"OVIDIUS" UNIVERSITY OF CONSTANTA

DOCTORAL SCHOOL IN APPLICATION ENGINEERING

AREA OF STUDY - CIVIL ENGINEERING

„STUDIES AND RESEARCH ON THE INFLUENCE OF MARINE ENVIRONMENT ON THE SPECIFIC PARAMETERS OF SELF COMPACTING CONCRETE, FOR ITS USE IN THE CONSTRUCTIONS MOUNTED IN THE BLACK SEA AREA"

- **Abstract of doctoral thesis -**

Thesis advisor,

Ph. D. Prof. Eng. Grămescu Ana-Maria

Doctoral candidate,

Eng. Cîinoiu-Marian Nicolae

CONSTANTA, 2016

FOREWORD

Now, at the completion of the research program conducted by me for obtaining the Ph. D title, I respectfully address my thanks to my scientific tutor, Ph. D. Prof. Eng. Grămescu Ana-Maria, who believed in me since college, when she was my coordinator for the dissertation and whose advices are guiding me today on my professional career.

I also thank to our teachers from the Civil Engineering Faculty of "Ovidius" University of Constanta, the professors in the support commission, for their patience and professionalism in analyzing all the results obtained during the research program.

Thanks to my teachers from the examination committee of the thesis for their kindness, dedication and professionalism in analyzing my works and the thesis, for their valuable contribution, things that will guide me in my future professional activity, to my teachers: Ph. D. Prof. Popa Constantin, Ph. D. Prof. Eng. Vacareanu Radu, Ph. D. Prof. Eng Bratu Polidor and Ph. D. Prof. Eng. Barbuta Marinela.

My thanks to my colleagues from Lafarge Romania, now SC CRH Romania, for the support given in realizing the practical trials and laboratory works, for the useful advices offered and opportunities aroused within the partnership created between SC Lafarge Agregate Betoane SA and Ovidius University of Constanta, to my coleagues from SC Lafarge UK, where I had the chance to perform a comparative analysis of the results of researches made in Romania with those in the Great Britain, thus realizing a correlation between the methods and techniques for obtaining the best solutions and performances..

Least, but not last, thanks to my family, to my wife for the moral support during the research program,, to my children, Dana and Mihai for understanding my absence from their life for such a long period of time, time taken out from the joy of being with them in the favour of study and research, with the hope that they will understand the sacrifice I made and the importance of this work, when they will grow up.

I thank to my parents for the favourable environment they created for learning and continuously support all my research activities, for the noble purpose of science development. Thanks to my sister who was an example for me for my whole life and inspired me to permanently exceeding my performances.

I dedicate this work to my parents to whom, along with my familly, I bring all our gratitude.

Cîinoiu Marian Nicolae,
Constanţa, 2016

CHAPTER 1 ENTRY

1.1 Importance and actuality of the proposed research theme

The studies and researches performed until now highlight the fact that the constructions mounted in marine aggressive areas are less durable than others, because of the special conditions they are exposed for the duration of their entire serviceable life. Nowadays, techniques allow the construction of bold buildings, if the materials and technologies applied are in accordance with the risk factors the constructions are exposed to, respectively, marine aggressivity, wind action, wave intensity, temperature variations and others. Starting from the necessity to have constructions made with durable materials, also taking into consideration the present results of research of special concrete, I put forth the idea of studying self compacting concrete behaviour in marine environment, as it is a modern material, of wide applicability in the European countries, but, presently, less applied in Romania. Considering two important aspects of the research theme, namely the Black Sea area and the properties of self compacting concrete, I intend to analyze its behaviour in marine environment, studying the properties of normal environment compatible concrete, their vulnerability towards the marine environment and techniques and methods for improving self compacting concrete used in the constructions mounted on the Blak Sea shore area. Thus, the theme of the thesis entitled **"Studies and research on the influence of the marine environment on the self compacting concrete specific parameters, for its use in the constructions mounted in the Black Sea area"**, develops a new concept in concrete manufacturing, more durable for Romania and, also, it proposes an improved composition for this type of concrete, that in the future will lead to more durable constructions mounted in the marine environment. I appreciate the fact that, presently, the studies and researches performed internationally lead to realizing a new type of concrete, able to sustain the new trends in constructions (reduced time of construction, easier operability and diminished costs).

1.2 Stage of researches on national and international level

The first practical demonstrations with self compacting concrete have been done in early 90's, in Japan. However, the concept of self compacting concrete did not have a fast ascendence in the domain. Only a few of the big Japanese companies, each developing their own recipe and testing methods, practically used the self compacting principle in concrete manufacturing. The lack of standardization methods or of generally agreed methods to measure the key properties of fresh self compacting concrete, prevented the addoption on a large scale. In order to solve the problem of international standardization of self compacting concrete, in 2001, the European Commission agreed to co-finance the project entitled "Testing of self compacting concrete", coordinated by ACM center, University of Paisley, Scotland. Because of the lack of european or international standardization for self compacting concrete, national operating manuals or even national standards were published containing truncated information, with no direct expertize or pre-standardized assessement.

The first European manual on the use of self compacting concrete was elaborated by EFNARC, a group of European companies implied in supplying materials for concrete manufacturing: "The European Guidelines for Self Compacting–Concrete"

In order to make konwn the studies and progresses in the self compacting technology and for promoting this, a series of international symposium were organized on self compacting specific subjects: Stockholm (1999), Tokio(2001), Rezkjavik(2003), Chicago(2005), Ghent(2007).

One of the most important works realized of self compacting concrete is the Akashi-Kaikyo Bridge. This bridge is 3911m long and its two pillars of the bridge are 298m heigh, being considered the longest suspended bridge in the world. Approximately 1.4 million sqm of concrete were used for its construction of which approximately 500000 sqm being self compacted concrete.

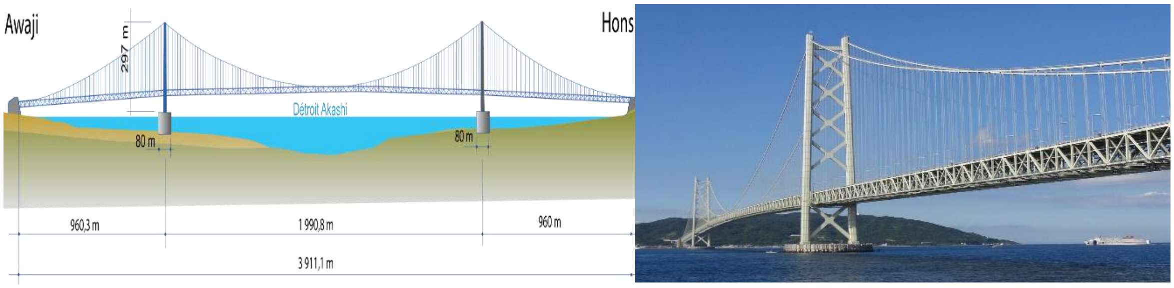


Figure 1.1, 1.2- Akashi Kaikyo Bridge [141]

At the end of 2012, a new department of Islamic arts was finalized within the museum of Louver in Paris. For realizing the structural concrete elements, Agillia® self compacted concrete was used, manufactured by Lafarge, with no finishing at the surface of concrete.

Figure 1.4, 1.5-Islamic art department of the museum of Louver-Paris [143]

Hepworth Wakefield, another important site, made of self compacted concrete, is another museum used as art gallery, located in Wakefield, West Yorkshire, designed by the British architect David Chipperfield. The faces of the structure are made of self compacted concrete, this being the first work of this type in Great Britain.

Figure 1.8, 1.10-HepworthGallery, Great Britain

The research stage regarding the operations, the casting technologies, casing, handling and then storage of the prefab realized of self compacted concrete were manufactured of Agillia® concrete, made in Leicester, supplied by Lafarge Aggregates LTD, Great Britain.

