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CIVIL ENGINEERING AND INSTALLATIONS

DOCTORAL THESIS

ABSTRACT

CONTRIBUTIONS ON THE BEHAVIOR OF SPECIAL CONSTRUCTIONS IN THE OIL INDUSTRY AND MEASURES TO INCREASE THEIR SUSTAINABILITY

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ABSTRACT

INTRODUCTION

A graduate of the Bachelor's degree program in Civil Engineering and Master's degree in Civil Engineering and Construction Management, with a deepening in the field of construction project management, and with a strong influence for the study and professional development given by the teaching staff of the Faculty of Construction of Ovidius University of Constanta, in 2019 Mrs. **prof. dr. prof. dr. eng. Ana Maria GRĂMESCU** finding out that I work in a top field of the industry, namely the oil industry, a field of processing, storage and transportation oriented my scientific concerns towards the special constructions intended for this industry in order to develop a research field that aimed at high-performance construction materials, high-performance technologies and high-performance protection systems, applicable to special constructions used in this industry.

I recognize that it was my field of activity, of professional concern and at the same time it has a desideratum of a whole management system implemented in the Petromidia platform.

Taking note of the trends and demands of European policy in the industrial field as a whole and in particular in the oil industry, appreciating that I am at the maturity of thought and a rich baggage of knowledge in the field of civil engineering I gladly received the suggestion of **Prof. prof. univ. dr. eng. Ana Maria GRĂMESCU**, that in the framework of the doctoral research program I should deal with special constructions in the oil industry, their behavior over time, detecting deficiencies, inadvisabilities, but also optimization aspects aimed at adopting measures to increase sustainability.

The structuring of this research project under the guidance of my PhD supervisor, together with the mentoring committee, instilled in me during the 5 years of doctoral study, passion, ambition, dedication, the results of the research being effectively applicable in my field of activity.

Now after going through the research program, the satisfaction of the results obtained, the way of interpreting and disseminating the research, I once again thank **Prof. Prof. dr. dr. eng. Ana Maria GRĂMESCU**, along with high feelings of gratitude for her total support along this path. At the same time, I sincerely thank for the guidance given to the professors of the tutoring committee**, Prof. Prof. Dr. Dr. Eng. Anca Constantin, s.l. dr dr ing Sunai Gelmambet,** the entire teaching staff of the Faculty of Constructions of Ovidius University of

Constanta, as well as **Mr. cert dr eng. Ionescu Marcel**, director SC EUROPLASTIC SRL Bucharest.

In particular, I would like to express my thanks, appreciation and gratitude to the team where I work, CIRASICO SRL company, its management **Mr. Serghei Antonevici**, for the understanding shown throughout the research process, for the support during this process and also for the assigned case studies, taking intervention measures and decisions in their maintenance and resolution.

All these aspects recorded above have contributed to the consolidation of my engineering knowledge and have made me take up this profession in the garb of fairness, dignity and high professionalism**.**

Before concluding this word of commencement, I confess that I have had an exceptional support from my husband, children, parents and the entire family who have supported me, encouraged me throughout the entire doctoral research program and have enlivened my soul and my hope of success by surrounding me with support, dedication, love throughout this journey towards completion, towards success and to whom I offer my sincere thanks expressing my high respect and gratitude.

02.09.2024

Drd ing Corina Ramona Grigoraș

ABSTRACT

DOCTORAL THESIS

CONTRIBUTIONS ON THE BEHAVIOR OF SPECIAL CONSTRUCTIONS IN THE OIL INDUSTRY AND MEASURES TO INCREASE THEIR DURABILITY

This doctoral thesis represents the results of the research, methodology and interpretation of the research carried out during the project with the following objectives:

- Correct diagnosis of special constructions, materials and technologies of realization with identification of risk factors;
- Identification of techniques and methods to increase their durability;
- Analysis of modern materials and technologies applicable to constructions in the petroleum industry, i.e. special storage and transportation constructions;
- Dissemination of research results;
- Knowledge development and identification of new research directions.

Within the doctoral research program we particularly followed the constructions related to the oil industry located on the Midia Navodari platform, analyzing the behavior of both reinforced concrete and metal constructions, as well as the importance of the nature of stored liquids on the duration of operation. The aim of this research has been to identify the destructive factors leading to premature degradation of buildings, as well as to investigate modern materials and technologies capable of increasing the durability of buildings, and hence their service life. In addition to the operating conditions and the ambient environment, the unfavorable factor of these constructions is the aggressiveness of the marine environment in conjunction with the effects of climate change.

The entire research was carried out taking into account the importance of the oil industry in Romania, as well as European programs aimed at reducing emissions and optimizing manufacturing processes. At the present stage, the Romanian government has the obligation to modernize and secure the national system for transporting petroleum products, to make investments capable of increasing operational safety and reducing specific consumption.

Another important task in Romania's policy is the development of storage capacity, modernization of storage related constructions, elimination of environmental problems by investments in greening.

In this context, the thematic of the research project, developed the concept of building material protection concomitantly with the increase of material quality in order to obtain both materials

with increased resistance and modern technologies applicable in the maintenance of existing buildings.

The research program highlighted the factors that lead to the decrease in the serviceability of oil industry constructions and at the same time identified intervention solutions, new solutions that can lead to outstanding results.

The research results were disseminated in the presentation of two research synthesis reports, three articles published in recognized journals and a fourth one in the process of being published, in the publication of a book chapter entitled "Construction in the face of climate change", as well as in presentations given in workshops at the Faculty of Construction. At the same time, in the XGEN 100 competition, 7th edition, I was awarded third prize with the theme "Adapting the construction quality system to the requirements and demands of the oil industry".

The research has identified new directions that can be pursued by other young people in future doctorl research programs.

A particular experimental application was the analysis carried out at EUROPLASTIC SRL which identified membrane-type solutions, colored or colorless, capable of protecting metal constructions from both high temperatures and corrosion. The research has shown that in the structural analysis of these constructions the dominant element is the correct and real diagnosis of the state of degradation. Based on the diagnosis, the doctoral thesis highlights the degrees of vulnerability according to which the specialist can decide the necessary intervention solution.

From the multitude of constructions of the petroleum industry, the research addressed the constructions necessary for the storage and transportation of processed products (synthetic products resulting from refining).

In the research project, starting from the above-mentioned aspects, we have studied the level of knowledge at national and international level. The studies carried out have highlighted the fact that Romania has an old tradition in crude oil processing, being the first in the world to have discovered the industrial procedure of oil processing at the beginning of the 19th century. Also in the research carried out, we found that Romania has an outstanding industrial heritage in the field of the oil industry (Câmpina Refinery), which proves the high level of training in this field.

The research carried out in the doctoral program has shown that the oil industry has evolved from a small industry localized in a few regions to a global, complex and important industry for the world economy. The research carried out in conjunction with European policy has shown that the main direction in this field is to promote the competitiveness, self-sufficiency and resilience of the sector, which in the future will be based on climate neutrality and digital leadership.

Modern technologies leading to$_{CO2}$ neutral processes are being promoted in the European Union. This is based on:

- Strengthening resilience

- Addressing strategic dependency

- Accelerating the green and digital transition.

Resilience, refers to having a single market able to respond to crisis situations.

Strategic Autonomy is based on supporting industrial oil alliances and monitoring dependent factors.

The green pact's industrial plan is about promoting zero-emission industrial policies. respectively climate neutrality.

Starting from these missions, the research program focused on the main components that are Romania's responsibility in the current context.

The PhD thesis is structured in 9 chapters.

CHAPTER 1 presents the theme of the research program, its importance and the objectives of the project, as well as the state of knowledge both internationally and nationally, the doctoral student having the opportunity to analyze in detail both known and less known elements.

Today, the oil industry is one of the largest and most complex industries in the world, helping to power global economic structures and meet the growing demand for fossil fuels. However, today the oil industry faces many challenges, such as climate change, depletion of natural resources and political instability in oil-producing regions.

The Romanian Government in the immediate next stage has proposed to realize investments in important companies for sustainable and efficient management of mineral resources, in which sense the regulation of geological storage of carbon dioxide becomes an obligation.

Taking into account these aspects as well as the existing applications in Romania in oil transportation and storage, the behavior of concrete or metal structures becomes of major importance. The need to study the behavior of concrete, its protection as well as that of metals, and the application of the most appropriate protections is a particularly important measure.

Starting from these aspects presented above as well as from the fact that the PhD student is working in the field of special constructions for the oil industry with reference to constructions for storage, storage and transportation of petroleum products, the research project aimed to carry out studies on the behavior of constructions intended for storage and transportation of petroleum products, measures to increase the durability of these constructions by:

- Materials with increased resistance;
- Construction systems to which durable protections are applied.

The research carried out within the doctoral program aimed to synthesize the research results in two reports:

- Behavior analysis of constructions in the oil industry.

- Modern materials and technologies applicable to constructions in the oil industry in order to improve operating conditions.

The objectives of the research program were:

- Correct diagnosis of special constructions, materials and technologies of realization with identification of risk factors;
- Identification of techniques and methods to increase their durability;
- Analysis of modern materials and technologies applicable to constructions in the petroleum industry, namely special storage and transportation constructions;
- Dissemination of research results;
- Developing knowledge and identifying new research directions.

During the doctoral research program we followed the existing constructions in the Midia-Năvodari platform, we applied different techniques and work procedures, we carried out a research internship at one of the companies with research activity in the field of chemical industry with the analysis of materials that can protect special c1.2onstructions in the oil industry from high temperatures. Depending on the state of degradation of these constructions we investigated ways of rehabilitation, protection and safe operation. The protective films studied to be placed on the outside of the tanks storing viscous petroleum products are designed to protect the optimal storage temperature, products that have been tested in SC EUROPLAST SRL by researcher dr. eng. eng. Ungureanu Valentin from Transilvania University of Brașov and PhD supervisor prof univ dr. dr. eng. Grămescu Ana Maria, the research results being presented within the EUREKA project. At the same time, the research methodology also included the SCIA analysis of the study of the structural depreciation of a petroleum products tank in order to establish the most effective rehabilitation measures. The applied research methods were finalized with concrete proposals for interventions by using new, efficient materials and their dissemination.

The Government of Romania in the immediate next stage has proposed to realize investments in important companies such as:

- modernization and securization of the national crude oil and derivatives transportation system, investments aimed at increasing operational safety and reducing specific consumption;
- development of storage capacity in warehouses, expansion and increase of loading/unloading capacity for crude oil, petroleum products, chemical and petrochemical products as well as other finished products and liquid raw materials, modernization of storage and transport related constructions, tanks, pipeline network, elimination of environmental problems by investments in greening;
- realization of partnership actions for new power generation capacities;
- realization of a combined heat and power plant, photovoltaic panel park;
- realization of a photovoltaic power plant,

As it can be seen, one of the priority programs of Romania is related to the development of storage capacity in warehouses, expansion and increase of loading/unloading capacity of crude oil, petroleum products, chemical and petrochemical products as well as other finished products and liquid raw materials, modernization of buildings related to storage and transport of tanks, pipeline network, elimination of environmental problems by making investments in greening.

The doctoral research project comes in the thematic of this program by modernization of constructions related to the storage and transport of tanks, pipeline network, elimination of environmental problems by making investments in greening.

A brief history of the oil industry is presented in **Chapter 2**

The oil industry was one of the first industries to revolutionize the modern world. The discovery and exploitation of oil had a major impact on the global economy, society and politics.

The beginnings of the oil industry can be traced back to the 19th century, when the first commercial oil exploitations were developed in the United States and Europe. The discovery of the first oil deposit at Titusville, Pennsylvania, in 1859 marked the beginning of the oil industry boom, making oil one of the world's most important natural resources. In the 19th century, oil was extracted from the ground by hand using rudimentary equipment. In later years, extraction and refining processes improved significantly and the oil industry became one of the most profitable in the world.

The exploitation of oil in Romania dates back to Roman times and refining began with the need for distillate products. The first distilleries in Romania appeared in 1840 in Lucăcești, in the county of Bacău. Processing was done exclusively by hand, in rudimentary boilers, and production was very low. In the second half of the 19th century, the first refineries equipped with modern installations came on stream.

Fig. 2.2.1 Moreni workshops in the early 20th century

The first refinery was built in 1857 in Rafov, near Ploiești, by Teodor Mehedințeanu.

In 1857 Mehedințeanu started the first gas factory in Ploiești, which was the first in Romania and in the world. In the beginning it was a refinery with simplistic equipment and construction, but it was a big step towards civilization.

