freyssinet's methods using prestressed concrete were used in diverse works, most noticeable in the construction of bridges. This interest led Rêgo to participate in the very first congresses dedicated to the use of prestressed concrete. Thus, in June 1949 he participated in the *Journées Internationales de Pré-Contrainte* in Paris and Rouen where he presented (in Rouen) a paper on "*Processos portugueses de pavimentos de Betão Pré-esforçado* [Portuguese processes of prestressed concrete floors]". This meeting gathered 450 representatives from 18 different countries, where important oral contributions were presented, including by "M.M. Caquot, Freyssinet, Lossier, Colonnetti [and] Lévy" (BTSR 1949, 221; Universidade do Porto 1950).

In the 1950s, Rêgo participated in several international conferences where European cases of the use of the new concrete process were presented. In 1950, with a scholarship from the Instituto de Alta Cultura, he participated in the *Jounées Internationale de l'Association Scientifique de la Precontrainte*, held in Paris, Rouen and Le Havre, presenting a paper entitled "*Fenómenos da temperatura nas grandes mesas de fabrico de betão pré-esforçado* [Phenomena of temperature in large manufacturing tables of prestressed concrete]", later published in the French magazine *Travaux* in 1951 (Rêgo 1951b). In the same year, he participated in Ghent (Belgium) in the *Congrès du Beton Précontraint* presenting the paper "*Les activités portugaises dans le domaine de la précontrainte* [The Portuguese activities in the field of prestressing]" and another entitled "*Quelques remarques à propos de la fabrication de poutrelles en béton précontraint sur des tables vibrantes* [Some remarks about the manufacture of prestressed concrete beams on vibrating tables]" (Rêgo 1951b). Between 12 and 17 May 1952 he took part, in Madrid, in the first general meeting of the *Instituto Técnico de la Construcción y del Cemento*, which was organized as a higher course in concrete. He presented a paper entitled "*El empleo de los procedimientos Freyssinet en Portugal* [The use of Freyssinet procedures in Portugal]" (CSIC 1953), which was published, in 1953, in the magazine of the same institute (Rêgo [1953], 1953).

On 29 August 1952, in Cambridge, he participated in the inaugural meeting of the International Federation of Prestressed Concrete (*Fédération internationale de la précontraint* – FIP), and was appointed delegate by Portugal (Rêgo 1953). At the first FIP congress, in London in 1953, he presented the papers "*Pavimentos mistos de betão pré-esforçado* [Mixed floors of prestressed concrete]" and "*Cálculo do betão pré-esforçado baseado no critério da rutura* [Calculation of prestressed concrete based on the rupture criteria]" (Rêgo 1953). He also participated in the second congress, in 1955. In 1956, he published the article "*50 anos de betão armado em Portugal* [50 years of reinforced concrete in Portugal)" in the magazine *Concrete and Constructional Engineering* (Universidade do Porto 1959) and in 1958, in the FEUP magazine, the article "*Impressões de uma viagem a Angola* [Impressions of a trip to Angola]", with the report of his experience in the construction of a prestressed concrete bridge over the Mucoso River, a tributary of the Quanza River, 220 km from Luanda (Universidade do Porto 1960).

Teixeira Rêgo would make exploratory visits, combined with the congresses he participated in, privately or with students. Consolidating his knowledge, he made, in 1950, a private visit to the *Escuela de*

Caminos Laboratories, in Madrid (Rêgo 1951b). Later, in 1954, he accompanied the final year students on a study trip to France and Spain (Universidade do Porto 1955). In the following years he would host several conferences in Portugal dedicated to prestressed concrete.

This intense international activity of Teixeira Rêgo, and other colleagues, engineers and professors, was the result of the growing importance of engineering training and the engineer profession. In the 1930s two social groups were affirmed: "engineers and industrialists, who will give guidance to the economic development of the country, convinced that their ideas and qualifications will play a determining role in the conduct of economic policy" (Rollo 2002, 11).