Figure 1.15, 1.16-Self compacted prefab factory, Leicester, Great Britain (author photo)

In Romania, as shown by the information given in the specialty literature the first practical application with self compacted concrete was in 2008 and consisted in the technical rehabilitation of a platform of the Romanian National Railway Company [4]. There are no relevant numbers on the sales of self compacted concrete in the latest years there are only references to the significant construction projects where this type of concrete was used.

One of the most important self compacted concrete works in Romania is the new bridge in Agigea that crosses the Danube-Black Sea Channel at Km 0+540. The main opening of the gate is of 100 m, it is 65 m heigh and its length over the channel is of 540 m. The self compacting concrete class used was C35/45, Agillia® manufactured by Lafarge, and the quantity of self compacted concrete used was of approximately 1500 sqm.

Figure 1.17, 1.18-Danube-Black Sea Channel, Km 0+540

1.3 Objectives and contents of the thesis

Analysis of the stage of researches on self compacted concrete on international level, the new policies for durable constructions, in accordance with the requirements generated by the environmental conditions imposed the application of such an efficient material in Romania. It was necessary that the general parameters defined until now are diversified also for certain conditions in Romania mainly for marine environment. Within this context I appreciated taht it is of outstanding importance to know the way in which this type of concrete can be used at maximum parameters for constructions or elements of constructions mounted in the area under the influence of marine environment (in contact with the water or in the immediate vecinity of this). The doctoral research plan set the following objectives:

- The analysis of the environmental conditions for the constructions mounted in the Black Sea shore area, the identification and characterization of the environment aggressivity, modelling the mechanism for the damage of concrete.
- Studies and comparative research on the elements of self compacted concrete and those of normal vibrated concrete, identification of transportation mechanisms for aggressive substances for concrete by the elaboration of comparative studies on the differences between conventional concrete and self compacted concrete in the marine aggressive environment.
- Procedures for the improvement of the properties of self compacted concrete in order to ensure durability and technology of operation.
- Optimization of the composition of self compacted concrete in order to ensure durability and increase performances of use in aggressive marine environment by identifying the factors that can lead to realizing a self compacted concrete that is resistant to marine aggressivity: non-reactive, cements resistant to sulphurs, moving air in order to obtain high resistance to freezing-melting.
- Contribution to the improvement of the present technical prescriptions regarding the use of self compacted concrete in the marine aggressive environment:

In order to fulfill these objectives I made documentation and research in the laboratories and the concrete plants of Lafarge, in Great Britain, in order to profoundly study the technology of operating self compacted concrete, Agillia® type, on the construction sites in Great Britain, country with an advanced experience in producing and operating self compacted concrete compared to Romania. Also, I realized studies and researches in Lafarge Constanta laboratories and ICH Central Construction Group Laboratory, the results being partially included in the objectives realized. The research methods used consisted firstly in laboratory research performed in Lafarge UK, period in which studies and analyses were conducted on the recipes of producing self compacted concrete, for its fabrication and operation. The second stage was in situ research method producing and operation of the construction elements. Studies were performed on the elements that were in direct contact with the water as well as on those that were not. The thesis present the results of the researches made on samples made of self compacted concrete and maintained in different environments: distilled water Black Sea water and tested in 28 days, 90 days and one year since their production. Also, within the research program the Casino-Mamaia walkway built in 1936 was analyzed in situ, the main purpose being the transfer mechanism of chemical aggressive agents towards the elements that are directly in contact with water and also the elements that are not in contact with the water. The activity was conducted in order to observe the vulnerabilities of conventional concrete used for the construction studied as well as the specific parameters of the operating environment aspects that are presented within the herein thesis and that stand at the basis of the concept of optimization of the SC Lafarge self compacted concrete for the conditions in Romania in order to use it in realizing constructions of adequate durability on the Black Sea shore. It is intended that the results of the researches contribute in creating a balanced Romanian standard. Also, the results of the studies and researches done shall contribute to the elaboration of specific technical regulations for marine aggressive environment.

1.4 Research methods applied by doctoral candidate during the research program

Research methods used were firstly consisted in laboratory research carried out in laboratories Lafarge UK, during which were studied and analyzed recipes for the production of self-compacting concrete, manufacture and the installation of it after the method was used for research situ production and put into practice the elements of construction.

CHAPTER 2. ENVIRONMENTAL CONDITIONS ASSESSMENT. PARAMETERS INFLUENCING THE CONCRETE CONSTRUCTIONS MOUNTED IN MARINE ENVIRONMENT

2.1 Evolution of concrete corrosion researches

During its life cycle, concrete undergoes a variety of degradation actions that can have a significant effect on performance and lifetime, such as durability, structural strength, workability and finishing. While these degradation actions may arise during the lifetime of elements, problems still arise in the production and casting of the concrete.

A problem that may occur during the **production phase** is the reaction silica-alkali (ASR), reaction between the active silicates in aggregates and cement alkalinity. In this reaction, alkali metal hydroxides attack the materials containing silica resulting in a gel silica-alkali which will form the capillaries of hardened concrete, the material being lifted up in the presence of water, generating internal forces in the concrete leading to cracking and then to destruction of the concrete by expansion

Problems related to **casting** are generally caused either by actions that can be easily prevented, or are difficult to monitor, things that can be avoided by careful preparation, a high level of knowledge and skills. The most common problem in the casting stage of concrete is the addition of water to the site of the installation, in order to improve the workability of concrete. Usually, this operation is performed at the contractor's request to help and ease concrete casting.

An alternative to increasing the workability of concrete can be the increase of the the amount of grout, but this action can cause problems due to excessive heat generation during the hardening process, but would also significantly increase the cost of such a type of concrete.

Figure 2.2-Segregated pillar area

Since ancient times, actions have been undertaken to study the corrosion of concrete caused by the action of seawater. Among the first researchers who studied the effect of seawater on the sustainability of concrete, of concrete corrosion effects induced by seawater, was L.J. Vicat whose researches on damage caused by seawater chemical attack on Alger port structures were published in 1841. Another major study of concrete corrosion given by the chemical action of seawater was initiated in Germany in 1908. The study was based on experimental research of seawater induced corrosion on some 8 m^3 concrete blocks placed on the island of Helgoland. Researches on seawater action on concrete had been taken in France, Italy, USA [52]

2.2 Characteristics of the marine agressivity environment on the Black Sea shore

Consideration should be given to environmental actions, to the identification and classification of environment aggressiveness as well as on the modeling transport mechanisms of aggressive substances when designing a class of concrete needed in a structure. The force of the waves combined with chemical aggression of seawater, with temperature variations, alternating freeze-thaw cycles lead to increased erosion and degradation of structures in close proximity to the Black Sea. When assessing the degree of coastal erosion, the currents caused by waves must be firstly considered. In case the sea level rises, the area where the storm waves break shall move closer to the shore, thus implicitly emphasizing the process of coastal erosion and degradation of the structures located in the close proximity of the shoreline.

Current issues related to increasing acidification of waters are found transposed into European directives that require measurement and monitoring of acidification of waters by using pH standards. In the researches conducted by the author upon Mamaia Casino walkway, a tendency of increase in the pH of the water in the Black Sea was observed. Water samples taken from the area showed an index of pH = 7.87 in 2009 and pH = 8.46 in 2016 which shows the trend of a small increase in the value compared to 2011.

2.3 Agents influencing concrete damage

From the point of view of chemical and physical processes that affect the durability of concrete, two factors are essential, namely, the content of the pores, and the existence of cracks and the presence of water. Related to this, the phenomena of gas, water and dizolving agents transportation into concrete are basic processes for sustainability.

2.3.1 Concrete porosity

Concrete is a porous material having a network of pores, depending on the size and distribution defining strength and durability of concrete.

The aggregates contained in the concrete may also contain pores, but they are usually discontinuous. The pores may be open to the surface of the aggregate particles or may be comprised entirely within the solid. The pore size of the aggregates can vary within very wide limits, the largest of which can be observed with the naked eye. In terms of porosity, the rock that has the best behavior is the granitic rock.