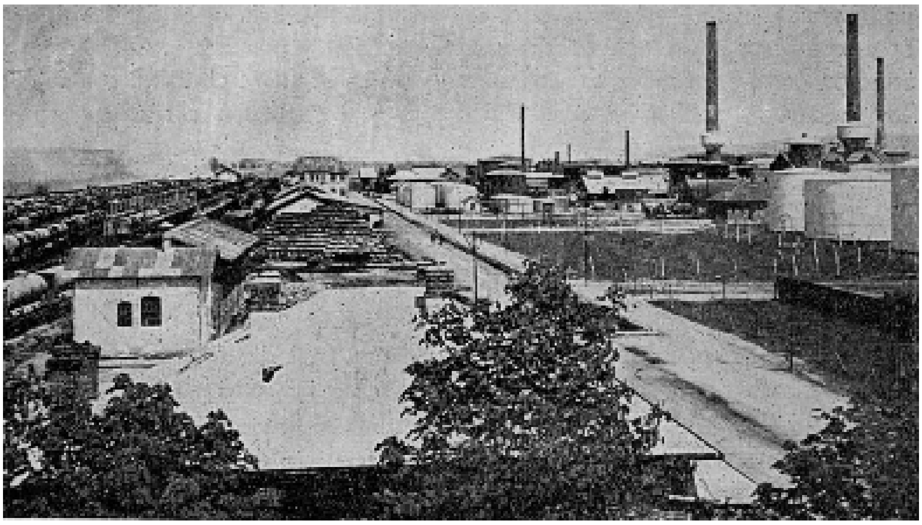


Fig. 2.2.2 Rafov refinery on the right side you can see the storage tanks

Fig. 2.218 Refineries in the Ploiesti area after World War II

Product storage tanks

This refinery obtained, on the basis of a contract concluded in October 1856 with the Bucharest City Hall, the right to supply electricity to the capital.

Romania had ten refineries in 1989, five of which accounted for 85% of the country's total refining capacity: Petrobrazi Ploiesti, Arpechim Pitesti, Petrotel Ploiesti, Petromidia and

RAFO Onesti. The remaining 15% of production was accounted for by Astra Ploiesti, Vega Ploiesti, Steaua Română Câmpina, and the Dărmănești refinery.

Currently the largest refinery is Petromidia Năvodari.

Chapter 3 is devoted to the presentation of the specific constructions of the oil industry, their structural compliance and their classification.

The constructions related to the petroleum industry include: extraction specific constructions, processing specific constructions (refineries), storage specific constructions, transportation specific constructions. The category of constructions for petroleum extraction includes: offshore platforms and onshore extractive structures.

3.1. Extraction constructions

3.1.1 Offshore or marine platforms - these are large structures that are placed on the seabed to extract oil and natural gas from the deep sea.

Offshore platforms are structures built to carry out exploration and production of marine resources, such as oil and gas, offshore. These platforms are made of steel and concrete and are designed to withstand the harsh conditions of the maritime environment, such as strong winds, high waves and corrosion.

From a construction point of view, offshore platforms are designed to withstand high operating loads and extreme conditions of the maritime environment. These structures are made of steel or concrete and are built to be as rigid and stable as possible.

Piles are used to secure offshore platforms to the seabed and to ensure their stability in the face of natural forces such as strong winds and large waves. In addition, the platforms are equipped with control and safety systems to prevent incidents and ensure the protection of personnel and the environment.

Concrete structures of marine platforms are generally considered as those structures exposed to the marine environment. They are designed and executed to remain permanently or semi-permanently fixed to the seabed by gravity, piles, or anchors or floating

3.1.2. Types of offshore concrete platform structures

Marine structures used for hydrocarbon exploration can generally be grouped as either sea-bottom or floating. Many of the structures founded on the seabed are designed to float at various stages of their exploitation.

Gravity-based structures, also referred to as GBS, maintain their position on the seabed due to their great weight. The sliding force and the overturning moment due to the maximum loads given by the surrounding environment are compensated by the weight of the structure, the payloads of the structure. This type of structure is applicable in situations where the extracted oil has to be temporarily stored for later retrieval by an oil tanker or pipeline. The practiced depth for the solution of such platforms is between 40 - 350 m. These structures are built on land or at the quay and then floated to the designed site.

Modern concrete marine platforms are designed with sufficient redundancy to withstand major accidental loads. Concrete has exceptional impact resistance and only a few isolated cases of structural failure due to ship impact have been reported. Sufficient ductility in the concrete structure may be required to eliminate the problem of progressive collapse. The fire resistance of concrete is well known, as concrete is often used to protect steel in many major constructions.

Floating concrete structures are designed for stability to failure of a compartment, which means that any local failure that causes seepage into the casing will not cause any risk to the floating structure.

Even though they are associated with hydrocarbon exploration and production, they can have many other specialized uses.

Most offshore platforms have a lifespan of 20 years. Because of their location, they are complicated to rehabilitate if problems arise. To eliminate possible high repair costs, the materials used, the concrete used must be of superior quality.

Durability of concrete for marine structures is defined as the ability of a material to withstand the actions of weather, climate change, chemical aggression, abrasion as well as any other deterioration process while maintaining its original shape, quality and capacity as a result of being subjected to environmental conditions. This includes resistance to deterioration due to freezing and thawing, chemical aggression of the sea, wave, floating body or debris forces, floating ice, corrosion of steel or other metals embedded in concrete and chemical reactions associated with concrete aggregates. When all of this damage is taken into account, it is easy to deduce that the most aggressive exposure to which concrete is routinely subjected is frozen water from wave forces. For most marine structures, the most important destructive action is corrosion.

Portland cements should contain as little tricalcium aluminate (C3A) as possible. This helps reduce the possibility of sulfate attack. The total cement alkalinity, calculated as sodium oxide should not exceed 0.60% to minimize any potential reactivity with aggregates. This includes thermal power plant ash, granulated slag or silica dust. These products contribute to a denser mix, increase impermeability and prevent water migration into the concrete.

3.2. Buildings for the processing of petroleum products

Petroleum refineries are large industrial facilities that process crude oil to produce petroleum products such as gasoline, diesel and kerosene.

The concrete and metal structures in a refinery are essential to ensure the stability, safety and efficiency of refinery operations. These structures are carefully and expertly designed and constructed to ensure the proper functioning of the refinery and to minimize the risks associated with petroleum activities.

Concrete and metal structures in a refinery

3.3. Storage buildings

3.3.1 Reinforced concrete structures:

For administrative or control buildings in the refinery, such as laboratory or process control buildings, reinforced concrete structures are used to ensure their stability and strength.

Reinforced concrete buildings are designed and constructed in accordance with safety and environmental standards, ensuring that they are capable of withstanding different operating conditions and withstanding possible incidents or accidents.

As is known, in the petroleum industry, constructions are both underground and above ground. In this paper I propose to detail all categories of constructions subject to aggressive factors.

Tank foundations are concrete elements that take the stresses transmitted by both the actual weight of the reservoir and the liquid stored in it. It is necessary, when designing tank foundations, to pay particular attention to the type of foundation.

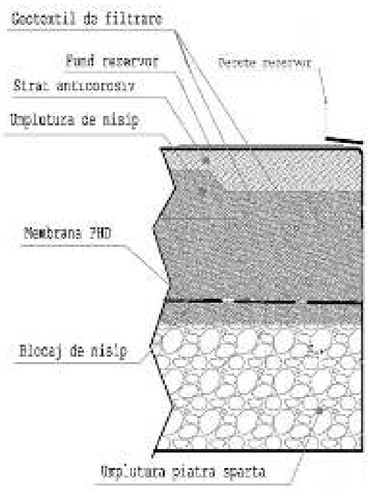


Fig. 3.1 – Foundation on normal elastic post

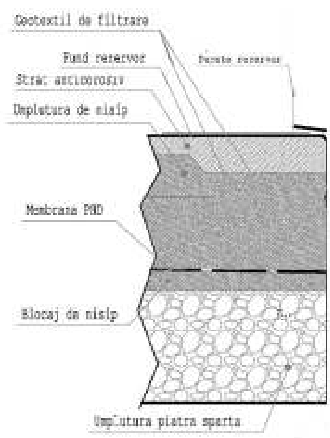


Fig. 3.2 – Foundation on high elastic post

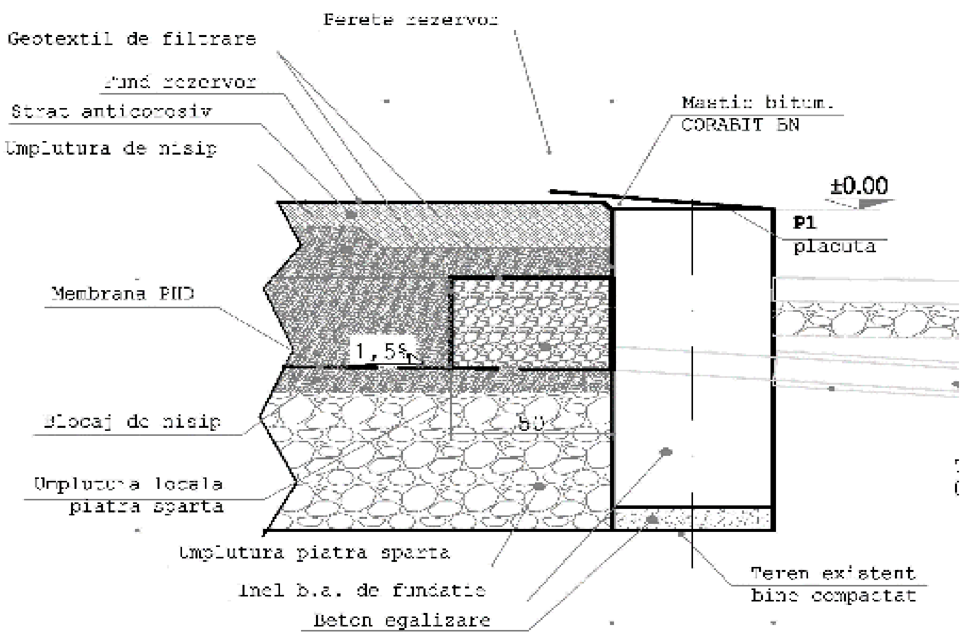


Fig. 3. 3 - Elastic post foundations with concrete ring

3.3.2. Storage stations / storage platforms

Storage racks are suitably constructed areas intended for the storage of oil and petroleum products for storage and onward transmission to processing racks. The facilities in which petroleum products are stored are called petroleum storage tanks or depots. They are usually made of steel, reinforced concrete or other corrosion-resistant material and are equipped with safety and control systems to prevent spills or fires.

Oil storage tanks are generally large steel or concrete structures that are used to store oil extracted from deposits before it is processed in refineries or transported. These tanks must be designed and constructed to resist corrosion from aggressive chemicals in the oil, the action of hydrocarbons that can damage the tank structure, and the aggressive environment in general.

Over time, constructions in the petroleum industry can be subject to wear and deterioration due to exposure to external factors such as water, corrosion, extreme temperatures and mechanical action. Therefore, periodic maintenance and regular inspections are essential to ensure proper operation of equipment and prevent accidents or breakdowns. To prevent wear and damage to equipment in the petroleum industry, it is necessary to carry out regular maintenance, including checking and replacing worn or corrosion-damaged components, lubricating moving parts, cleaning the filter and cooling system, and monitoring temperature and pressure gauges.

3.4. Transportation constructions

Transportation facilities are pipeline-type systems that transport crude oil or other by-products and natural gas. They provide transportation from extraction sites to refineries and to loading terminals. They can be visibly mounted, on booms or buried.

- Pipelines in the petroleum industry are essential components for the efficient and safe transportation of fuels from extraction or refining points to distribution or consumption sites. These pipelines are made of corrosion and pressure resistant materials, such as steel or aluminum, and are designed to withstand extreme temperature and pressure conditions.

- Pipeline construction in the petroleum industry involves several stages including design, manufacture, installation and maintenance. Pipeline design is crucial to ensure efficient and safe operation, and this includes determining routing, diameter and other technical specifications.

- Pipeline manufacturing involves the production and assembly of component parts, followed by testing and inspection for quality assurance. Pipelines are usually installed by digging a trench or using drilling techniques to insert the pipes into the ground or water. They are secured using various anchors and are constantly monitored to prevent leaks or other safety issues.

- Maintenance of pipelines in the oil industry is essential to prolong their service life and prevent accidents. This involves periodically checking the integrity of pipelines, repairing or replacing worn or damaged parts, cleaning and degreasing them and other measures to prevent corrosion or other damage.

- Pipelines in the petroleum industry are constructed with great attention to detail and are under constant supervision to ensure efficient and safe transportation of fuels. Their design, manufacture, installation and maintenance are essential for the proper functioning of the entire system.