The engineers' protagonism was also due to the implementation of reforms in technical education. In 1911, with the introduction of the Republican regime, a re-organization of the main Engineering schools was undertaken. Moreover, in 1915 and 1926, the reforms allowed: the renewal of study plans, the definition of an engineering graduate, and the introduction of theoretical-practical training including laboratory experiments, particularly in the testing of materials, with a strong emphasis on specialist knowledge (Matos & Sampaio 2018). It was within this framework of the acquisition of technical skills and competences that a generation of engineers developed, such as Antão Almeida Garrett (1897–1978), José Júlio de Brito (1896–1965), engineer in 1924 and architect in 1926, Francisco Jacinto Sarmento Correia de Araújo (1909–81), and also António Teixeira Rêgo (1906–67), our case study.

3 ANTÓNIO TEIXEIRA RÊGO, DESIGNER AND INDUSTRIAL PROMOTER

António Teixeira Rêgo began work as a structural designer soon after finishing his course in 1935, signing the Terms of Responsibility in several areas (reinforced concrete calculations and safety of workers) and working with different architects, such as Mário de Abreu, Cassiano Branco, David Moreira da Silva, Homero Ferreira Dias, Rogério de Azevedo and J.A. Brito e Cunha. He also collaborated with fellow engineers, for example, the team that undertook construction of the City Hall building and the project of the Massarelos berth (Rodrigues 1937, 184). We also find reference, in 1938, to his role as technical manager of the construction company Ferreira dos Santos, a large company in Porto, responsible for the construction of housing blocks.

His activity was intense. A total of 338 processes licensed between 1935 and 1952 (276 between 1935 and 1939) have been inventoried so far in the Historical Archives of the Municipality of Porto. About 150 correspond to the construction of new buildings and the rest to other types of works including the construction of garages and warehouses or small alterations, namely the construction of reinforced concrete slabs in kitchens and bathrooms of existing buildings. Terms of Responsibility in the neighboring Municipalities of Vila Nova de Gaia, Matosinhos and Vila do Conde were also identified, and a reference to a building in Lisbon. Further research may show a widening of his geographical area of influence.

António Teixeira Rêgo's period of professional activity corresponds to a time of great change in construction systems and in the construction industry in Portugal, mainly in what concerns horizontal structural elements, with a progressive replacement of wooden floors by several types of reinforced concrete slabs.

He was directly connected, as a designer, to a number of notable works in the city of Porto, such as the Garagem de Passos Manuel (1937–9), the house of Serralves (1925–43), the Coliseu do Porto (1939–44), the building block of the Palácio do Comércio (1940–54) as well as in nearby municipalities, such as the Matosinhos Cotton Warehouse (1950–1), the facilities of the Portuguese Cellulose Company in Cacia, Aveiro (1952–3), and the pavilions of the Seca do Bacalhau in Lavadores, Vila Nova de Gaia (1958–9).

4 INNOVATION AND NEW MATERIALS: THE COTTON WAREHOUSE AND THE INTRODUCTION OF PRESTRESSED CONCRETE IN PORTUGAL

Technical progress develops through the introduction of innovations. According to Schumpeter (1883–1950) innovation can consist of the production of a new product, the introduction of a new production process, the adoption of new management processes and business organization (Amaral et al. 2016). The motivations to introduce an innovation can be to obtain a profit, obtain an advantage over other competitors, gain competitiveness, but can also constitute an improvement in the quality of products and processes through compliance with international standards.

The introduction of prestressed concrete in Portugal, and its production methods, corresponds to the application of innovative techniques that had been introduced between the wars, resulting from the cumulative work of several engineers from 1886.

For E. Freyssinet it was introducing the use of prestressed concrete for consolidating the maritime station of Le Havre; being the first application of prestressed concrete in a large engineering work (Freyssinet 1951, 1). After Le Havre, other works became significant, namely the Balma Ship Model Basin in Toulouse, a major work created in 1906 at the instigation of engineer Louis-Émile Bertin (1840–1924), and with additions over the years, especially the opening in 1952 of a 1200 m long tank (Figure 1).