The mineralogical composition of cement influences concrete permeability, to the extent that it affects the rate of hydration. The higher the concrete strength, the lower its permeability, as concrete strength is a function of the relative volume of the gel in the space available to it.

Porosity of a material affects its physical properties and its subsequent behaviour to the environmental influences. Since mercury does not spontaneously penetrate into the pores by capillary action, it must be forced into the pores of concrete through the application of external pressure. Required balanced pressure is inversely proportional to the pore size, the higher the penetration of concrete into macropores requiring only a low pressure while a greater pressure is required to force mercury entering the small pores. The porosimetry analysis is the progressive intrusion of mercury into a porous structure under controlled pressure.

Figure 2.11-Comparisson between normal vibrated concrete porosity and self compacting concrete porosity- laboratory testing (author photo)

2.3.2 Concrete cracking

Durability of concrete and reinforcements embedded in it is closely connected with the existence of cracks in concrete. Penetration of aggressive substances in concrete element, carbonation and chloride penetration into the reinforcement tends to be at a much higher speed for cracked concrete compared to compacted concrete. If the crack does not exceed 0.4 mm, the rate of corrosion of the reinforcement is relatively low, because for such cracks, when water is present, the so-called self-cementing phenomenon occurs, meaning the self-healing of the cracked area.

Several types of shrinkage of concrete in the specialty literature:

- Thermal contraction;
- Drying contraction due to pore water migration
- Plastic contraction;
- Aggregates settlement caused contraction;
- Carbonation induced contraction;

The transfer of heat to the environment generated by the hydration of cement is difficult especially for massive elements. The tendence to balance the temperature between the core layer and its outer concrete creates tensile stresses leading to the production of cracks. This is achieved particularly in the case of heavy elements where there is a strong exothermic reaction generated by the hydration of cement. For such structures it is advisable to use belite Portland cement, where $C_3S < 37.5\%$ and $C_2S > 37.5\%$.

Concrete drying contraction occurs after water migration phenomenon to the surface of concrete, evaporating. Following this phenomenon, superficial cracks in the concrete surface appear due to the water suction efforts. If, however, the cement paste was sufficiently hydrated before drying, the phenomenon of cracking of concrete is greatly diminished.

Plastic contraction occurs mainly due to the phenomenon of rapid migration of water from its surface and rapid evaporation phenomena due to high winds, excessive temperature

The laboratory researches that we have carried out, we noticed a clear tendency of forming a smooth layer of about 1.5-2 cm at the conventional concrete surface, with higher fluidity, S4 consistency class, while for self compacted concrete, aggregates distribution remained uniform after hardening, as demonstrated by a cross section of concrete samples with dimensions of 150X150X150 mm.

Figure 2.17, 2.18- Distribution of aggregates in self compacted concrete compared to normal vibrated concrete, laboratory test (author photo)

The contraction of the concrete due to carbonation reaction is the reaction of carbon dioxide from the air with the minerals from the hydrated cement, resulting in carbonic acid. The reaction rate depends on the concentration of CO_2 in air and the moisture content of the concrete, and the relative humidity of the air. From the reaction of carbonation, $Ca(OH)_2$ passes into $CaCO_3$.

In this work, we have particularly studied the cracking due to the ingress of aggressive substances in concrete, reinforcement corrosion and finally expulsion and destruction of concrete. These surveys were conducted within the project study made on concrete degradation at Mamaia Casino walkway.

An important role in the penetration of aggressive substances in concrete is played by permeation and compactness of concrete.

Compaction is the second important concern in concrete activities. Compacting, although an action that is vital to ensure the quality of concrete, can also have a negative effect if the material is not compacted properly or even over-compacted. [71]. This activity is a delicate one, because of the fine balance between sufficient, insufficient and over-compacted and requires skill and knowledge.

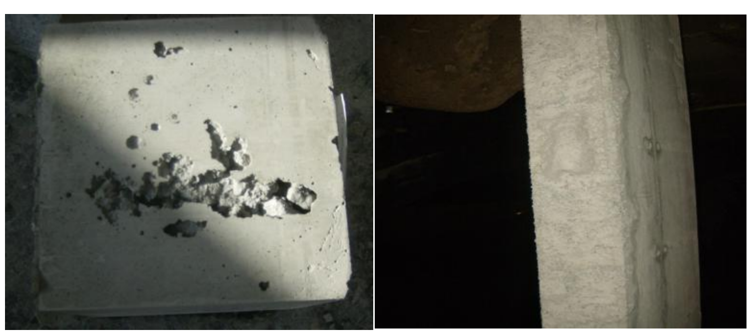


Figure 2.22, 2.23- Poor compacted concrete area: laboratory and construction site (author photo)

The degree of compaction obtained can be determined by measuring the pore volume remaining in the hardened concrete. It was determined that a normal vibrated concrete after a corresponding vibration compaction, will air at a rate of up to approx 1.5% of its volume. A completely uniform distribution of all particles and constituents of concrete, 100% homogeneity can be obtained only in theory. This would involve a completely uniform distribution of all constituents of concrete in the concrete. [43].

Figure 2.24, 2.25-Construction elements made of self compacted concrete (author photo)

2.4 Mechanisms of transportation of agressive substances in concrete structure

The movements of gases, liquids and ions in concrete are given by different combinations of change in air pressure, water pressure, humidity or temperature. Function of the intensity of the process and the nature of the substance transported the transport processes of the substances which lead to the degradation of the concrete are of the following types:

- Difussion;
- Capillary absorbtion
- Penetration caused by htdraulic pressure

2.4.1 Transport of gas

2.4.1.1 Difussion

The diffusion of the gas through concrete occurs when a different concentration of a gas is present at the surface of or in the concrete. The most common situations are represented by the diffusion of water vapor through concrete and CO_2 molecules diffusion in concrete. Water vapor transmission through concrete processes influences the rate of deterioration. High levels of moisture in the concrete carbonation lead to a slower or a higher absorption of chlorides. The diffusion of molecules of CO_2 by the carbonation of the concrete has the effect thereof. A gas diffusion through the concrete can be most easily described using Fick's law

2.4.1.2 Gas permeability

Gas permeability may be characterized by penetration of the gas level in a porous material, due to the hydrostatic pressure. In determining the level of penetration of gas in a material, the network connectivity and isotropic pore are of particular importance. Also, the moisture content of the concrete has an impact on in determining the level of penetration of the gas into the concrete.

Determination of gas permeability is important for gas containers, nuclear reactors, etc.

2.4.2 Transport of liquids

2.4.2.1 Capillary absorbtion

Capillary absorption occurs when an unsaturated material is in contact with a liquid. Concrete transport liquid through concrete depends not only on the pore structure but also on the degree of saturation of concrete, of the surface energy, and the properties of the liquid.

There are two possibilities of analysis in order to determine the capillary absorption. The first analysis method is the transport mechanism for immersion when the material is in contact with the fluid for a long time. Structures are continuously under water. The transport mechanism of water may be continuous only if at least one of surfaces of the element allows water evaporation. Another method is the transport mechanism when the material is not in permanent contact with water, namely in case of rain and splash.

2.4.2.2 Permeability

Substances in solution entry into the concrete can seriously affect its durability. This happens especially when the concrete is attacked by aggressive liquids such as the aggressive substances contained in seawater. Penetration of reinforced concrete by moisture and air will cause corrosion of steel accompanied by an increase in its volume. Therefore concrete cracking and peeling occur. [71]

Water permeability in concrete is a property that can be determined with various tests. Test methods vary greatly in terms of the degree of pressure applied and preparation of water, all having a significant influence on permeability coefficient result, making the results extremely difficult to compare to.