3.5. Pumping stations are specific to refineries and are facilities that pump crude oil and natural gases and ensure transportation to refineries.

Pumping stations in refineries are essential components of the petroleum refining process as they are responsible for the transfer of fluids during the various stages of the process. These pump stations are designed with a number of key features from a construction engineering point of view, such as:

- Reliability

- Energy efficiency

- Safety

- Maintenance and service facilities

Refinery pumping stations are a vital element of industrial infrastructure and are carefully designed to ensure reliability, energy efficiency, safety and ease of maintenance.

CHAPTER 4 deals with the concept of durability of special constructions related to the petroleum industry, their ability to maintain their properties and functional performance throughout their service life under specified environmental and operating conditions.

Durability is the basic requirement of a construction in which it maintains the necessary requirements for normal operation. The European Union's current zero-emission policy imposes industrial, economic and geopolitical shifts worldwide. In the context in which the European Union has to respond to these developments, it is incumbent on the Member States to take measures in the field of climate change and energy transitions, which will have a considerable influence on the sustainability of buildings.

In recent times, sustainability has been discussed in terms of materials, technologies and the environment. The environmental sustainability is ensured by the successive procedures related to industrialization.

In this paper the author aims to detail sustainability as a phenomenon specific to the materials used for oil industry constructions with reference to storage and transportation constructions. As it is known, the two most commonly used materials are reinforced concrete and metal constructions, while composite materials are also used for small capacity constructions.

This notion is closely related to other key indicators such as safety and quality, both of which have a significant impact on construction practices. Safety refers to the set of requirements that must be respected in the design and execution of a construction in order to prevent damage caused by various external or internal actions. Quality, on the other hand, is defined as the desired level of excellence, referring to the specific characteristics that a project aims to achieve.

In engineering and construction, construction safety is inextricably linked to the concept of quality, and quality is usually measured by the probability of operation without defects or failures over a given period. Durability, given the time factor, becomes a fundamental aspect of quality, emphasizing the importance of maintaining the performance of a construction throughout its lifetime.

Durability can also be interpreted as related to the service life of buildings, which varies according to the materials used, environmental conditions and regular maintenance. A sustainable construction is not only resilient and able to withstand the challenges of time, but also includes aspects of sustainability, energy efficiency and environmental impact, thus contributing to responsible urban development. Sustainability is thus becoming a central pillar in civil engineering, engaging designers and engineers to create innovative solutions that ensure long-term usability and minimal environmental impact.

Depending on their severity and complexity, the impairments that a reservoir may suffer over time can be sensed/detected by direct observation and inference. Thus, noise can be heard through the senses. You can see corrosion and cracks, deformations, tears and separations. You can smell gas fumes. You can feel and/or see surface roughness and feel vibrations. Sensing phenomena, however, is subjective and qualitative assessment is descriptive. Depending on the nature and the specific nature of the phenomena detected, quantities are used for the quantitative assessment of the observed impairments, i.e. dimensions in plane and space, volume, humidity, speed, mass, weight, temperature, frequency, etc. By measuring quantities, more accurate comparisons can be made than by simply assessing the quality of the phenomena detected, which is generally subjective. Each phenomenon has at least two quantities. The quantities that are of decisive importance in defining phenomena are called parameters.

Essentially, the interaction between a reservoir and its external environment consists in the emergence and development of certain phenomena to which quantities are assigned. Those that are important in defining the phenomena are called parameters. Thus, the behavior of a reservoir is assessed by means of phenomena, quantities and behavior parameters.

Behavior properties and performance

In tracking the in situ behavior of any reservoir, behavioral properties are used. The property being the attribute of a material entity, whether it is at rest or in motion, to bring out those elements by which it can be characterized in order to know it. The behavioral properties of any reservoir are revealed by the reservoir-environment interaction, but also by the connection between the materials of which the reservoir is composed, i.e. by itself. For example, permeability and/or porosity may be noticeable when interacting with a liquid. Behavioral properties may relate both to specific physical-material parts of the container and to its functions. In practice, behavioral properties may refer to both function and structure.

Service life

The period of time between the start of construction works on a reservoir and its voluntary/accidental destruction is called the lifetime of the reservoir. During its lifetime any reservoir goes through the following phases:

- realization,

- operation in accordance with its stated function,

- conservation, where applicable,

- decommissioning, which is accompanied by the recovery of reusable/recyclable or non-recyclable parts,

- voluntary demolition/destruction.

The most important phase is operation, as this is the purpose for which the reservoir is built. In essence the in situ behavior of a reservoir is the expression of its behavioral performance.

Fitness for service

The purpose of any construction work is to satisfy the need for which it was designed and built, under the conditions and for the time period for which it was designed and built. The ability of a reservoir to satisfy, through its behavior in service, the user's requirements is its fitness for service. Satisfaction of the user's requirements in service is in practice the primary aspect of quality in construction.

In essence a tank performs well if safety requirements and cost efficiency requirements are met. Safety requirements are essential and imperative. They relate/are directly related to minimizing the risk in terms of loss of human life, damage to human health and integrity, damage to human health and safety, and damage to property. Tanks and related equipment and fittings must be designed-built-operated in such a way that the user is confident, preferably even certain, that they are not and will not become a potential threat and that all possible measures have been taken to minimize the risk of accidents-incidents-damage. Cost-efficiency requirements are aimed at minimizing all types of expenses throughout the period of use.

Impairment of fitness for service

The deterioration of the fitness for service of a container may be caused by a worsening of an original defect, i.e. a pre-existing cause, or it may be caused by physical wear, degradation over time, accidents, incidents, technical or other malfunctions. Thus, a container may:

- Defect. Failure is the consequence of an error. The purpose of any construction work is to finally create a structure, which by its function-functions is able to satisfy all the needs-requirements-requirements of the user. Uncertainties and/or unknowns may or may not manifest themselves at a given moment during the stages of identifying the need for thinking, designing and realizing any construction work. The behavior of the construction during the operational period is conditioned and determined by random factors, which intervene during the fundamental stages of its design and implementation. To these are added the random factors that occur during operation, monitoring and maintenance, with all the possible risks involved in maintaining the quality of the construction.

- Degradation is a slow process by which reservoir performance alters over time. It is caused by physico-chemical changes. During the operation of a tank these changes occur due to the interaction of the tank with the external environment. Any reservoir over time degrades in any part/at any point of it. Degradation being a natural and continuous process throughout the lifetime of any material thing. Degradation can be faster or slower. In practice, over time, deterioration of the technical condition of any reservoir occurs, which manifests itself in concrete terms in the depreciation of its qualities. The degradation of a reservoir can in most cases be predicted on the basis of knowledge of the evolution of phenomena and causes, the laws according to which they develop and experience. For example, the most common degradation of metal tanks is corrosion, which is the consequence of corrosion. Other common examples of degradation of metal tanks are erosion, fatigue, change in shape, change in geometry, staining of the metal and even cracking.

- Malfunctions. Malfunctions in the operation-functioning of a tank, i.e. malfunctions of functional qualities. For example, partial or total blockages of outlet or communication openings.

- Accident. An accident is by definition an unforeseeable event which interrupts the natural course of things. In the case of tanks, technical accidents are the sudden deterioration of one or more of its parts and/or components or even of the whole tank and/or the installations and fittings serving it. There are also exceptional situations where one or several tanks may be involved in accidents of different natures. However, as far as technical accidents of tanks are concerned, these situations are foreseeable and can be prevented by proper and regular monitoring in accordance with the standards and the designers' instructions, by being aware of defects or advanced states of degradation and, last but not least, by experience in operation. For example, burst valves, loss of stability, differential subsidence, cracking of the wall.

- Damage is by definition a significant, even important, deterioration, which also interrupts the natural course of the operation of the tank in question. Constructive, technical or functional accidents may be the cause of a technical failure. It is most often necessary to take part or several or even the whole tank out of service for a limited period of time. as a result of constructive, technical or functional accidents. This results in a progressive or rapid decline in the behavioral qualities of a tank.

In essence, the deterioration of fitness for service significantly shortens the service life, especially if the necessary monitoring and/or interventions are not carried out through measures to maintain and/or restore the original qualities and suitability of a reservoir, and even through improvements. Thus, interventions are maintenance and rehabilitation.

The mechanisms of deterioration of **reinforced concrete** are:

- concrete corrosion,

- corrosion of concrete reinforcements,

- concrete frost,

- fatigue of concrete elements,

- concrete surface erosion.

In **CHAPTER 5** I refer to the behavior over time of constructions intended for the petroleum industry, an aspect carefully researched and analyzed, taking into account the extreme operating conditions, exposure to corrosive substates and intense mechanical stresses that can accelerate the degradation processes.

5.1 General elements

Construction and infrastructure play an important role in each country's economic development and growth. The oil industry is a sector that contributes to Romania's GDP growth. Investments in this sector are made in the long term, when an increase in production or storage/storage capacity is desired, rehabilitation works and new constructions are necessary to modernize or maintain storage capacities for the products obtained in the refineries. These investments are correlated with the evolution of the refinery's raw material processing parameters and help to increase operational safety. The performance of petroleum industry buildings over time is influenced by a wide range of factors including the environment, materials used, design and maintenance. Constant attention in the management and monitoring of these structures is crucial to ensure safe and efficient industrial operations.

5.2 Performance over time of oil industry constructions

The behavior over time of oil industry buildings is related to the specific conditions in which these structures operate. Key aspects related to this topic are:

1. Maintenance and Durability factors (corrosion, material fatigue)
2. Structural Performance Assessment (monitoring, periodic inspections)
3. Environmental impact and deformations (landslides, thermal deformations,
4. Design and Materials
5. Regulations and Standards
6. Specific Challenges (material degradation, natural phenomena)

New tank constructions are designed with double jacketed, vertical hydrostatic tank in welded construction. The double jacket acts as a holding tank. The tanks shall be constructed with all necessary measures for safe operation and shall be provided with all necessary facilities for their integration into the technological flow of a refinery for normal or emergency operation, including process and utility piping, autimatization equipment, safety systems, utilities and fire intervention, monitoring systems. New piping is intended to minimize losses.

The concrete used in these constructions must be resistant to the aggressive action of hydrocarbons/petroleum in the various stages of decomposition that attack the concrete composition.

Concrete is the result of a mixture of the following materials: cement, aggregates of various sizes and water. In certain situations, additives and/or admixtures may be added to improve the homogeneous mixture called concrete by hydrating the cement.

The following defects in the appearance and integrity of reinforced concrete elements are permissible:

- surface defects (pores, surface segregation or local unevenness)
- defects in the cover layer of the reinforcement (local bumping, segregation),

The durability of concrete is influenced by the degree of exposure and the cement content. In the operational context, reinforced concrete constructions are subject to the action of liquids, gases and solids. Alkaline substances have a negative impact on the durability of concrete, that is why it is recommended to use a concrete with a higher density, it will resist the effects of moisture penetration much better. Let's not forget that concrete is a porous material that quickly absorbs moisture from the air, so even the component elements (concrete reinforcing bars) can be subject to corrosion if safety measures are not taken.

Fig 5.1 Pylon pole with a cantilevered bracket

Fig 5.2.
Column with explolished concrete cover

Fig. 5.3 Corroded sheet protection (source author))

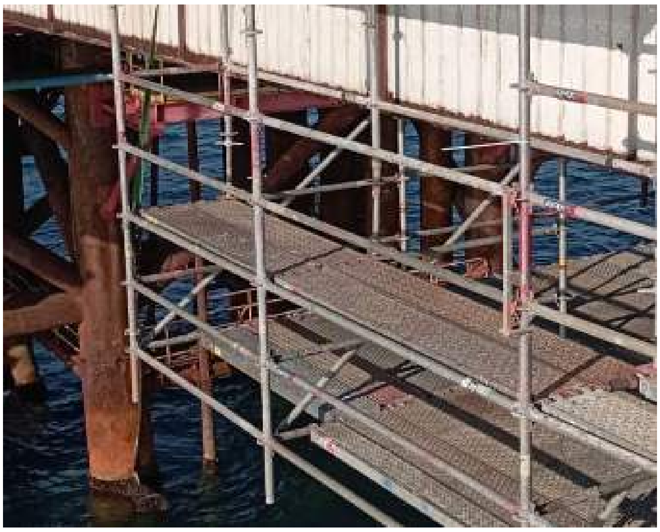


Fig. 5.4 Metal structure of the Black Sea marine platform (source author)

Fig.5.5. Metal structure of the Black Sea marine platform (source author)


Fig 5.6, 5.7 poor technical condition of pipelines (source author)

Fig 5.8 Poor technical condition of pipelines (source author)

Fig 5.9 Pipeline refurbishment (source author)

Concrete surfaces in direct contact with the ground or air are painted with cement slam - aracite. The composition shall be 96 percent cement and 4 percent aracite, and the consistency shall be fluid plastic.