António Teixeira Rêgo, through his international contacts, became aware of the advantages of the new process and the value of better organization of the execution procedures it involved. He followed Freyssinet's technique as well as the work of engineer Yves Guyon, responsible for several works carried out by STUP

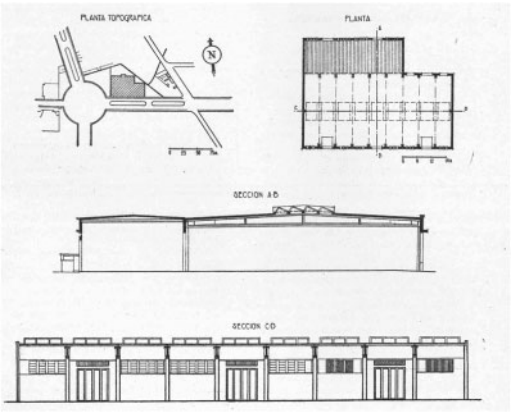

Figure 1. The Design of Cotton warehouse (Rêgo [1953]).

(*Société Technique pour l'Utilisation de la Précontrainte*), with innovative solutions that widened the use of prestressed concrete. Along with Myle J. Holley Jr – a professor at the Massachusetts Institute of Technology (MIT) – António Teixeira Rêgo promoted that prestressed concrete allowed for great savings in steel, a fact that made it immediately advantageous from an economic point of view (Rêgo [1953], 4).

He manufactured and employed for the first time in Portugal "prestressed concrete hollow slabs (Porto – August 1948), using a type designed in France, which was soon put aside. It was a beam of rectangular section, in a coffin, lightened with two cylindrical holes" (Rêgo 1958, 50).

In 1951, António Teixeira Rêgo published, in the magazine of the Order of Engineers, an article entitled "*A primeira construção portuguesa de betão pré-esforçado com cabos* [The first Portuguese prestressed concrete construction with cables]" (Rêgo 1951a) and in 1953 he published in the magazine of the *Instituto Técnico de la Construcción y del Cemento* another article about the "*Empleo de los procedimentos de Freyssinet en Portugal* [Use of Freyssinet's procedures in Portugal]" (Rêgo [1953]), following a conference in May 1952. In both, he describes in detail the plan for the construction of the cotton warehouse at, then, Av. Menéres, in Matosinhos, belonging to the firm Carlos Marques Pinto & Sob. Limitada, designed by the architect Homero Ferreira Dias (1904–60). The team responsible for the execution of this project and construction work was composed entirely of local technicians. Looking at the accounts of the prestressed structure the names of the following engineers stand out: Gustavo Natividade and Aurélio Morujão, from the technical office "Precomate" of Porto, under the guidance of António Teixeira Rêgo, who appears as coordinator of the prestressed concrete works (Rêgo 1951a, 19). The contractors were the *Cooperativa dos Pedreiros Portuenses* and Angelo Ramalheira (1908–75), a former student of Gustave Magnel, whose construction company would be linked with important national works, such as the

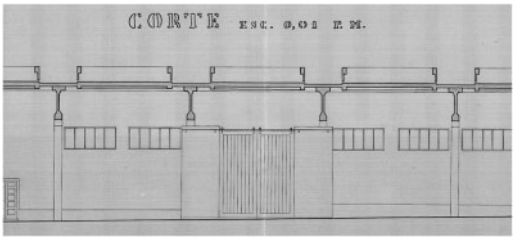

Figure 2. Close up of the architectural section of the Cotton Warehouse, with the representation of the structure (Matosinhos et al. 1950).

School Hospital and the Crystal Palace sports pavilion in Porto, the headquarters of the *Diário de Notícias* and the block of *Águas Livres* in Lisbon. The granulometry studies of the concrete, formwork and execution project were carried out by engineer António Gonçalves, in collaboration with Ramalheira, who "had been in Paris between 1949 and 1950 where he had studied the system of fungiform slabs and prestressing" (Gonçalves et al. 2004) (Figure 2).