2.4.3.Transport of ions

With the transport of fluids through the structure of pores, ionic transport occurs which, however, is affected by many parameters, such as the transport of water, ions in the solution moving to the others as well as local ionic strength of the electrolyte solution. Ions can be found in two forms, free in solution or bound to the solid matrix of cementitious system. Ions moving through a cementitious system is usually achieved in liquid form.

2.4.3.1 Agressive attack of magnesium ions

Magnesium ions are found in seawater as $MgSO_4$, $MgCl_2$ and $MgCO_3$. The contents of Mg^{2+} ions in the seawater is usually of 1.3mg / l and they are in the form of $MgSO_4$ and $MgCl_2$.

All salts of magnesium, except carbonates acids have a detrimental effect on the concrete, and are more aggressive than $CaSO_4$ and $Na_2 SO_4$ since they can react not only with calcium hydroxide and by the other salts of calcium, thus a type II corrosion occurring.

If present only in small amounts, the magnesium ions tend to form an insoluble compound to the concrete surface $Mg(OH)_2$ which is an obstacle to the diffusion of SO_4^{2} ions - delaying sulfate corrosion.

2.4.3.2 Agressive attack of sulphur ions

Aggressive ions may be responsible alone or in a mixture of the destructive action on concrete. The most important aggressive ions are: sulphate ion, magnesium ion, ammonium ion, chlorine ion, hydrogen ions, hydrogen carbonate ions (HCO_3) and hydroxyl ion. The most aggressive attack on concrete isthe action of sulphate ions, primarily because the sulphate ions form salts.

For Portland cement, he more aggressive salts of sulphate are: ammonium sulphate, calcium, magnesium, and sodium.

The presence of sulfates in water that is in contact with cement stone can increase the solubility of mineralogical constituents of the cement stone, resulting in type I corrosion.

Water aggressiveness is primarily given by the presence of sulphate ions, water containing sulfates having the ability to penetrate much deeper and faster into the concrete, primarily because of its wetting.

Aggressive environment containing sulphates, acting outside on concrete, firstly attacking hydrated clinker particles. Cement stone surface is unstable in a solution of sulphate as well as mineralogical individual components [52].

CHAPTER 3. CONCRETE DURABILITY. MECHANISMS OF DAMAGING OF CONCRETE CONSTRUCTIONS EXPOSED TO MARINE ENVIRONMENT AGRESSIVITY

3.1 CONCRETE PHYSICAL DAMAGE

3.1.1 Concrete freezing and thaw resistance

Resistance to freeze-thaw is an important parameter of concrete structures durability. When the concrete is not sufficiently resistant to frost or agents of degradation attack, two types of damage may occur: internal damage and peeling. The internal damage, inside the concrete, mostly occurs as a crack along the aggregate grains. This degradation can lead to a modification of the properties of concrete. External damage manifests itself in the form of cracks in the concrete surface, leading to flaking of the cement stone. In case of porous aggregates or aggregates susceptible to frost, cracks can also occur at the level of aggregates. When porous beads are aggregated on the surface, the cement stone will be pushed outwards.

Factors that influence the freeze-thaw resistance is the microstructure of the concrete, the water / cement ratio, the cement content, type of cement, fillers, freezing rate, the number of freeze-thaw cycles, driven air or not, etc.

The air entrainment into concrete has a special influence on the durability of concrete, particularly on increasing resistance to freeze-thaw. This is achieved by admixture. Improved freeze-thaw resistance is achieved when the volume of air entrained into concrete is between 4-6%, up to 9%, an important role being played by the size and distribution of entrained air bubbles, bubbles size usually ranging from 0.05 mm to 1.27 mm.

The study on freeze-thaw resistance of concrete made with CEM III A 42.5 N-LH was conducted in February 2013 within Eforie Sud Treatment Plant Project.

The study was conducted on a C35/45 concrete class with granitic rock crushed aggregate, of max. 16 diameter. Air was deliberately entrainment into concrete to increase resistance to freeze-thaw using an air entraining additive, MICROAIR 107, at a rate of 0.1%, with a water/cement ratio of 0.4. Cubic samples with a side of 150X150X150 mm were manufactured and maintained for 7 days in water at a temperature of (20 ± 20)°C and a humidity of (65 ± 5)% for 21 days. By way of comparison, samples of class C35/45 self compacted concrete were carried out under the same conditions in the laboratory. Tests were conducted in Grade II ICH-Constanta Laboratory. Results are summarized in the table below.

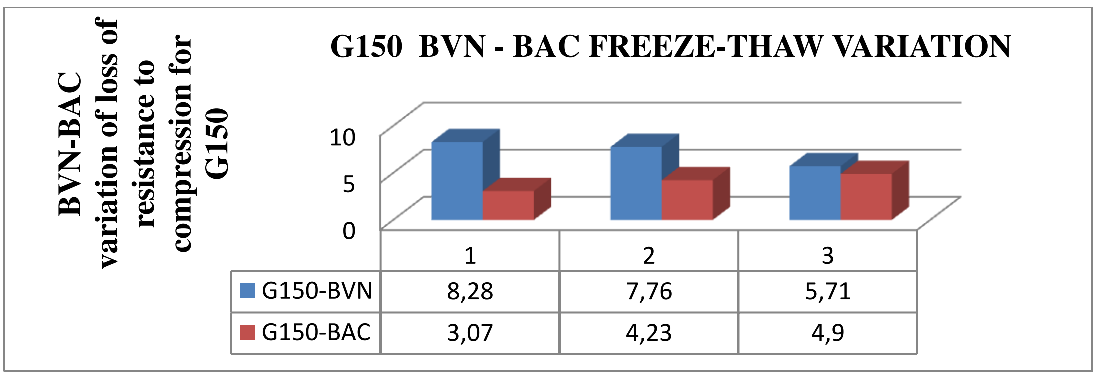


Figure 3.3- G150 BVN freeze thaw variation compared to BAC

By comparison, it is observed that resistance reductions were significantly greater for vibrated concrete self compacting concrete than for normal concrete. Better resistance to freeze-thaw of self compacteded concrete compared to normal vibrated concrete, can be explained by the greater compactness and permeability of the self compacted concrete compared to normal vibrated concrete.

3.1.2 Concrete resistance to erossion

In many cases the outer surface of the concrete is subject to wear. This may be due to sliding friction, scratching or hitting [71].

Erosion rate depends on the amount, shape, size and density of the particles transported the speed of their movement. Another feature that results in a behaviour of the concrete to erosion is the presence of large aggregates in the concrete composition that protects the less resistant mortar against mechanical action, either in water or in the air.

The waves are of particular importance in the design and furnishing of coastal port constructions. The force of the waves influences the erosion process over the concrete used in dams or construction works executed in seashore in contact with the sea.

The study of wind created waves in the Black Sea Coast, in the area between Sulina and Mangalia, is of interest in this doctoral work.

The quality of the concrete is of major importance on the rate of concrete erosion speed; it is usually expressed by concrete strength to compression. Thus, we conducted a comparative analysis of compressive strength for class C25/30 normal vibrated concrete and self compacted concrete of the same strength class.

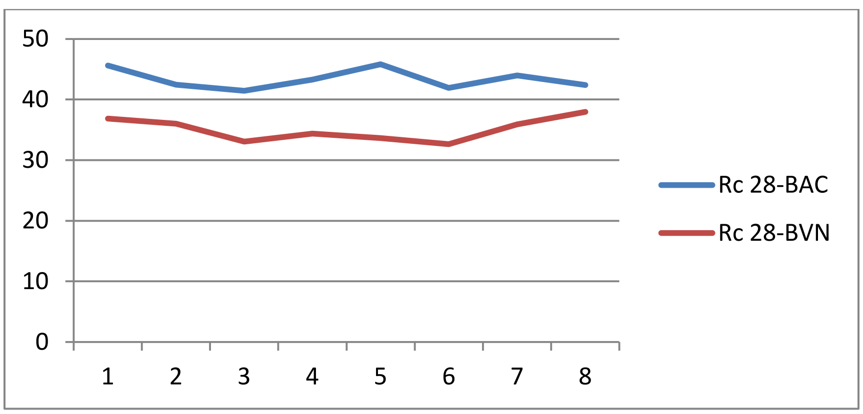


Figure 3.6 Compression strength for 28 days for self compacted concrete compared to normal vibrated concrete

3.2 Concrete chemical damage

Concrete chemical corrosion processes concrete are classified into 3 categories:

- Type I corrosion. At this stage partial selective dissolution of the components of cement stone occur, at the same time transforming it into a mixture of gels.
- Type II corrosion. It is specific to the aggressive agents who act in the same way as in Type I corrosion, in addition to this stage exchange reactions with components of

cement stone are carried out, compounds that usually are readily soluble and without binding properties.