The substrate as a general rule shall be concrete of minimum grade C20/25, at least 14 days old, smooth, clean, free of grease or oil stains, and free of loose parts. Segregated areas of concrete shall be previously repaired and sealed with cement mortar.

Mixing shall be accomplished with an electric mixer on low speed until a fluid plastic consistency is obtained.

Tank

After validation of the hydraulic test, the tank shall be prepared for the application of exterior and interior corrosion protection.

1. Tank exterior

On the exterior, the following elements of the tank shall be protected:

- the jacket

- the cover of the lid

- connections and manholes.

For the realization of the anticorrosive protection on the outside of the tank, the corrosivity category (according to SR EN ISO 12944): C5-M.

The tank painting system consists of:

- sandblasting - Sa 2 1⁄2;
- 2 coats (of 60 µm each) - Zinc phosphate epoxy primer (final dry coat 120 µm);
- 2 coats epoxy enamel (60 µm dry coat thickness). Total dry coat thickness - 240 µm.

After the application of anticorrosive protection on the outside of the bottom - sleeve joint, it will be additionally protected (on the outside) by the application of a mastic type protective material, water-repellent, UV resistant, resistant to temperature differences. The mastic shall be compatible with the anticorrosive protection applied.

1. Tank interior

The following elements of the tank interior shall be protected:

- Tank bottom:
- Tank bottom + 1.5m of mantle (at the bottom of the tank);
- Blasting - Sa 2 1⁄2;
- 2 coats of primer (60 µm each) - epoxy primer (final dry coat 120 µm) - the primer must be resistant to the stored product;

Epoxy paint (thickness 100 µm) - the quality of the paint must be in accordance with that of the primer and must be resistant to the stored product. Total dry coat thickness - 220 µm.

- Coating:

- Lid sandblasting + 1.5m of mantle (at the top, inner side of the tank) - (including the metal construction elements of the lid resistance)
- Sandblasting - Sa 2 1⁄2
- 2 coats of primer (60 µm each) - epoxy primer (final dry coat 120 µm) - the primer must be resistant to the stored product
- Epoxy paint (100 µm thick layer) - the quality of the paint must be in accordance with that of the primer and must be resistant to the stored product. Total dry coat thickness - 220 µmStalpul central se protejeaza anticoroziv (inclusiv la baza interior);

Access and service metal construction

The metal access and service metalwork (spiral staircase, access platform on cover, service platform on light shaft) shall be primed and painted as follows:

- Sandblasting: grade Sa 2 1⁄2 according to SR EN ISO 8501-1;
- Degreasing;
- 1 coat primer G 3282 (thickness 80 µm);
- 2 coats paint conventional colors, thickness 50 µm/coat.

METAL CONSTRUCTIONS

Metal constructions (pipe supports, brackets, etc.) supporting metal structures (other than those on the mantle)

Current manway railings, metal beams supporting decks and stairs, except vertical ones.

The paint must comply with the RAL provisions.

5.3 Protection of metal constructions

In the execution and erection of the metal construction, the provisions of GP 121-2013 "Design and Execution Guidelines on Corrosion Protection" shall be observed.

Corrosion protection is determined according to the aggressiveness class of the environment and the mode of action of the corrosive agent. The choice of the solution is also conditioned by the way in which the corrosive medium acts on the material: continuous immersion in corrosive solutions; spraying with corrosive solutions; vapors, aerosols, air-borne corrosive droplets.

Before applying each coat of paint, check that the application conditions specified in the technical documentation of the product, object temperature, dew point and humidity are met.

For the application of protective coatings, there are two important factors to be considered, namely: substrate condition and surface temperature.

In terms of the thermal and hygrometric conditions during application procedures application procedures shall not be performed if:

- The effective air temperature is below the lower drying or curing line of the coating

- Fog, rain or snow conditions are imminent

- If the surface to be painted is damp due to condensation or if condensation occurs during the initial paint drying period.

The choice of the application techniques used is made according to the requirements of the project, geometry of the workpieces, required durability of the corrosion protection system, etc.

Through the research project I also intend to study the quality of some materials suitable for the realization of these constructions, with reference to special concretes, which by their composition can ensure a higher durability of this category.

Anti-corrosion protection of concrete and metal has belonged to the corrosion process. Corrosion is a process of alteration due to external factors such as humidity, oxygen, etc. It attacks the superficial layer on the surface of piles/foundations/ columns. Corrosion protection is the totality of measures taken to protect the surface of concrete that comes into contact with aggressive factors.

The preparation of a quality concrete consists in the use of conforming and quality materials and attention to the quantities. Using concrete of the right quality is the simplest method of protection.

Concrete can be protected against this damaging influence by covering it with a film within the first 24 hours after pouring.

If the concrete is damaged, protective measures must be taken.

The vulnerability of buildings is an important factor directly influencing the ability of structures to withstand different types of stress, which is detailed in **CHAPTER 6** entitled 'Vulnerability and criteria for assessing the degree of vulnerability of petroleum industry-related buildings'

6.1. General elements

The oil industry plays an essential role in the global economy, but the related constructions are exposed to various risks that can affect both the safety of personnel and the integrity of the infrastructure. The vulnerability of these constructions refers to their ability to withstand external threats such as natural disasters, terrorist attacks or industrial accidents. In this paper, we will explore the concept of vulnerability in the context of oil industry constructions and the criteria used to assess their vulnerability.

6.2. Definition of vulnerability

Vulnerability refers to the degree to which a system or structure is susceptible to damage from adverse events. In the case of constructions in the petroleum industry, vulnerability can be influenced by several factors including:

- Type of construction: steel, concrete or other material constructions

- Geographical location: Areas exposed to earthquakes, floods or storms are more vulnerable.

- Design and maintenance: Proper design and regular maintenance can significantly reduce vulnerability.

6.3. Vulnerability assessment criteria

The following criteria can be used to assess the vulnerability of oil industry buildings:

- Hazard analysis: identification and assessment of potential hazards, including natural and man-made.

- Structural assessment: Examination of the physical condition of the construction, including materials used and construction techniques.

- Impact studies: Analysis of the potential impact of various threats on the functioning and safety of the construction.

- Rules and regulations: Compliance with construction standards and safety regulations specific to the petroleum industry.

6.4. Examples of vulnerability in the oil industry

- Natural disasters: Floods and earthquakes can cause significant damage to oil installations such as refineries and drilling rigs.

- Industrial accidents: Explosions and oil spills can have devastating consequences, both for the environment and surrounding communities.

- Terrorist attacks: Critical infrastructure in the oil industry can be a target for attacks, which underlines the need for adequate security measures.

The vulnerability of buildings in the oil industry is a crucial issue that requires special attention. Proper vulnerability assessment using these criteria can help improve safety and protect critical resources. It is essential for the industry to invest in advanced technologies and risk management strategies to minimize the impact of threats and ensure safe and efficient operation.

6.5. Oil industry related constructions and their vulnerability

All these industries from oil extraction to refining, storage, pipeline transportation raise particular issues which mainly concern factors such as durability, mechanical strength, safety, fire protection, etc.

In this context, constructions in the petroleum industry, whether for extraction, refining or transportation, made of metal or concrete, must meet certain requirements and demands. Events in the history of construction demonstrate the importance of the use of advanced materials and technologies compatible with operating conditions.

At a time when energy and sustainability issues are high on international agendas, the role of concrete is paramount. Concrete's versatility and global availability make it the world's first choice in many applications, both onshore and offshore, above and below ground. It is also unique as the only inorganic, moldable material that can be used on a significant engineering scale. However, for concrete and other cement derivatives to continue to be used, we need to develop the use of alternative hydraulically active materials made with or without plain Portland cement, the impact of secondary aggregate use, technical properties, durability issues.

In recent times the amount of petroleum contamination of soil and the environment has continuously increased and now constitutes a significant fraction of the waste materials in the environment.

Contaminants in concrete aggregates or constituents affect not only the appearance of concrete in terms of color and rotting, but also its strength, durability, abrasion, water tightness, volume stability, freeze-thaw resistance and resistance to de-icing of chemicals.

The effect of crude oil on certain technical properties of concrete in a crude oil contaminated area investigated by some authors showed reduction of compressive strength by about 11%, reduction of tensile strength of concrete when soaked with crude oil.

Deterioration and cracking of concrete in marine environment is more severe than in any other terrestrial environment, therefore it has been observed that deterioration occurs as a result of factors such as physical and chemical characteristics of the repair compound, initial curing periods, environmental conditions, among other factors, in his work on some properties of crude oil soaked concrete exposed to ambient temperature observed variations in mechanical properties over time.

However, studies have shown that factors significantly affecting the properties of concrete include the curing conditions prior to exposure, the moisture state of the concrete at the time of exposure, the storage temperature of the crude oil, and the type of cement. The occurrence of concrete deterioration and cracking due to crude oil leakage has remained a green area in the literature.

6.6 Research methodology carried out

The research focused on the artificial contamination of constituent concrete samples in terms of fine aggregate in different percentages and crude oil contaminated water sample and subjecting these samples when constituted as concretes to investigate the effect of the contaminations on the properties of concrete, both fresh as well as in the hardened state, which actually models many of the situations arising from oil plant failure, crude oil spillage or vandalism, since most of the construction materials or concrete components are extracted from contaminated river bodies or the most contaminated water is used for construction.

Hydrocarbons do not chemically react with high strength concrete to alter its physical properties. Concrete test samples showed minor changes in properties due to the effects of hydrocarbons under pressure on the internal moisture in the concrete. Pressurized seawater had no adverse effect on the properties of the concrete samples. The properties studied were compressive strength, creep velocity, fatigue life and permeability, as they could affect the design of a gravity based oil storage/production structure in the North Sea.

Prestressed concrete, gravity-based, prestressed concrete structures for oil production storage applications are designed, constructed and installed in the North Sea. The environmental effects of hydrocarbons on concrete properties for this relatively new application are not well known.

In short, the ultimate potential strength of concrete is obtained by a low water-cement ratio in the initial mix, maximum available water during the curing stage and minimum free water at the time of testing. Hydrocarbon flooding during the curing stage could alter the strength and related properties of the concrete.

Tanks in the petroleum industry can be made of concrete or metal. They are used for storing petroleum products, oils for which they must have high impermeability. As is known, during filling and emptying operations, hydrocarbons evaporate. Evaporation occurs even through the tank walls. Practice shows that these losses are normally 5% of the stored quantity. A tank for hydrocarbon storage must have two qualities: high tightness and product storage to ensure an overpressure of 0.2 ats. To eliminate evaporation losses. If for heavy products a good impermeability can be achieved only by the concrete structure supplemented with a surface protection of the needle for light products special measures are necessary. Heavy petroleum products raise another problem related to the need for heating during filling or emptying and this heating produces significant stresses in the walls and requires thermal insulation to mitigate the effect of heating on the constituent material.

Research has led to new materials based on polyurethane products.

Metal constructions are increasingly used in today's society. Metal can be considered as one of the versatile materials with varied strengths, allowing a wide variety of products and applications. However, all metal parts are susceptible to some degree of deterioration (corrosion). It is therefore important that they are treated correctly to ensure that their durability is compatible with their intended function. Metals corrode over time due to chemical reactions occurring between the metal and the environment. This deterioration normally causes visual changes and can also have a detrimental effect on the overall strength of components or the construction as a whole. An example of the most common corrosion is iron oxide (rust), which normally occurs as a result of the chemical reaction between iron and oxygen in the air. Corrosion can occur rapidly or slowly, depending on the quality and treatment of the metal, the way it is coated and the environmental conditions in which it is placed.

Fig 6.1

Corrosion resistance tests of metals are tests that highlight vulnerable areas where corrosion can initiate and how their corrosion resistance can be assessed.

Fig 6.2 Corrosion detail

There are several ways to protect against corrosion. The most common of these is to apply an additional coating that protects the metal from environmental exposure. This is normally done by painting or coating the device, for example using zinc or cadmium. Another common method normally used in aluminum alloys is anodizing. This surface treatment gives the metal a harder surface coating, making it more resistant to weathering and corrosion. Even with this extra protection, regular metal inspections are recommended to ensure that problems are identified at an early stage.

Fig 6.3, 6.4 Inside tank cover

Fig 6.10 Metal constructions are subject to corrosion degradation.