The warehouse, with its large span and considerable height, is still recognizable despite the transformations undergone over almost 70 years. It currently accommodates a large commercial area, and above the false ceilings can still be seen the beams and prestressed slabs of the initial industrial warehouse which was intended "for the storage of large imported shipments of cotton bales, after their unloading at the port of Leixões" (Matosinhos et al. 1950). Its construction was to follow the rules imposed by Ministerial Order that required these spaces to have waterproof and load-resistant flooring, fireproof insulated ceilings, and walls resistant to temperature variations, as well as meet the requirements of the fire-fighting services. It was thus decided to build a warehouse with a cavity wall of stone and concrete blocks, a terrace roof, windows with double frames, those of the south and west elevations being protected with brise-soleils executed in vibrated concrete plates, and those of the annexes at the rear executed in "gracifer", a reinforced concrete frame system (Figure 3).

The roof structure would be re-enforced with "large prestressed concrete master beams, calculated and executed using 'Freyssinet' (…) processes, a 7 m space between axes and with a total span of 32 m (…) the terrace (…) will be formed with prestressed concrete beams (Precomate), [with] a coating layer in cellular cement, of 0.05 m thickness, for thermal insulation" (Matosinhos et al. 1950).

According to António Teixeira Rêgo, the warehouse construction took advantage of the prestressed concrete characteristics, using master beams with a span of 32.40 meters, and "136 cables of 12 wires of 5 mm each, using Freyssinet cones and the work of jacks" (Rêgo 1951a, 5). These are "isostatic beams, calculated for a bending moment of 484,000 m.kg., with a 1.80 m. corner at the midpoint of the span and 1.10 on the supports. The maximum width (…) is 0.76 m

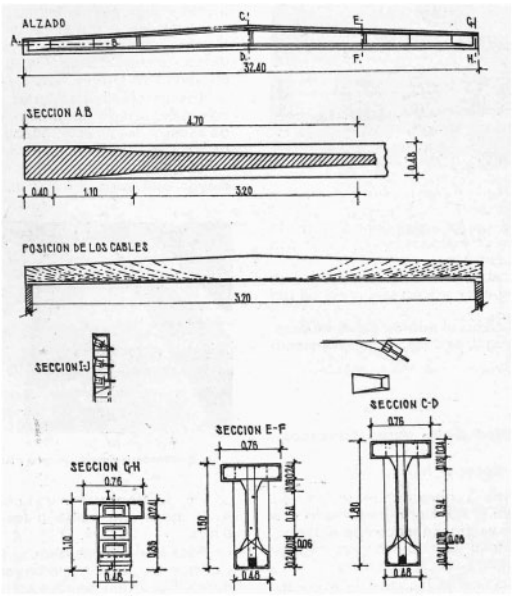

Figure 3. The design of the prestressed beams of Cotton warehouse (Rêgo [1953]).

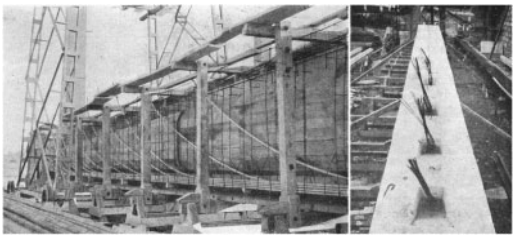

Figure 4. The layout of the prestressing cables, on the left, the anchorage of the cables, on the right (Rêgo [1953]).

at the flange and the minimum is 0.13 m at the web. Only one wooden formwork with a supplementary base plate was built on the ground" (Rêgo [1953], 7). The proposed system allowed faster manufacture by removing the sides of the formwork after 24 hours, keeping the base for six or seven days, and concreting a new beam with the laterals and the supplementary base (Figure 4).

The construction followed the requirements to obtain a concrete with the necessary granulometry, respecting the relation of water-cement, workability, form of kneading and application, and was achieved "as average values, resistances, at 6 days, usually over 300 kg/cm2, which are considered sufficient to proceed with the stretching of cables" (Rêgo 1951a). Rêgo also made mention of the use of six electric vibrators of national manufacture with 1.5 CV in the process of filling the molds that shortened the process of concreting the beams, which took on average four and a half hours to 16m3 of concrete (Rêgo 1951a, 7).