- Type III corrosion is caused by sulphate solution and concentrated solutions of calcium chloride. In this stage, a bulky salt complex is forming, causing destruction of the cement stone due to the crystallization pressure which is higher than the stone cement own cohesion, phenomenon called sulfate expansion.

3.2.1 Acid corrosion

Acid aggression on concrete caused by carbon dioxide is another factor that can lead to premature deterioration of concrete. Carbonation is a phenomenon where the carbon dioxide in the air, in the presence of moisture, reacts with the hydrated cement minerals, such as for example calcium hydroxide, to form carbonates.

The level of carbonation of concrete can be determined by treating the freshly exposed concrete surface with phenolphthalein or manganese hydroxide: free $Ca(OH)_2$ is colored i pink, while carbonated portion remains uncoloured.

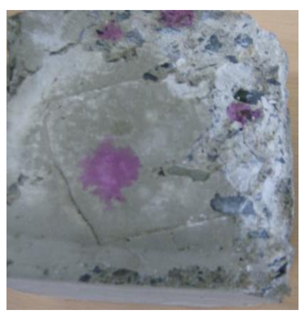


Figure 3.7 Determination of concrete carbonation by treatment with phenolphthalein (author photo)

The phenomenon of destruction of concrete through carbonation is carried out in the following stages: early leaching water containing carbonic acid aggressive is gradually saturated with calcium hydrogen carbonate and attacks the cement stone. Hydrogen carbonate is removed with water and non-linked final products remain from the degradation of cement stone (silica gels, hydrated alumina and iron). This area where water is saturated with hydrogen carbonate is called degradation area. Further, the solution saturated with hydrogen carbonate in contact with calcium hydroxide and the sparingly soluble calcium carbonate is gradually precipitated, the so called compacting area, characterized by gradual clogging of percolate crossings. Then, the percolated water completely loses carbonic acid and dissolves the cement stone [52].

3.2.2 Sulphur corrosion

Aggressive environment with high sulfur content, which acts from the outside on concrete, firstly attacks the clinker particles hydrated. The cement stone surface is unstable in a solution of sulphate, as well as the mineralogical individual components. The main sources of the suphur attack on concrete are the sulphatic ions of of magnesium, calcium, sodium and potassium.

Sulphate attack can lead to loss of strength, expansion, flaking skin layers and, last, to disintegration.

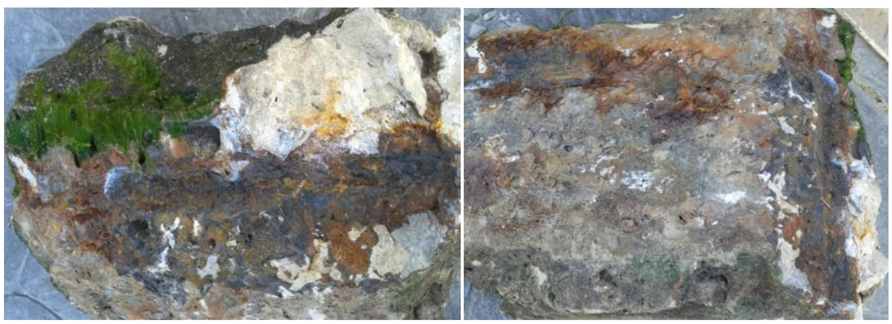


Figure 3.10, 3.11- Expelled concrete area, taken from Casino Mamaia walkway (author photo)

Concrete attacked by sulphates has a characteristic whitish appearance. Degradation firstly manifests on the edges and corners, being followed by progressive cracking and flaking [71].

Figure 3.12- Concrete under sulphate attack, laboratory sample (author photo)

The position of the concrete towards the level and level variations of aggressive water has a special influence on the rate of concrete sulfate corrosion. In case of total immersion of concrete, this will corrode at a lower rate than that partially submerged in sulfate solution. This is because, in case of partial immersion, due to the possibility of evaporation of water from aggressive solution, a higher concentration of aggressive agent is produced in the area above the solution level. If the concrete element is subjected to a variation of level, a series of physical factors appear, such as: drying alternated with watering, saturation, temperature variations, etc. [103].

Figure 3.13, 3.14- Degraded concrete elements at Casino Mamaia walkway (author photo)

3.2.3 Alkaline corrosion

A third category of reactions with a mechanism similar to sulphates attack consists of alkali chemical aggression on aggregate. Alcalii -aggregate reactions are reactions that take place inside the concrete. They occur when aggregates containing silica are attacked by alkaline solutions leading to formation of alkaline silicate gels. In the presence of sufficient water, they can lead to an expansion of the concrete. Deterioration of concrete through the formation of hairline cracks begin to surface with irregular route, followed by cracks. Other symptoms of deterioration of concrete due to alkali-aggregate reaction may be:

- local detachment from the concrete surface in the form of shootings, due to the existence of an internal pressure. It is possible that a silica gel in combination with altered aggregate is observed in the degraded area;
- deposits on concrete of alkali-silica reaction products in the form of whitish deposits;
- the presence of the silica hydrogel on the surface of the concrete through the pores, cracks.

Until now, three types of alkali-aggregate reaction are known: alkali-silica reaction, alkali-carbonate reactions and alkali-silica / silica reactions. Silicate minerals associated reactions were initially called alkali-silica reactions, but due to conflicting issues raised by some, researchers have adopted the terminology of alkali-silica reactions / silicate.

Regarding the experimental research of alkali-aggregate reaction in self compacted concrete, the specialty literature only presents a few experimental results, as the domain laks in research.

The most commonly encountered reaction of alkali and aggregate is the reaction between the active constituents of silica and alkali in the cement. The reaction is manifested by alkaline hydroxides derived from alkali attack under cement (Na_2 and K_2O) on siliceous minerals in the aggregate, with the formation of an alkali silicate gel. This gel embedded in cement paste has the ability to increase the volume, creating an internal pressure that can lead to the disintegration of cement paste [71].

The minimum amount of alkali in the cement that can complete the reaction is of 0.6% equivalent of sodium carbonate.

There are two types of reactions alcalii- aggregate:

- alkalii- silica reaction (ASR)
- carbonate alkali reaction (ACR)

There is necessary to verify the alkali-aggregate reaction where concrete comes in constant or alternate contact with water or a wet environment.

3.3 Concrete biological damage

Concrete constructions can suffer mechanical damage under the influence of vegetation growing on them or near them. Mention may be done on lichens, mosses, algae and small roots which penetrate through concrete cracks and weaknesses, creating splitting forces, producing growth of the cracks and deterioration of concrete [75]. This vegetation can retain water on the concrete surface, which could lead to saturation and implicitly increasing the risk of degradation of concrete through freeze-thaw phenomenon.

Due to increased oxygen content of seawater, microorganisms and algae sits on the concrete surface anytime there are favorable temperature conditions [52]. Thus, a barrier against migration of ions in both directions is formed in this way, the plants consuming the oxygen before it is delivered in concrete.

Stroger roots can destroy concrete by physical action or by their ability of producing carbonic acid and other organic acids.