6.7. Classification of corrosion types by attack distribution

For the assessment of the corrosion resistance of metals and alloys, in addition to the corrosion rate, the distribution of the attack zones on the surface or in the mass of the metal is important. Thus, if a small amount of metal is destroyed over a small area, it can put a part or a tool out of service. If the same amount of destroyed metal is evenly distributed over the surface of the part, the part will not be affected for a long time.

Fig 6.10

Depending on the distribution of the attack, there are several dozens of types of corrosion that can be grouped into two categories: uniform corrosion and localized corrosion.

Uniform corrosion

This type of corrosion is where the destruction of the metal is distributed over the entire surface of the part or machine. The rate at which the metal is corroded, in this case called the penetration rate, depends on the nature of the metal, the environment in which it is found and the nature and adhesion of the corrosion products.

Uniform corrosion is the least dangerous type of corrosion, since the behavior of the machine can be predicted by measurements on samples.

The rate of uniform corrosion is expressed in terms of the penetration rate (mm/year) or metal loss per unit area per unit time (g/m2h). For ordinary steel, e.g. in sea water, the corrosion rate is 0.125 mm/year, which means 25 mg/dm2 day. When specifying corrosion rates, the time to which they refer should also be given, because, with small exceptions, the corrosion rate is high at the beginning and then decreases over time.

The decrease in corrosion rate over time is due to the formation of corrosion products on the metal surface.

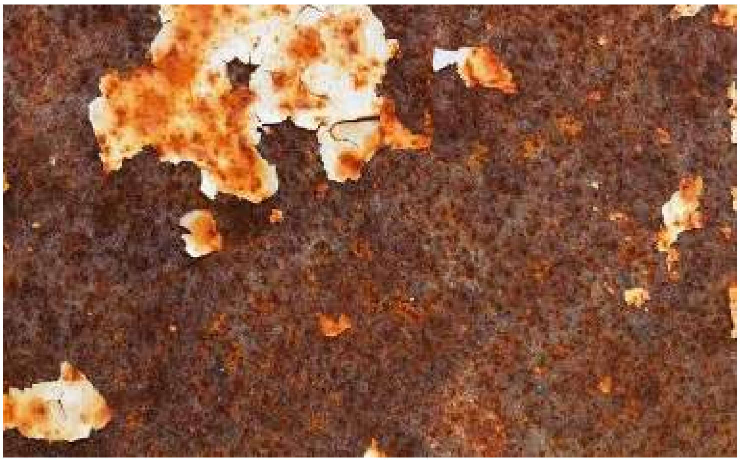


Fig 6.11 Uniform corrosion - tank

Typical cases of uniform corrosion are the corrosion of steel in the atmosphere or the corrosion of metals in strongly aggressive media (iron in HCl, Al in hard bases, Cu in HNO3).

Being the least dangerous type of corrosion, measures are often taken to convert other types of corrosion into uniform corrosion. One such method is the insertion of cathodic inclusions in alloys.

Localized corrosion

Localized corrosion is characterized by the wide variety of forms in which it manifests itself. These forms can be divided into two categories: (i) concentrated localized corrosion and (ii) intercrystalline localized corrosion.

Concentrated localized corrosion can be present on very small areas (spot corrosion), on areas of the order of mm2 (patch corrosion) and on larger areas (zone corrosion).

Fig 6.12 Tank detail inside

Fig 6.13

Fig 6.14

Pitting or spotting is characteristic of passivated metal constructions. For various reasons the protective coating on the metal surface can be pitted, so that corrosion occurs at the pitting sites. Penetration of the protective layer may be due to physical causes or the presence of ions such as Cl- in the environment. This type of corrosion is found in iron, chromium or stainless steel in the presence of Cl- ions. At the points where the protective film is pierced, small deep craters appear.

This type of corrosion becomes very dangerous with time, as small amounts of destroyed metal lead to the disabling of entire machines. In addition, the coating of these areas with corrosion products - a common phenomenon - makes it difficult to assess the degree of corrosion of the metal.

Zone corrosion refers in particular to cases where conditions are created for the operation of macro-elements, for example when some components are made of other materials from different sheets. Metal with inferior properties will be corroded in the vicinity of contact with the better metal. This type of corrosion is less dangerous because it is visible and can be anticipated.

Localized intercrystalline localized corrosion includes cases of inward destruction in the constituent material, localized in the bulk of the metal or alloy.

Selective intercrystalline corrosion refers to metal destruction at the boundary between crystals. Depending on the preferential corrosion of a component or a structure, we speak of selective component corrosion or selective structure corrosion.

Structure selective corrosion is sometimes found in low alloy steels.

Inter-crystalline stress corrosion cracking (corrosive cracking) is common in constructions working in aggressive environments and subject to varying mechanical stresses. This type of corrosion does not occur in pure metals.

Corrosion protection

Based on their mode of action, corrosion protection methods fall into the following categories:

- Protection by treating the environment to reduce its aggressiveness

- Protection by increasing the corrosion resistance of metals and alloys

- Protection by electrochemical methods

- Protection by surface coating

The petroleum industry relies on a variety of specialized constructions to extract, transport and store oil and petroleum products. The most important of these constructions are tanks, pipelines and offshore platforms, predominantly made of metal or concrete due to the strength and durability of these materials.

Tankers are essential structures for storing crude oil and refined petroleum products. They can be categorized according to their use, such as storage tanks for long-term storage or temporary tanks for short-term storage.

In general, tanks are made of metal, usually steel, due to its ability to resist high internal pressures and corrosion, especially when treated with various protective coatings. In some cases, for greater durability and insulation, reinforced concrete tanks are also used, especially for storing products underground or in areas with extreme conditions.

Pipelines play a vital role in transporting oil and natural gas from extraction sites to refineries and on to distribution points. They are predominantly made of metal, especially steel, because of its resistance to pressure and its ability to transport fluids at varying temperatures and over long distances. Modern pipelines are often coated with protective layers to prevent corrosion and are equipped with monitoring systems to detect possible leaks or damage. In some cases, for specific applications, concrete pipelines may also be used, especially in underwater environments or in areas with unstable soils.

Offshore platforms are complex constructions used for the extraction of oil and natural gas from subsea reservoirs. They are made of either metal or concrete structures, depending on water depth and environmental conditions. Metal platforms, usually made of steel, are preferred for deep water due to their flexibility and structural strength. Concrete platforms are commonly used in shallower waters and in areas with harsher marine conditions as they offer greater stability and are more resistant to marine corrosion. These structures are designed to withstand extreme natural forces, such as storms, waves and earthquakes, and are fitted with sophisticated equipment for drilling, extracting and processing hydrocarbons.

In conclusion, tanks, pipelines and offshore platforms are essential to the efficient operation of the oil industry, and the choice of materials such as metal and concrete for their construction ensures the durability and efficiency needed to operate in varied and often extreme conditions. These structures are designed to maximize safety and reliability in the exploitation of petroleum resources, contributing to the continuous global energy supply.

Fig 6.17 Tank interior case study 2

Fig 6.19-6.21 Pipelines Before rehabilitation and after

CHAPTER 7 is dedicated to the case studies.

7.1 Case study 1 - reinforced concrete structure

Visual inspection of the reinforced concrete structure revealed the following:

- the reinforced concrete columns (10 pcs.) show cracks and cracking, especially along the edges, swollen, loose and expelled portions with corroded reinforcement exposed to the environment;

- the longitudinal reinforced concrete beams, deployed on two height levels (+3.60m and +5.80m), show cracks and cracking, especially along the edges, broken and expelled portions, with corroded reinforcement exposed to the environment;

- cracked and exposed portions of concrete are also observed in the area of column and beam joints;

- the corrosion protection of the concrete is totally degraded;

- there is a risk of accidents;

Fig 7.1

Proposals:

- Removal of non-adherent concrete by hydrosandblasting and bushhammering degraded concrete

- cleaning by de-stripping, passivation and corrosion protection of all reinforcement exposed to the environment;

- re-coating of concrete reinforcements of columns, beams and their joints;

- corrosion protection of concrete.

Materials used

- Primer - a one-component polymer-modified cement-based product containing fumed silica, used as a coating layer to act as a bonding bridge and corrosion protection for reinforcements.

- Single-component, polymer-modified, synthetic fiber-reinforced, low-shrinkage, polymer-modified repair mortar containing corrosion inhibitors

- Synthetic modified mortar, cement based, additivated, used as a spackling mortar, for filling voids, minor repairs

- Single-component acrylic resin, containing solvents, used to protect concrete against carbonation and water infiltration, realizing a self-cleaning effect on the treated surface. The material does not influence the characteristic texture of concrete.

Example 2

Visual inspection of the reinforced concrete beam structure revealed the following:

- The fire protection (made of concrete slabs (C12/15) and reinforcements of the metal beams located between two axes of the installation, shows cracked concrete, especially at the intrados of the beams, locally expelled, with exposed and corroded metal profiles, favoring hydroleakage and accelerating the degradation process.

Fig 7.2

Proposals:

- removal of degraded fire protection from identified areas

- cleaning metal profiles, inspecting them, checking welds and joints with reinforced concrete columns and longitudinal beams;

- passivation and corrosion protection of all metal elements;

- protecting the beams by applying a fireproofing coat of thermo-foaming hydrocarbon fire-resistant paint, the thickness of the coat will ensure a fire resistance of 120 minutes.

Materials used

- Anti-corrosive epoxydic primer which has good adhesion to metal and steel, shows good water and corrosion resistance

- Thermosetting paint designed to withstand the most severe hydrocarbon hazards in both onshore and offshore oil industry environments.

- Carbon fiber mesh

- Polyurethane paint sealing layer

7.2 Case Study 2. Metal tank stucture

The present case study concerns the solution for the construction of a new tank with a geometric capacity of 12720 m3 for the storage of Euro 5 diesel and gasoil components. The tank is intended for the storage of Euro 5 diesel and gasoil components.

<u>Main technical characteristics of the tank</u>

From the construction point of view the tank is a hydrostatic, vertical cylindrical tank, in welded construction, of sheet-metal to sheet-metal type, with a fixed spherical self-supporting lid.

CONSTRUCTIVE AND TECHNICAL CHARACTERISTICS		
Tank type		vertical cylindrical, with self-supporting fixed spherical cap, welded construction
Dimensions: internal diameter V1 x mantle height		32,408 x 15,43
Geometric capacity		12720 mc
Useful capacity		11700 mc
Maximum pressure mm water neck	permissible working	hydrostatics
	allowable calculation	overpressure 65 / -40
Ambient temperature (^{0}C)	Minimum	-25
	Maximum	+40
Permissible working temperature (^{0}C)	Minimum	-5
	Maximum	+40

Climatic conditions in the refinery

The refinery is located north of the city of Constanța, near the town of Năvodari, at a distance of about 100 m from the Black Sea shore. The climate of the whole Navodari area is influenced by the presence of the Black Sea basin. The climate of the Năvodari area is characterized by a moderate thermal regime. On summer days, the vertical thermal stratification of the air is more stable and results in the formation of vertical downward currents that prevent cloud formation, so cloudiness is lower and the duration of exposure to high temperatures is longer than in the rest of the country.

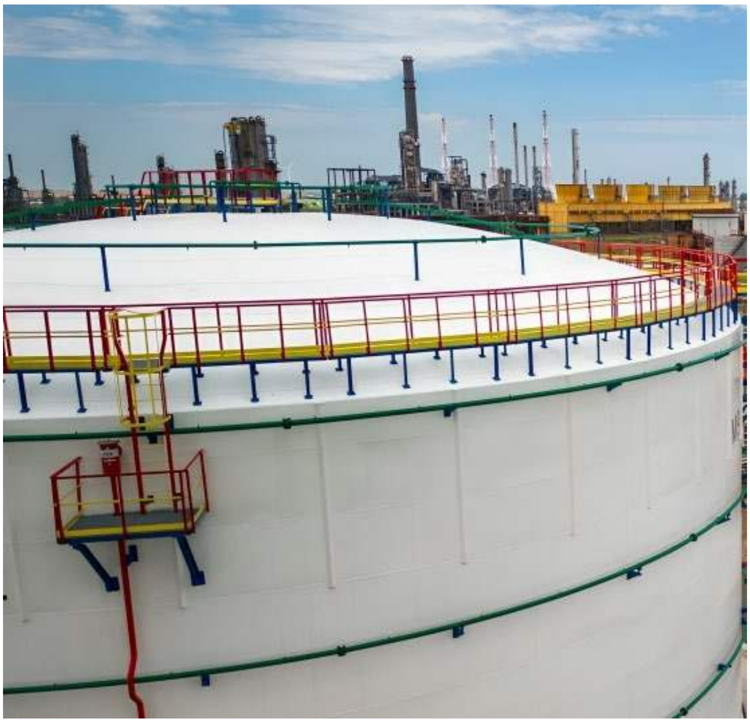


Fig. 7.1. Calculated tank

The following air humidity values have been recorded over time: mean annual humidity 80%;

It is noted that the number of days with 80% humidity is 129 days/year.