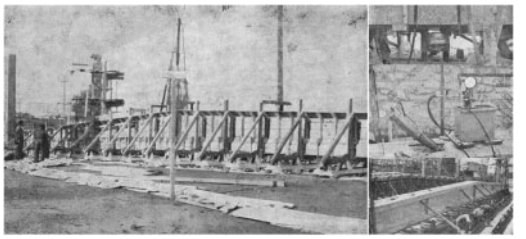

Figure 5. The beam formwork, on the left, and the electric vibrators used, on the right (Rêgo [1953]).

The beams were lifted on the seventh day "with the help of two metal towers of 20 tons each" (Rêgo 1951a, 11).

The slabs were made using prestressing, by means of "industrially manufacturing tubular beams, with adherent wires" with the space between them "filled with special type bricks, covered with concrete" (Rêgo 1951a, 12).

At the end of his description, António Teixeira Rêgo mentions that this warehouse in Matosinhos "was the first construction using prestressed concrete with the use of cables, without the use of foreign technicians, carried out in Portugal following the Freyssinet methods" (Rêgo 1951a, 19). He also stressed that its technical and economic viability was possible due to the cooperation between the designers and the technical office of the company *Precomate, Sociedade de Preconstrução de Materiais Lda.*, based in Águas Santa, Maia. It was one of the first European companies dedicated to the manufacture of prestressed hollow slabs of STUP patent (Sarmento 2005, 10), submitted to the evaluation of the National Laboratory of Civil Engineering (LNEC), becoming one of the first national industries to invest in prefabrication in the construction sector. It should be noted that after the publication of the General Regulations for Urban Buildings (RGEU) in 1951, all new constructive solutions would have a type-approval document issued by LNEC. This company, which was technically directed by António Teixeira Rêgo, and administered by other partners, is recognized as one of the first in Europe to successfully advance the industrial manufacture of prestressed beams (Lalande 1949). The investment made in Precomate, created by engineers, shows that the industrialization of these processes took substantial steps in the 1950s, after the issue of law n°. 2005 (14 March 1945) that promoted the "*Bases a que deve obedecer o fomento e a reorganização industrial* [Conditions with which the development and industrial reorganization must comply]". This was followed by the launch of the "*Planos de Fomento* [Development plans]" (1953–74), the first to cover the period from 1953 to 1958 and to be an instrument to stimulate the national economy in the post-war period, seeking to define an investment strategy more in line with the development prospects of the time (Figure 5).

António Teixeira Rêgo would lead in the manufacture of prestressed beams for the construction of

the buildings of the Portuguese Pulp Company in Cacia, Municipality of Aveiro, also under execution by Angelo Ramalheira. For this project, 24.5-meter-long beams were built for the machinery room and 15.90-meter-long beams for the warehouse, being 4.92 in cantilever, which is the reason why he stated that "in addition to the parabolic cables characteristic of the system employed, these beams carry, in the support submitted to negative moments, an additional reinforcement, used for the first time in Portugal" (Rêgo [1953], 13). The suggestion to use the prestressed system, which "solved the problem of fast execution", was the result of an alteration proposed to the initial project made by the contractor, replacing the reinforced concrete porticos with an equal number of prestressed beams. The change to the initial solution "was studied in the technical office of engineer Ramalheira by engineer António Gonçalves, and was approved and adopted because it is the most advantageous and fastest" namely to allow prefabrication of the roofing of the main naves of the company independently of other works, leaving the interior space free (Rêgo [1953], 13).

Other works with prestressed beams were, in this decade of 1950, planned to be undertaken in the short term in the city of Porto, among them the new Lapa telephone center and the construction of a warehouse to repair the STCP buses, among others.