Figure 3.16- Concrete elements subjected to the action of vegetation

CHAPTER 4. SELF COMPACTING CONCRETE CONCEPT. COMPARATIVE ANALISYS BETWEEN SELF COMPACTING CONCRETE PROPERTIES AND CONVENTIONAL CONCRETE PROPERTIES

4.1 Tests on fresh self compacting concrete

Fresh self compacted concrete is characterized by three parameters:

- Filling capacity, ie the ability of self compacted concrete to flow under its own weight and fill the spaces formwork;
- The ability to easily pass through reinforcing bars through narrow openings;

High resistance to segregation, the concrete capacity to maintain the homogeneity of the concrete under high fluidity conditions.

In order to study the characteristics of self compacted concrete and normal vibrated concrete in fresh and hardened state in aggressive marine environment, we produced two self compacted concrete compositions and 2 normal vibrated concrete compositions.

To study the properties of fresh concrete we realized a self compacting concrete composition and a normal vibrated concrete composition using a fly ash-based cement, CEM IIAV42,5R manufactured by CRH (Cement) Romania SA. This cement contains a thermal power plant fly ash addition of between 6-20% and is characterized by high stability.

In this study we observed the fresh concrete, for both types of compositions, self compacted concrete and normal vibrated concrete, spreading ability, resistance to segregation. The following characteristics of the self compacted were observed: flowability, the ability of passing through the reinforcement bars, the resistance to segregation using the standardized methods mentioned above.

I made the mixture in a central automated concrete mixing mixer with a capacity of 2.25 cubic meters. Concrete mixing time was 45 seconds from the addition of the last component.

In the first stage fresh concrete properties were screened. The tests were conducted in the Grade II CRH Concrete SRL Ovidiu Laboratory. Subsequently, hardened concrete determinations were done in Grade II CRH Concrete Ovidiu Laboratory and Grade II ICH Constanta Construction Group Laboratory.

Comparisons were made for self compacted concrete and class C30 / 37normal vibrated concrete, with the following characteristics:

C30/37 CONCRETE	SCC	TVC
Cement dosage [kg/mc]	390	380
Calcar filler [kg/mc]	135	-
Admixture Glenium 115 [kg/mc]	-	2.09
Admixture Optima 203 [kg/mc]	8.58	-
A/C	0.48	0.47

Table 4.5- The recipe used for manufacturing SCC and normal vibrated concrete samples

4.1.1 Determining propagation

For the evaluation of the properties of fresh concrete, the representative test was to determine the spread of compaction, resulting in a spread of compaction of about 700mm as compared with the normally vibrated concrete where visible segregation and moisting were observed on class C30/37 concrete, class S5 consistency, with a slump of approx. 230 mm. The test can be performed easily with Abrahms cone, the result being the average of the two diagonal measurements.

Figure 4.1, 4.2-Test for self compacted concrete spreading compared to subsidence to a fluid concrete (author photo)

4.1.2 V-Funnel test

V-funnel and O-funnel testing methods on the self compacted concrete intended to assess the viscosity and the compacting ability of concrete. The procedure included a 12 lt bucket of self compacted concrete poured into the O'funnel. After 10 sec from filling, I opened the hatch, the time required for the concrete to flow being of 11sec between the opening of the hatch and the moment the entire quantity of concrete was poured.

Figure 4.4- O'funnel test on self compacted concrete (author photo)

4.1.3 L-box test

In order to determine the flow and transition capacity, to visually detect the flow capacity, we used the L-box test. The test may be performed in two variants, using 2 bars, simulating the presence of a more permissive reinforcement and using 3 bars simulating the presence of more congestionate reinforcements. We determined the PA crossing ability as a ratio between concrete height on vertical section and concrete height in horizontal section, according to **EN12350-10 SR: 2010**. The result was 1, concrete fits in PA2 class, ie concrete with a good ability to pass

Figure 4.5- L-box test for self compacted concrete

4.1.4 J-ring test

This determination aims to assess the carrying capacity of self compacted concrete. The layout of the ring bars simulates the presence of a fine reinforcement or a more permissive one. An Abrahms cone is necessary for this test. It is installed in the, making it possible to perform the spread test at the same time. The spread flow was calculated in accordance with **SR EN12350-12: 2010** as the average of the sum of the largest spread diameter and the 90º spread to the largest diameter of the spread. The rate of spread was of 8mm.

Figure 4.6-J- ring test for self compacted concrete

4.1.5 Testing segregation resistance using sieves

This method is used for determining the resistance to segregation of self compacting concrete. We made this determination in accordance with **SR EN12350-11:2010**. For making the determination we needed a balance, 5 mm of square mesh and drip tray. The result in this determination was SR = 16.94%, which puts the self compacted concrete studies into SR1 segregaton class.

$$SR=\frac{(m_{ps}-m_p)X100}{m_c}\ [\%],$$

SR-the segragated part in procents;

The results obtained in accordance with **SR EN12350-11:2010** were as follows:

m_{ps}=2113 gr.

m_p=1275 gr.

m_c=4945gr.

$$SR=\frac{(2113-1275)X100}{4945}=16,94\%$$

Figure 4.7, 4.8-Determinining the resistance to segregation using sieves

The results obtained on the studied self compacted concrete are shown below:

Test	Unit of measurement	Result	Standard
Total settling with Abrams cone	mm	700	SF2
V funnel	sec	6	VS1/VF1
L box		1	PA2
J ring	mm	7	PA2
SR segregation resistance	%	18	SR1

Table 4.6-Parameters of the tested self compacted concrete

Following the determinations made it was found that self compacted concrete studied fulfills the the predetermined consistency and viscosity parameters, the specific behavioral self compacted concrete parameters falling within the limits set in the European Guide for self compacted concrete.

4.2 Tests on hardened concrete. Comparative studies on self compacting concrete samples and vibrated concrete in marine environmental conditions

For determining the mechanical strength of concrete specimens and study their behavior under the action of seawater, we have made 48 series of concrete: 17series of normal vibrated concrete and 17 series of self compacted concrete. In both cases, the desig class was C30/37. To simulate the aggressive marine environment, the immersion in seawater, we sampled sea water from the Black Sea in Mamaia Casino area, and put the samples of self compacted concrete and normal vibrated concrete. In order to compare the results, we filled with distilled water some tanks in which we maintained the samples. Testing on hardened concrete as part of the herein thesis were: determining the resistance to monoaxial compression, determining the tensile strength of bending and splitting, determining concrete static elasticity modulus, determining water permeability of concrete and determining the depth of carbonation.

4.2.1 Determining the resistance to monoaxial compression

One of the most common tests used to highlight the quality of concrete is that of determining monoaxial compressive strength. This determination is of particular importance because the structural safety of the building depends on the compressive strength of concrete and the fact that this test on hardened concrete reveal other characteristics of concrete durability, namely the resistance to erosion, resistance to freeze-thaw, permeability, the modulus of elasticity of the concrete. At the same time, it is the easiest tes to perform.

To achieve this determination, we made 10 self compacted concrete cube samples and 10 samples of conventional concrete, with 150X150X150 mm sides. Samples of self compacted concrete was made by pouring the actual concrete in molds, intervening with only the finishing of the surface layer with a trowel, while the samples of conventional concrete ware made by placing a layer, shoving a metal rod and by vibrating on a vibrating table as pe SR EN 12390-2:2009.