Rainfall is torrential in the warm half of the year and alternates with long dry periods.

Barometric pressure values fall within the following range: Multiannual average: 1013.3 mbar

Due to the fact that the Năvodari area is dominated by clear skies and a relatively high frequency of tropical and continental air invasions, the maximum daily air temperature exceeds 25oC on more than 60 days per year.

Wind speed: 39 m/s.

Construction description

The tank shall be used for storage of diesel component and Euro 5 diesel shall be vertical axis, welded sheet metal to sheet metal. The bottom of the tank shall have a slope (1.5%) from the center to the edges. The sleeve shall be cylindrical with vertical axis and shall be composed of 11 rows of ferrules. The cover shall be self-supporting spherical. Access to the cover will be from an access platform and a circular access way which will be reached by means of a helical ladder.

Foundation data

The tank will be supported on elastic bed inside a new concrete ring. A new sidewalk will be constructed around the concrete ring with a sloping swale connected to the sewer.

Tank bottom data

The bottom of the tank will be made of S355J2 sheet metal with a thickness of 12 mm for the annular and S275J2 with a thickness of 7 mm for the bottom elements. The welds shall be butt welded to the supporting clamps.

Dimensions and composition of the ferrules:

Number of ferrules: 11 pcs

Ferrule dimensions: 16x1500x6000, 16x1500x4000, 16x1500x1863, 6x1500x5657

Materials used: S355J2

The tank will be supported on an elastic bed (slope of 1.5% from the center to the edges) inside a new concrete ring. A new sidewalk will be constructed around the concrete ring with gutter connected to the sewer.

The elastic bed, concrete ring, sidewalk and rainwater inlet channel will be executed on the basis of the construction documentation.

Measures shall be taken to avoid damage to the resilient bed during the entire duration of the work on the reservoir bottom.

The slabs of the reservoir bottom will be protected against corrosion on the side in contact with the elastic bed by applying two coats of citom with a total thickness of at least 250 µm. A data sheet shall be prepared.

Particular attention shall be given to the removal of sand or bitumen from the areas to be welded.

The manner of performing the butt welds shall be determined by the Contractor on the basis of the approved welding procedures and work procedures in such a way that the deformation of the butt after welding is minimized.

The manner of execution of the mantle welds shall be determined by the Manufacturer on the basis of the approved welding procedures and work procedures in such a way that the deformations of the mantle after welding are minimized.

For access to the cover fittings the tank has been provided with a helical ladder. The helical ladder shall be mounted outside the container.

Prefabricated galvanized steps with galvanized frame with fixing holes shall be used for the helical ladder. The supplier shall also supply the fastenings.

The tank shall be fitted with five foam generators. Access to the foam generators shall be gained from the lid by means of a circular access route, attached vertical ladders and the foam generator platforms. The circular access shall be provided with a guardrail.

The gratings mounted on the circular access way and on the foam generator platforms shall be galvanized honeycomb type, the supplier shall supply including fasteners.

Verification, deviations and examination of welds

After completion of the assembly and prior to hydrostatic testing, the dimensions and shape of the tank shall be checked on the basis of the corresponding drawings in the design drawing.

The deviations from the theoretical slope (1,5 % from center to edge) and flatness of the tank bottom plates shall be checked.

For measuring the deviations from the theoretical slope and from the given shape of the surface, the tank bottom shall be divided into 36 identical sections (with 18 equidistant diameters).

The deviations of the shape of the bottom plates of the reservoir bottom must be measured with a topometer.

The tank will be subjected to a hydraulic test by filling with water to + 15500. All connections are to be shielded.

The hydraulic test shall be carried out before the permanent piping connections to the tank are made. The fittings shall be welded to the tank before the hydraulic test sample is carried out.

Prior to the start of the hydraulic test sample, measures shall be taken to clean the reservoir, remove any debris and other bodies and substances that have been used during the fabrication work.

Filling shall preferably be carried out with potable water, but water from another source may be used subject to quality checks. Acid water, water containing mechanical impurities, water contaminated with oils or flammable substances, etc. shall not be used.

The hydraulic test shall be carried out during periods when the outside temperature does not fall below 5 oC.

After the completion of the hydraulic test, no welding work shall be carried out on the container. The maximum filling velocity shall not exceed 450 mm/h for the lower ferrules (V1, V2 = 3000 mm) and 300 mm/h for the upper ferrules. Filling takes approximately 140 hours.

After complete filling the reservoir shall be kept filled with water for a minimum of 24 hours, during which time it shall be monitored for any pores, leakage or deformation. If, after holding the water at the final filling level, there is no water leakage or spillage on the liner and the water level does not drop within 24 hours (minimum), the container shall be considered to have passed the hydraulic test.

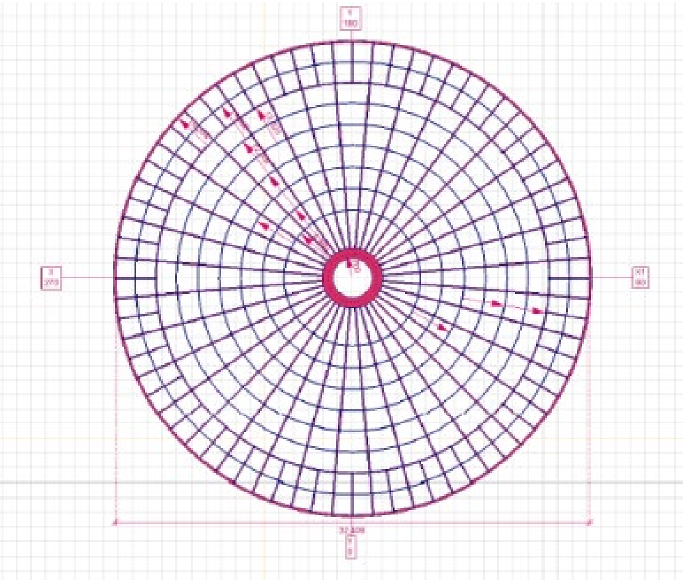
No work shall be carried out on the tank while it is filled with water. If any deformation, cracks or other defects are found during the hydraulic test, the tank shall be drained, the appropriate repairs shall be carried out, the welds checked with penetrating fluids and the hydraulic test repeated. Any defects found (pores, cracks, etc.) shall be repaired and the repaired areas shall be retested for leak tightness. Defects found to be unacceptable in terms of deviations in form shall be removed and repaired by a procedure approved by the client and designer.

It is prohibited to carry out any work to remove leaks while the tank is full of water.

- **Tank**
- After the hydraulic test, the tank shall be prepared for the application of protection on the inside and outside.
- (a) Container exterior
- On the exterior the following elements of the tank shall be protected:
- - Blanket;
- - cover cover;
- - connections and manholes.
- (b) Container interior
- The following parts of the container shall be protected on the inside:
- - tank bottom (prior to assembly, the plates making up the bottom shall be cushioned on the side facing the elastic bed);
- - 1500 mm of the lower part of the cover;
- - 1500 mm from the upper part of the mantle;
- - cover supporting structure;
- - the cover.
- c) Metal access and service structure
- The metal access and servicing structure (helical ladder, access platform on the cover, manhole servicing platform, circular access way and platforms for access to the foam generators) shall be primed and painted as follows:
- - Sandblasting: grade Sa 2 ½ according to SR EN ISO 8501-1;

- Degreasing;
- 1 primer coat (thickness 80 µm);

7.3. Case study 3 - Dome tank cover rehabilitation



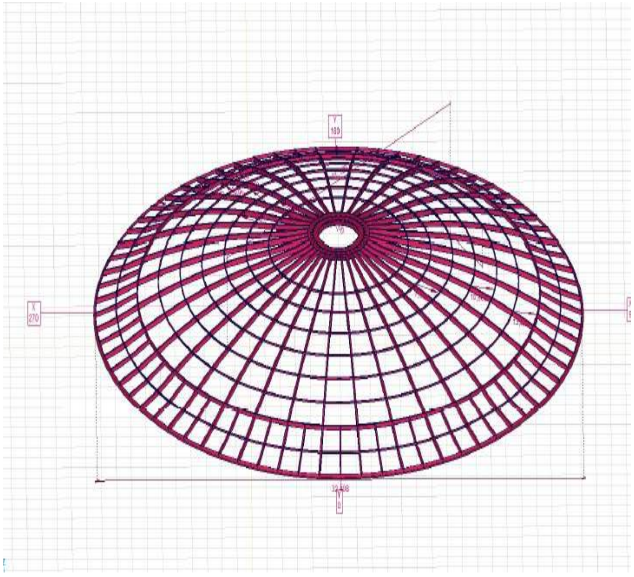


Fig. 7.4. Top view of the tank lid Fig. 7.5. Lid perspective

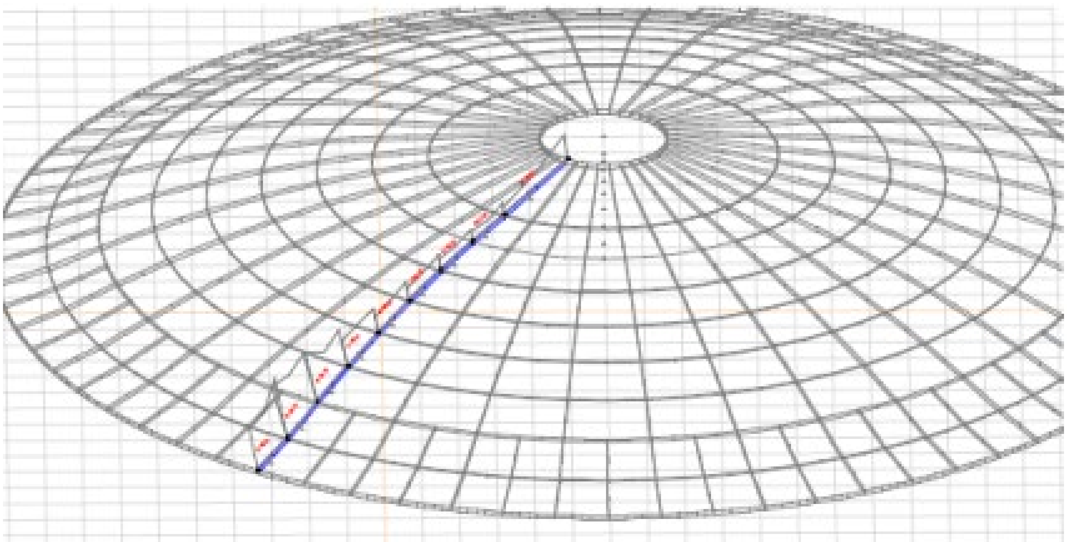


Fig. 7.6. Main rafter

The max stress to which the elemental (main truss) is subjected is 1224.30daN/ft, compared to the yield strength (fy) of S355 steel (3550daN/ft), the result is that the main truss takes the loads efficiently.

The structural elements 118,121,122,125,126 are analyzed.

The calculations show that the efficiency of the metallic elements is satisfactory (expressed in percent).

NOTE: The higher the percentage value the lower the efficiency of the metallic structural elements.

VERIFICATION OF STRUCTURAL STEEL MEMBERS

Sizing element: 118

Nodes: 88-456

Standard: Eurocod-ROSR EN 1993-1-1, SR EN 1993-1-5

Material: S 355

Section: IPN 220

Load Ip: Ci 5

Seismic hypothesis increase coefficient: 1,0

Section class: 1 (Plastic dimensioning)

1.