This engineer, professor and industrialist, argued that the prestressed concrete construction would allow the transition between craft production on site and industrialization of the process, supported by the new construction model and pre-manufactured elements. Support for this idea is evident in Rêgo's article "*Industrialização de pavimentos em construção civil* [Industrialization of floors in civil construction]" where he pointed out how the great alternative in civil construction is the prestressed concrete joist because "it was the prestressed concrete that completely solved the problem of designing the most convenient types of prefabricated floors of industrial provenance (…) allowing also to obtain more resistant joists and reduce the height of floors" (Rêgo 1958). However, one of the obstacles to the industrialization of these prestress construction systems was the large investment necessary for the construction of industrial facilities, requiring large installations, "projects that can only be made possible by powerful industrial companies" (Rêgo 1958, 49). But António Teixeira Rêgo's voice in favor of prefabrication in civil construction was joined by that of Antão Almeida Garrett who, in the same year of 1958, published an article entitled "*A habitação prefabricada* [The prefabricated dwelling]" in the magazine of the Faculty of Engineering of Porto in which he emphasized the importance of industrializing construction in order to advance with a "comfortable, well-built dwelling, in sufficient quantity to provide and maintain a voluminous production" (Garrett 1958, 25). Both professors of the Faculty of Engineering pointed to the need to replace craft methods with prefabrication, because only this would allow control of the measurement of the pieces, the greater operationalization of the work and a rationalization of construction. To the engineers' voices we can add that of architects, like Arménio Losa, who at the first national congress of architecture in 1948, presented two papers with the same focus, "Industry and Construction" and "Architecture and the new factories" (Losa 1948a; Losa 1948b).

António Teixeira Rêgo died on 7 October 1967, a year before his death having founded, together with Júlio Ferry Borges, Aurélio Morujão, and Joaquim Sarmento, among others, the Portuguese Prestressing Group (still active), formed the Portuguese group of the *Fédération Internationale de la précontrainte*, being the main partner and belonging to the associate bodies (Pipa 2016, 5).

5 CONCLUSIONS

António Teixeira Rêgo is a protagonist in the history of construction of the twentieth century, and pioneer of prestressed concrete in Portugal. A student of civil engineering at the Faculty of Engineering of the University of Porto, he was of the first generations of graduates who received a theoretical and practical training, based on experimentation with processes and materials. Professor of Hydraulics since 1936, he came to develop his career as an engineer of structural calculations in reinforced concrete, participating in numerous projects. Based on archival documentation, since 1949, he liaised directly with the engineers who introduced prestressed concrete into Europe, a connection which allowed him to safely assume the use of prestressed concrete in large span beams in the construction of the cotton warehouse in Matosinhos. Surrounded by a group of engineers, he advanced the prefabrication of prestressed beams, with Freyssinet's patent, and was technical director of one of the first European companies dedicated to this constructive system – Precomate, Sociedade de Preconstrução de Materiais Lda (Figure 6).

Aware of the challenge of industrializing these processes, António Teixeira Rêgo shared through professional magazines, at the congresses in which he participated, and in seminars, the methods of E. Freyssinet, obtaining orders from large companies to optimize an investment that required large capital and large spaces for production. The importance of the relationship with Angelo Ramalheira must be mentioned – they even had an office in the same building, at Praça Filipa de Lencastre in Porto – and is a subject that requires further investigation.

The introduction of prestressed concrete created new construction practices and processes that, combined with horizontal property regulation, allowed the introduction of new building models responding to new cycles of city development and of civil construction industrialization. The development of this new process was the result of the study and testing by

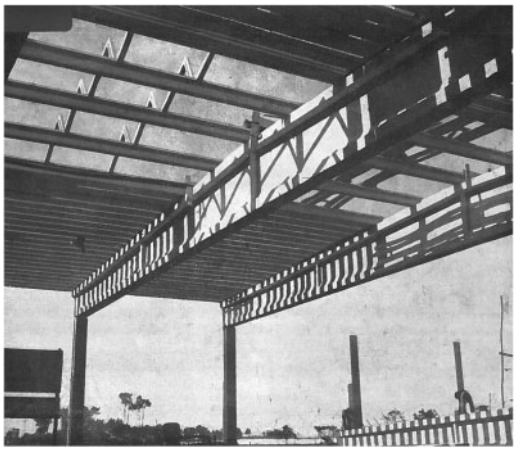

Figure 6. The Cotton warehouse in construction, with the prestored beams and the hollow slabs (Rêgo 1951a).

generations of engineers who had solid technical skills but also the ability to experiment and innovate in the context of design and execution of work.

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