Fig.4.9-Manuacturing of concrete samples

The results obtained are presented below:

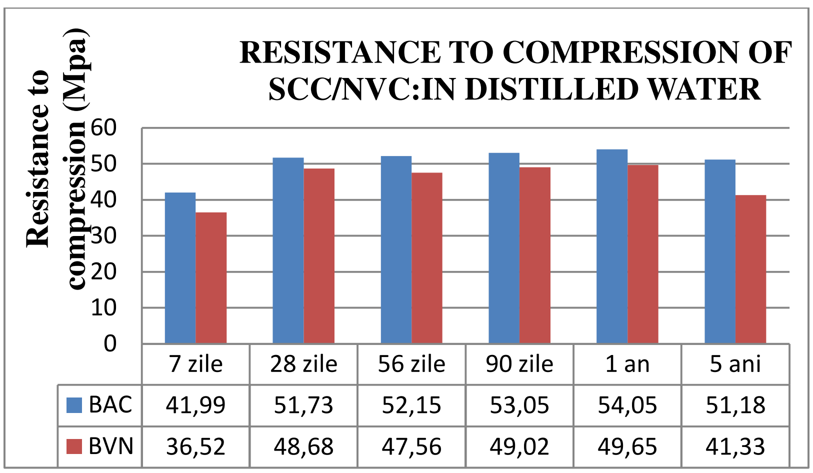


Figure 4.11- Resistance to compression of SCC/NVC kept in distilled water

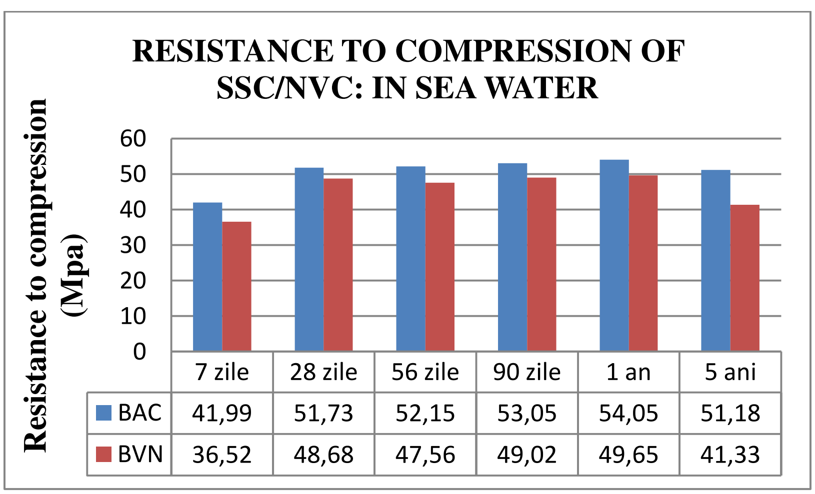


Figure 4.12- Resistance to compression of SCC/NVC kept in sea water

From tests performed both on self compacted concrete and normal vibrated concrete it was found that the self compacted concret has a superior compressive strength versus normal vibrated concrete, which can be explained by the improved adhesion between aggregate and paste in self-compacted concrete, as well as by its better compactness. Up to 56 days there were no visible degradation signs of concrete specimens. The concrete test pieces were immersed in water and their mass increased as compared to when they were immersed in water up to the age of 56 days, when the saturation phenomenon ceased.

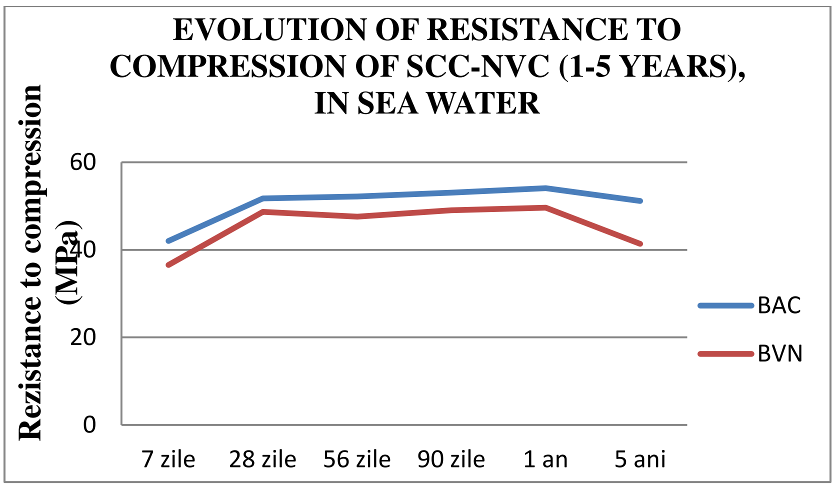


Figure 4.13-Evolution of resistance to compression of SCC/NVC for 5 years in sea water

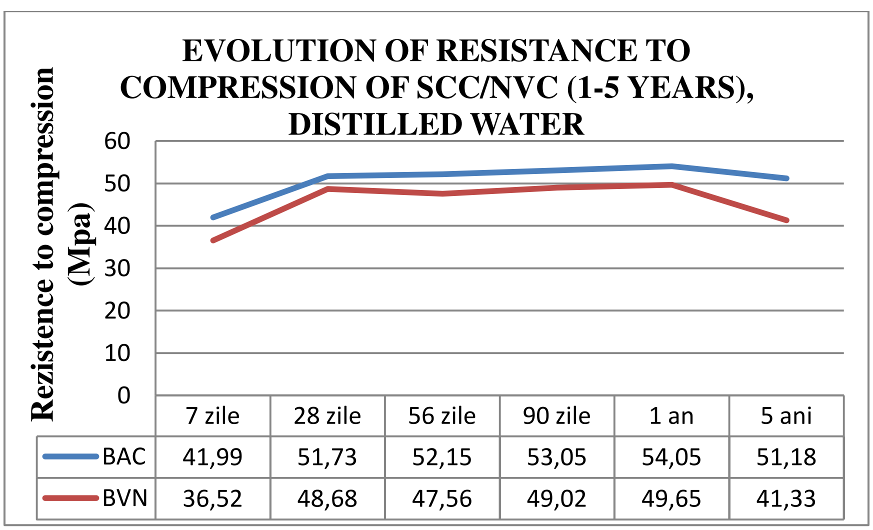


Figure 4.14- Evolution of resistance to compression of SCC/NVC for a period of 5 years in distilled water

.2 Determining flexural tensile strenght

The flexural strength of concrete should be so that to estimate the area where the construction element can be cracked. This is of particular importance for marine constructions operated since cracking in concrete is the main way of penetration of aggressive substances in concrete.

In order to achieve this, we manufactured 6 series of prismatic samples of self compacted concrete and 6 series of samples of of normal vibrated concrete with dimensions of 100X100X550mm. Both samples were maintained only in the worst condition, ie in pools with water taken from the Black Sea, Casino Mamaia area. The test was carried out according to STAS 1275/88