EN 1993-1-1: 6.2.1, 6.2.8, 6.2.9.3

Critical section: x=1,00·L=1,00·300,29=300,29 cm

N_{Ed3} = -27,47 kN;$V_{y,Ed3}$ = 0 kN; $V_{z,Ed3}$ = 4,99 kN ;$M_{y,Ed3}$ = 1034,91 kNcm; $M_{z,Ed3}$ = 0,01 kNcm
$\eta_{MNVpl}=\eta_{MN}=9$,0% is verified

2. Axial Force-Compression-Compression-Incovection-Bending

EN 1993-1-1: 6.3.3, Annex B: Method 2
Sectiunea critica: x=1,00·L=1,00·300,29=300,29 cm
C_{my}=max(0,2+0,8·αCm,0,4)=max(0,2+0,8·0,342,0,4)=0,474≥0,4
C_{mz}=max(0,2+0,8·αCm,0,4)=max(0,2+0,8·0,342,0,4)=0,606≥0,4

$f_{yy}=\min(\lambda_y^*-0,2,0,8)=\min(0,45-0,2,0,8)=0,247$

$f_{zz}=\min(2\cdot\lambda_z^*-0,6,1,4)=\min(2\cdot1,94-0,6,1,4)=1,4$

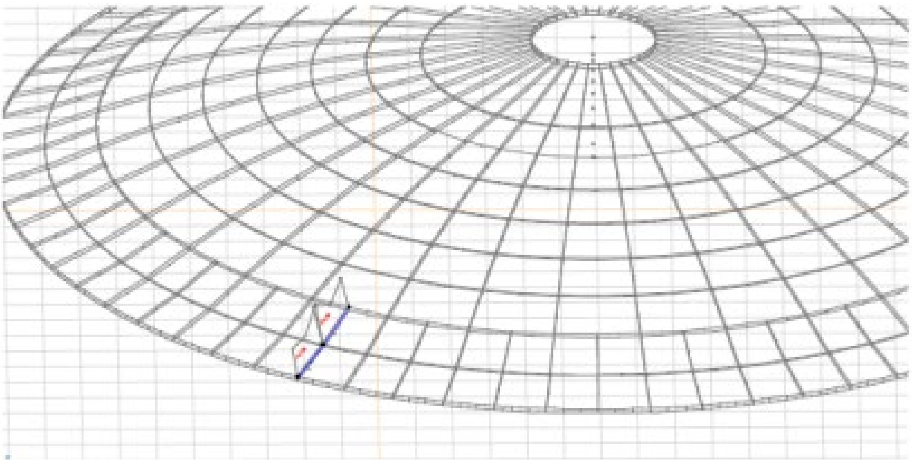


Fig. 7.10. Secondary element sectional voltages

The maximum stress to which the element is subjected is 925,90daN/cmp, compared with the yield strength (fy) of S355 steel (3550daN/cmp) from these calculations it results that the main head effectively takes the loads.

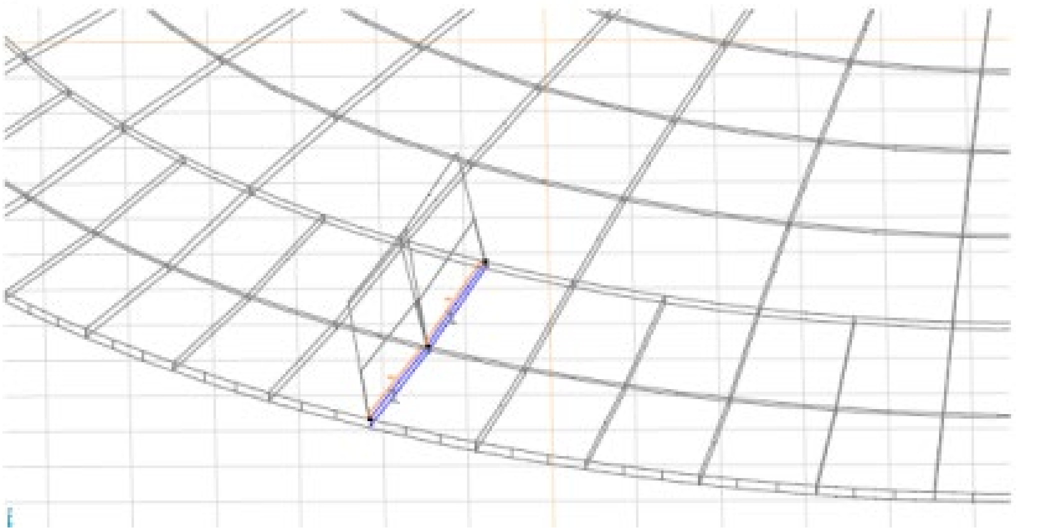


Fig. 7.11. Secondary rafter - numbering structural elements

The structural elements 351, 352 are analyzed.

The calculations show that the efficiency of the metallic elements is satisfactory (expressed in percentages).

NOTE: The higher the percentage value the lower the efficiency of the metallic structural elements.

CHAPTER 8. Presents the requirements and demands of special constructions intended for the petroleum industry.

As is well known, the oil industry offers a multitude of emergency situations, which cannot always be avoided, but can be managed. A first management measure is to ensure the quality of the constructions serving this industry. From the civil engineering point of view, i.e. special storage and transportation constructions, the performance assurance requirement covers the following aspects:

- Optimal conceptual criteria for the design and realization of the constrcutions
- Operating requirements respectively to ensure certain technological parameters both through the structural concept and through protective measures to avoid vapor losses, liquid losses, temperature losses. non-compliant that can generate explosions, fires or inadequate operation.

The oil industry is a strategic sector of the national economy and fundamental to the development of many industrial sectors of the Romanian economy. The constructions must respond to both the extraction and the hydrocarbon processing sectors, which is particularly important given that the oil market is a liberalized market and crude oil is a product quoted on the stock exchange. At present, we can define a national crude oil transportation system which is composed of a set of trunk pipelines designed to ensure both the collection of crude oil and its transportation to the processing and distribution units. In Romania the national transportation system is approximately 3800 km long, and is made up of the domestic transportation subsystem, the import transportation subsystem, the gasoline transportation subsystem, and the liquid ethanol transportation subsystem.

Romania also has an oil terminal operated by OIL TERMINAL S.A., which has 7 operational berths and links with transportation depots in both above-ground and underground pipelines. It should be noted that OIL TERMINAL has 3 depots with a capacity of about 550,000 cubic meters, equipped with tanks with capacities between 50,000 - 100,000 cubic meters, with capture installations, with transportation pipelines for petroleum products with diameters between 100 and 1000 mm, which transport crude oil and derived products, as well as analysis laboratories.

1. The largest crude oil processing platform in Romania is the Petromidia refinery, where there is an offshore terminal, a crude oil tank farm, berths, tanks.
2. All these constructive structures must meet the requirements and exigencies imposed by the European Union in terms of environmental protection, at the same time that they must meet the quality requirements in order to ensure a limited risk, which can be generated from the following causes:

1. Transportation failures: these can arise from pipe degradation, failure of joints, failure of the supporting elements of the pipe bundle when above ground, and corrosion degreasing, both in underground and above ground pipelines.
2. Imbalances due to the quality and/or density of the product being transported through the pipelines
3. Extreme weather conditions, i.e. temperature variations that may bring about changes in the density of the material being transported through the pipelines.

These risks also apply to tanks used for the storage of petroleum products. Research has shown that buried metal tanks have a fairly advanced exposure to corrosion, with the possibility, in many cases, of infestation of the ground with petroleum product. It has been shown previously that temperature is a risk factor. Research carried out at EUROPLATIC has shown that there are methods of protection against high temperatures for each individual case, depending on the requirements of the products resulting from the respective industrial process:

White petroleum products (gasoline, gasoline and diesel, white spirit, etc.)

1. Black petroleum products (fuel oil, specialty fuels, lubricating oils, etc.)
2. Specialty products (benzene, phenol, naphthenic acids, and others)
3. Other products (light liquid fuel)

Such platforms benefit from special safety conditions that refer to minimum distances, exposure to thermal radiation, as well as emergency facilities, being equipped with special safety measures, not only protect employees, but also contribute to increasing the efficiency of operations.

Special elements can also be found in the design of the storage constructions, as shown in Chapters 4 and 5, aboveground tanks are exposed to the aggressive chemical environment of the platform, the aggressive marine environment due to the site, which in conjunction with temperature variations can lead to significant degradation.

Within the PhD research project, we analyzed the possibility of protection of these constructions against both chemical aggressiveness and temperature variations. The research carried out within EUROPLASTIC has shown that an appropriate solution for oil industry constructions is an environmentally friendly coating based on ceramic nanospheres, which gives the treated surface very good thermal insulation properties.

The case study presented in chapter 7 refers to the calculation of a tank with a capacity of 43,000 m3 located on one of the berths of the port of Constanța, which in the unprotected situation could have an operating life under normal conditions of at least 40% reduced compared to the solution that gives it a protection.

Tanks for storing products made of metal are widely used in the oil industry. They can be flat-bottomed vertical cylindrical, short-bottomed vertical cylindrical, horizontal cylindrical spherical tanks, prismatic and others.

The most common solutions are flat-bottomed cylindrical tanks which must be sized to an overpressure of about 0.02 at and a vacuum of 0.0025 at. These measures take account of the fact that, due to the heating of the petroleum product during the summer, pressures usually exceeding 0.02 at occur through evaporation. Such tanks are fitted with valves through which the vapors escape. As the thickness of the walls is very small in relation to the geometrical dimensions of the reservoir, the jacket is considered to be a membrane whose shape is determined by the median surface. The deformations are assumed to be small in relation to the wall thickness, a favorable assumption in the structural calculation.

In the calculations, membrane stage conditions are applied, taking into account the stress generated in the joint area between the membrane and the bottom of the tank. In the structural calculation specific programs for metallic structures are applied.

In the oil industry, vertical cylindrical flat-bottom tanks are mounted on a sand bed. To the side of the sand bed, an annular girder is installed, dimensioned to the stresses generated by the positioning of the tank.

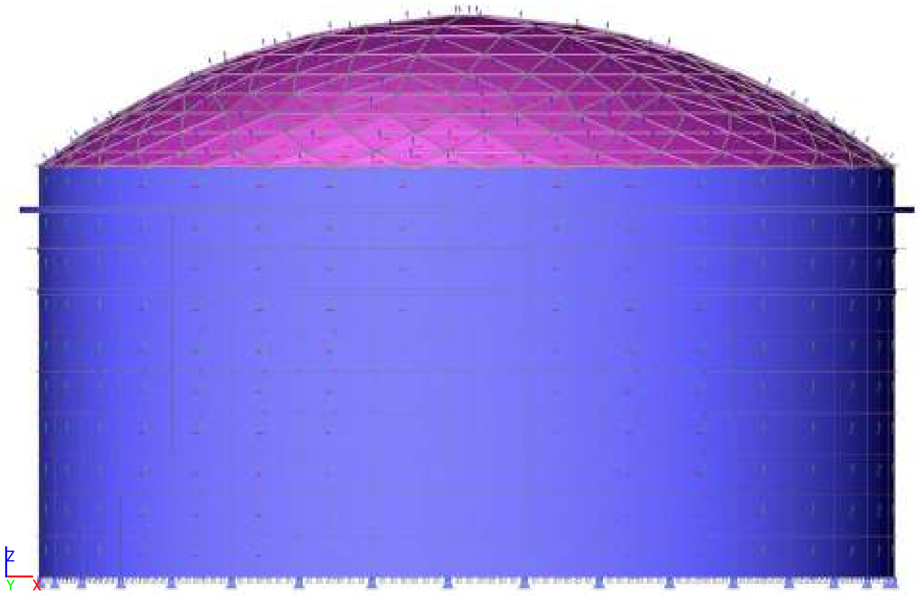


Fig 6.9 Analysis model

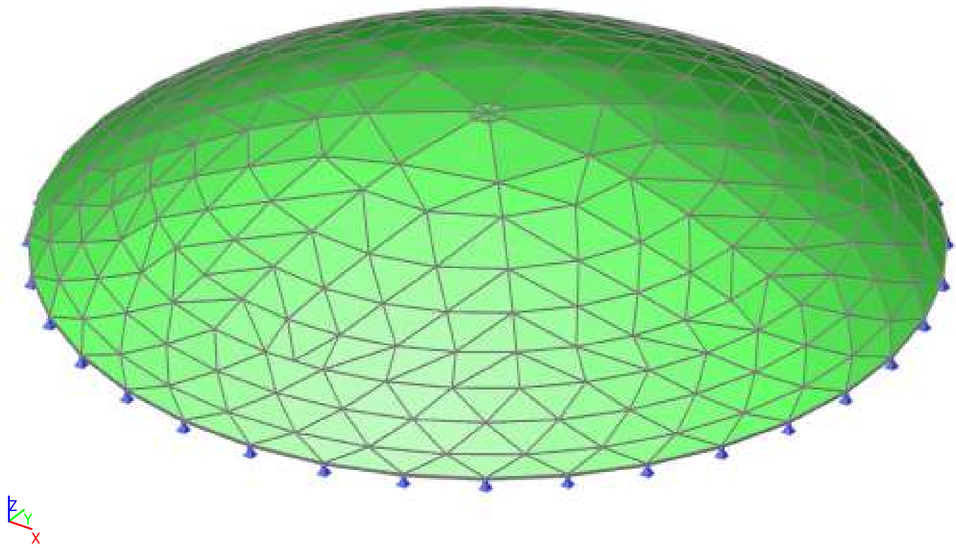


Fig 8.1 Dome roof analysis model

The cylindrical sleeve consists of several metal shells which may be of constant or variable thickness. The tank cover is made of sheet metal and discharges on radial trusses.

In service, the sheets making up the tank bottom are exposed to more intense corrosion.

Particular attention must be paid to the jointing of the sheets. The joint areas are the most vulnerable, which is why welded joints are practiced in the petroleum industry as they are more reliable in terms of tightness.

Horizontal cylindrical horizontal tanks are widely used as buried tanks mounted on saddle-shaped supports at their ends. They are used to store both petroleum and refinery products.

Another type of tanks are gasometers which are usually vertical cylindrical tanks. Another category of tanks used in the petroleum industry are those storing refinery by-products and oils. In some cases they may be made of reinforced concrete. One characteristic of these tanks is their impermeability and the limitation of losses through evaporation of hydrocarbons. Light petroleum products and mineral oils such as diesel, gasoline, fluids flowing through pipelines are not allowed to be heated for transportation and have high penetration power into the concrete structure, which is why metal is used.

Another category of products are heavy petroleum products which acquire the fluidity required for moving, transportation at temperatures exceeding 40 degrees Celsius and which must be heated in tanks by water or steam coils.

If concrete tanks are used, they must have adequate protection of the stored product. Good sealing of heavy products requires the use of high performance concretes or concretes over which protective films are applied.

Up to now, in reinforced concrete tanks storing light petroleum products, waterproofing has been achieved by a layer of water enclosed between two concrete walls to maintain the humidity of the tank wall so that the water pressure must be higher than the pressure of the stored product. In many situations, this has led to moisture reflux and seepage. This was considered a method of sealing the walls on the hydraulic principle. The advantage was that the application of the method decreased the danger of explosion. In order to prevent the water from freezing in winter, alcohol or glycerine was added. This method has been applied since the time of Gogu Constantinescu.

Another method of making tanks is the prefabrication system, which is less used in the oil industry because of the vulnerability of the assembly areas.

Another sealing system in heavy petroleum products was clay sealing, which consists in the construction of double-walled tanks into which clay is introduced and must be kept moist at all times.

Metal constructions related to the oil industry are usually storage and transportation constructions.

Fig. 8.7

Fig 8.8

A similar situation was analyzed by the PhD student on a smaller capacity tank, approx. 12.000 mc, located on the Petromidia platform 15 years ago, for which an intervention procedure was applied, which concerned:

- Sandblasting: grade Sa 2 1⁄2 according to SR EN ISO 8501-1;

- 2 coats (60µm each) of epoxy primer with zinc phosphate (final dry coat 120µm);

- 2 coats epoxy enamel (60µm dry film thickness), with min 75% reflectivity;

- Total dry coat thickness up to 240µm

To ensure both to stop the corrosion phenomenon, but also to continue operation as required,

Of course, the method applied to this small capacity tank is costly to larger capacity tanks, such as the tank in the case study, the result of which is shown in Appendix 1. This is the reason why a constructive structure with a design that provides adequate protection from the commissioning phase represents with modern and appropriate concept for oil rigs. Some pictures of how thermo -SAVE film is applied on the pipelines are shown below.

Fig 8.9 TermoSave application on pipes - England

Fig 8.10 Application of thermal protective coating on vertical metal tanks

The advantage of this method is that it keeps the transported product at a constant temperature and at the same time protects the constituent material of the pipeline from external destructive factors. Another advantage of this product is its elasticity. The elasticity stems from the organic structure of the material, i.e. it is generated by numerous silicon and ceramic spheres mixed with latex-based acrylic substances. This composition allows the film to expand and contract depending on the outside temperature, insulating the product from the inside.

Fig 8.11-9.12 Detail

In terms of durability, research has shown that a protected metal structure, whether tank or pipeline, doubles its service life, increases its resistance to weathering and in particular to marine corrosion. In addition to the thermal barrier quality, in this context we appreciate that the protection solution can be successfully applied to other constructions specific to oil industry platforms and not belonging to the special storage or transportation category. What is important to note is the fact that the protection is applied on a support layer both on the metal deck and on the joint area at a minimum temperature of 10 degrees Celsius. Of note is the fact that the protection has a fire importance class A, the insulation has also been researched in a laboratory for application in Dubai, obtaining very good results. In this context, we can appreciate that for the platforms with products resulting from oil processing, together with the quality requirements of the constrctions that refer to:

- The quality of concrete, defined by workability, permeability, increased strength;
- Metal quality, defined by homogeneity, density, and coefficients of elasticity as well as by the quality of joints.

In case of degradation, in case of destruction, in case of decrease of quality parameters, together with the intervention measures that refer to the application of additional layers of high performance concrete, the application of protective coatings, represents a basic solution that can respond both to the stompation of degradation, structural rehabilitation and to the appropriate protection against destructive factors.

CHAPTER 9. - Final conclusions. This chapter presents the fact that all the objectives have been met, that they have been analyzed in depth generating new research directions. The results have been disseminated.

9.1 Degree of achievement of objectives:

Within the research project we studied the identification of the factors that lead to the degradation of reinforced concrete and metal constructions located on oil industry platforms especially refineries in order to adopt high performance materials, appropriate protection solutions that meet the requirements and demands that the operation on the constructions demands, leading to the reduction of the risk of the degree of vulnerability, generated by possible explosions or fires or even through environmental pollution, but also to respond to priority programs related to the reduction of carbon emissions. As part of the research project we have carried out activities in the field of construction with particular reference to those of storage, storage and transportation of petroleum products, carrying out studies on the behavior of various tanks and pipelines on the Petromidia platform, Navodari. The purpose of these researches carried out during the 5 years was the importance of realizing sustainable material constructions, the application of adequate protection of the operating environment in order to reduce the degree of vulnerability. In this context I can say that the doctoral research program was structured on the following objectives:

- A real diagnosis of the buildings with identification of risk factors;

- Investigation of the degree to which the constructions can still be used, identification of the diminishing capacity of use;
- The identification of new methods to increase durability through intervention work on their resistance structure and the application of coatings to meet the requirements.

Another important objective was the dissemination of research results.

For this work methodology, in the framework of the PhD thesis we analyzed both the state of knowledge at international and national level, identifying the main measures included in the European Union directives so that any intervention on these constructions would lead to the application of carbon-free technologies, to the change of some intervention concepts, to the change of some traditional attitudes directed towards an energy transition with a favorable response to climate change.

In chapter 2 in the framework of the doctoral research we have studied the development of the oil industry, which is more than 160 years old in Romania, reviewing the structural concept for the oil industry constructions, even emphasizing a series of aspects that at the present date can be considered as national heritage. In chapter 3 we have highlighted the special constructive structures of the oil industry, analyzed them, presented them with a detailed analysis of their behavior over time versus the concept of durability.

Chapter 6 deals with the demands and requirements, the concept of performance of these constructions, and chapter 8 contains the conclusions resulting from the results highlighting criteria for the choice of intervention solutions. The addressed case studies highlight two variants:

The first one refers to a small capacity metal tank that has been subject to corrosion and on which classical methods are used to intervene, and for the second tank whose calculation brief is presented in Appendix 1, with a capacity of 43,000 cubic meters, the follow-up of the studies carried out by the PhD student recommends increasing its durability by applying modern coatings that also provide the necessary protection against the effects of climate change. The calculations performed for this last reservoir is a calculation based on the finite element method, using spatial discretization with specific characteristics.

The research results have been summarized in two research reports presented to the committee, the first one with the topic "Behavior analysis of oil industry constructions" and the second one with the topic "Modern materials and technologies applicable to oil industry constructions for improving operating conditions".

I would like to point out that within the research center of the Faculty of Constructions, Constanta, in two organized work shops, attended by students, master's students, PhD students and teachers, we presented the intermediate results of the research carried out.

Analyzing the completed research project it can be seen that all the proposed objectives have been achieved.

9.2 Personal contributions, elements of originality

In the research project carried out I identified different stages of behavior of construction materials for various solutions resulting from oil refining, finding with great accuracy the arguments demonstrating the state of degradation, as well as in some situations identifying risk factors. Taking into account that the oil industry is a strategic industry at national level and that risk situations represent a decisive factor in the management and exploitation of such platforms, we have specified that a thorough knowledge of the materials, of the realization technologies for the specific constructions of this industry, represents an important factor at the present time, as there are no instructions or a guide that regulates the procedure of choice of the material as well as the technology of realization by categories of constrcuctions.

The identification of protective materials applicable to both existing degraded constructions and new constructions, for thermal protection, but also to increase durability is a novelty, a personal contribution that can be capitalized in the future for special constructions both in the Petromidia platform and in other platforms.

Also novel is the structural analysis of the tank cap by performing a special discretization and finite element modeling.

Also with character of originality is also the presented technology concerning both intervention works on existing and new constructions.

9.3 Exploiting research results

During the completion of the doctoral research program I defended two research reports:

Research report1: Behavior analysis of constructions in the oil industry.

Research report 2: Modern materials and technologies applicable to oil industry constructions in order to improve operating conditions.

Two (2) communications referring to the intermediate phases of the research results, we published a chapter:

1. **Grigoraș Corina**, Ana Maria Grămescu, Filip Cosmin "The impact of climate change on constructions in the oil industry" chapter 19 of the book "Constructions in the context of climate change" ed MATRIX 2021 ISBN 978-606-25-0680-3.

And 3 articles published in journals as follows:

1. **Grigoraș Corina**, Panchici Andrei, Grămescu Ana Maria, Stoian Maria-Georgeta, Domolescu Nicoleta, Universitatea „Ovidus" Constanța, Noi direcții de cercetare în expertiza judiciară din perspectiva protecției mediului – emisii neutre CO2./ New Research Directions in Forensic Expertise from an Environmental Protection Perspective – CO2 Neutral Emissions, 16-17 mai 2024 Constanța - A-III-a Conferință Internațională de Criminalistică „Emilian Stancu" - Probleme actuale ale criminalisticii și mediului , în curs de publicare;
2. **C.R. Grigoraș**, A.M. Grămescu, C. Filip - Adaptarea sistemului calității construcțiilor la cerințele și exigențele industriei petroliere (Adapting the construction quality system to the requirements and demands of the oil industry), XGEN 2024 International Conference of Scientifics Communications May 20 – 24, 2024 Baia Mare, Technical University of Cluj-Napoca, No. 3, 2024.
http://www.opacj.org, https://events.universitas.ro/event/4/contributions/430/
3. Grămescu A.M**.**, Isopescu D., Stoian M.G., Barbu A.M.D., Buta C., **Grigoraş C**., Aspecte privind influența schimbărilor climatice în interpretarea științifică a probelor din expertiza tehnică judiciară – Studiu de caz, CZU: 340.6:349.6, în revista Legea şi Viaţa, Publicaţie ştiinţifico-practică, acreditată de Consiliul Suprem pentru Ştiinţă şi Dezvoltare Tehnologică al Academiei de Ştiinţe a Moldovei, ediţie specială cu ocazia Conferinţei Internaţionale „Mijloacele tehnico-științifice în serviciul expertizei judiciare", Editor Academia „Ştefan cel Mare" a MAI, Chişinău, noiembrie 2023, pp. 159-167, ISSN 2587-4365, E-ISSN 2587-4373, tipul C, Index Copernicus International (Republica Polonă), **CEEOL** (Central and Eastern European Online Library GmbH), **ROAD** (Directory of Open Access Scholarly Resources), **IBN** (National Bibliometric Instrument)
https://www.academy.police.md/editii-lv și http://www.legeasiviata.in.ua/

At the same time, in the XGEN competition we won third prize in Civil Engineering research

9.4 New research directions

The research carried out in the program has highlighted new issues to be considered in the next stage. The PhD student believes that new EU environmental policies will generate new technologies in the oil industry. At the same time, climate change will impose a new attitude in terms of defining environmental requirements and demands in relation to temperature and humidity variations, and therefore the construction materials industry related to petroleum products will also have to respond to these new challenges. As a very important directive that has emerged in the framework of the research project considered as a new directive is the zero net technologies.

Also a new research direction is also new film materials capable of providing durability, thermal protection, corrosion protection due to humidity variations. In the future, such research will generate interdisciplinary studies in which the construction materials industry, in partnership with environmental policy and artificial intelligence programs, will be able to obtain valuable results that meet the demands of the future.

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