Figure 4.17, 4.18- Determinining the flexural tensile strength for SCC

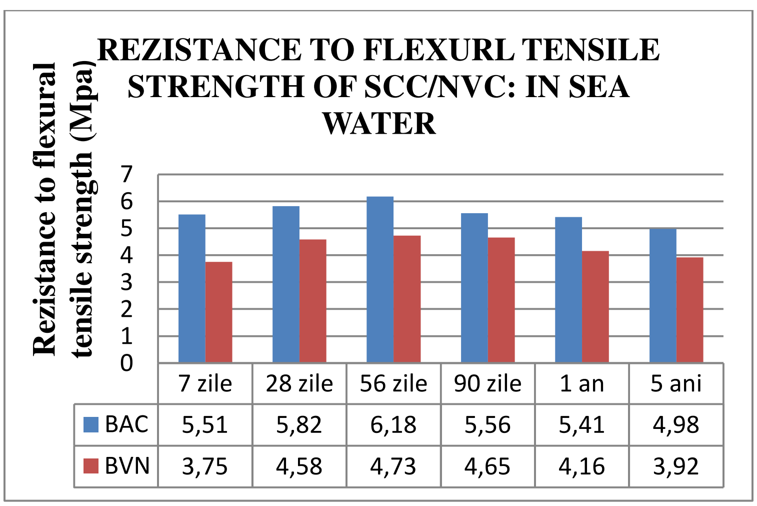


Figure 4.19- Rezistance to flexural tensile strength of SCC/NVC in sea water

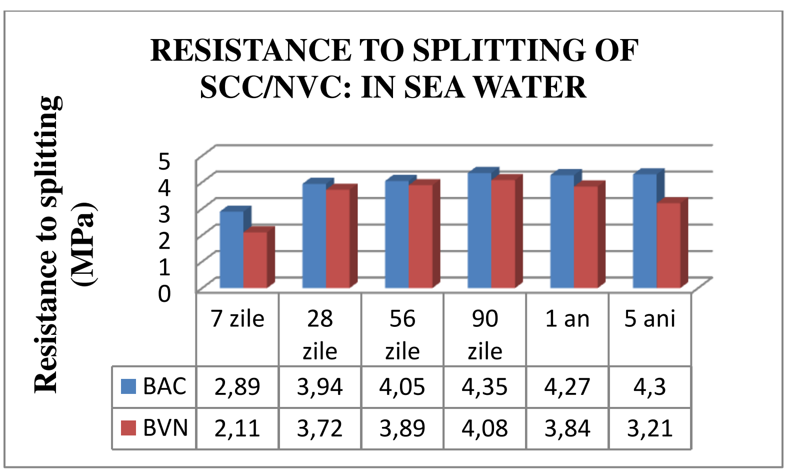
4.2.3 Determining splitting resistance

To achieve this we made cylindrical concrete specimens of SCC and 6 normal vibrated concrete cylindrical specimens, and kept them up to the age test in seawater. Cylindrical test pieces were 100x300 mm size, and the test was conducted in accordance to STAS 1275-1288.

In order not to distort the trial because a very large compressive stress shall be applied in the load application area, 2 wooden pieces shall be placed between the cylinders and the press platens.

The rezults and interpretation of the determinations performed are preseted i the below graphs and tables. The measurement units are fo the mass [gr], the resistance to splitting being noted as Rt [MPa or N/mm^2].

Figure 4.21, 4.22- Determining the resistance to splitting of SCC



	7 zile	28 zile	56 zile	90 zile	1 an	5 ani
BAC	2,89	3,94	4,05	4,35	4,27	4,3
BVN	2,11	3,72	3,89	4,08	3,84	3,21

Figure 4.23- Resistance to splitting of SCC/NVC kept in sea water

From the results one can observe a higher density of self compacted concrete batch series versus normal vibrated concrete but also a slightly higher resistance when vibrated concrete self compacted concrete to normal. This is due to the better and better compactness of the self compacted concrete thanks to a more dense structure, self compacted concrete without defects. Following tests on cylindrical elements split, for self compacted concrete there is a homogeneous structure of concrete with a uniform distribution of aggregates, without pores while the cylindrical elements of vibrated concrete normally there is a porous structure even after vibrate. These issues found for the two types of concrete confirm the suitability for use in the construction on the Black Sea marine aggression area.

4.2.4 Determining water permeability

Determining the degree of permeability of concrete is of special importance for the quality assessment of concrete exploited in the marine environment. The permeability of the surface layer of the concrete depends on the ability of penetration of aggressive substances in concrete and thus the overall sustainability of the construction element located in aggressive marine environment.

To determine the water permeability of concrete, we have made a series of self compacted concrete and a number of normal vibrated concrete samples that we have maintained in seawater until the age of 90 days. The test was carried out according to STAS 12390-8: 2009 by applying a water pressure of 1200 kPa for 48 hours. We achieved better results for self compacted concrete than for normal vibrated concrete, due to the better compactness and density of the self compacted concrete compared to normal vibrated concrete. Water penetration depth was 5.3 cm in the case for self compacted concrete compared to 7.8 cm for normal vibrated concrete at 28 days.

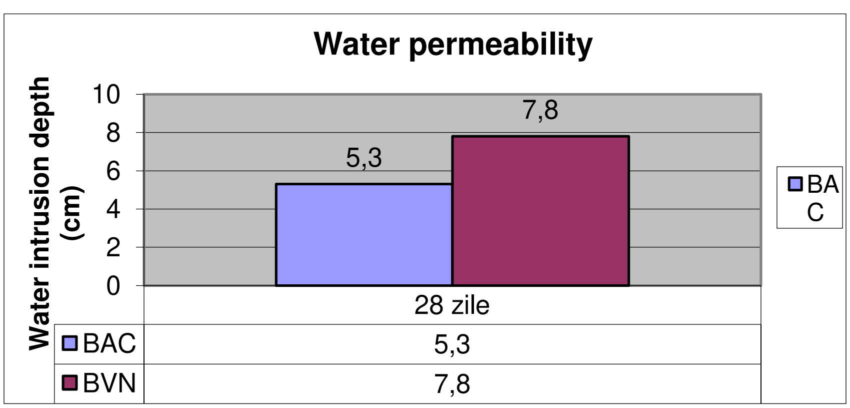


Figure 4.25- Water permeability of the self compacted concrete compared to normal vibrated concrete

4.2.5 Determining carbonation depth

Carbonation of concrete is another phenomenon which results in premature degradation of the concrete operated in the marine environment. Concrete carbonation reaction is a chemical reaction by means of which the cement slurry during hydration using CO_2 molecules through the process of diffusion, a phenomenon accelerated in the presence of moisture

The phenomenon of carbonation of concrete can be detected by treating it with freshly exposed phenolphthalein.

Carbonation of concrete depends largely on the water / cement so it can be appreciated that for the upper class concrete with a low water / cement ratio, the carbonation of concrete phenomenon occurs at the margins. The reduction depends on the phenomenon of carbonation of concrete and reinforcement steel protection.

To highlight the phenomenon of carbonation I made 2 series of concrete that were kept in seawater until the age of 90 days. Between the ages of 90 days and five years, the samples were kept outdoors, in the marine of Constanta, in concrete CRH storage house. Phenolphthalein reagent was used, a 1% solution in 96% ethanol. In the test we did at the age of 5 years, the phenomenon of carbonation is evident at the normal vibrated concrete (about 5 feet),for self compacted concrete (about 3 cm), also due to better compactness and permeability of self compacted concrete. The tests were conducted on the same formulation of self compacted concrete and normal vibrated concrete, i.e. C30 / 37 presented at the beginning of the case study.

Figure 4.26- Highlighting the carbonation by treating the concrete crack with phenolphtaleine

The results are shown below :

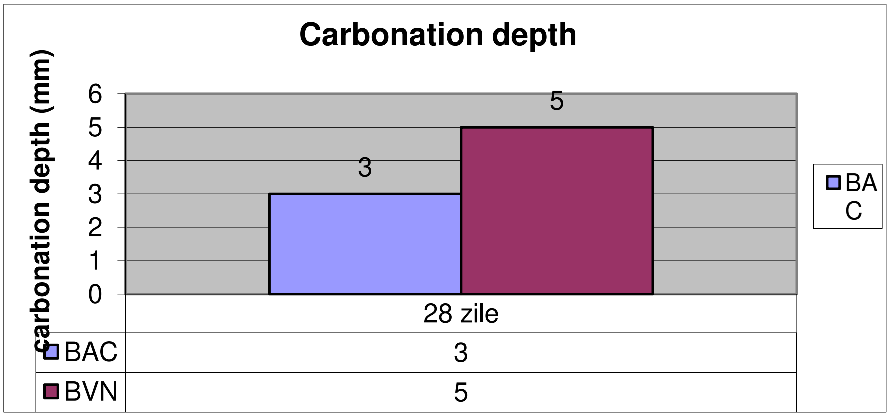


Figure 4.27- Determining the carbonation depth of self compacted concrete compared to normal vibrated concrete

4.3 Presentation of self compacting concrete samples realized by the candidate withing the research project for comparison with similar samples of normal vibrated concrete

After laboratory testing in the second part of the PhD program, I moved on to manufacturing of prefabricated elements, a pole, a wall aperture and small plate to study the behavior of self compacted concrete in horizontal vertical element respectively. In the manufacture of concrete elements, we used a concrete composition having the strength class C20/25. The elements made fulfilled the expectations, as we obtained perfectly smooth sides without vibrating the concrete, the elements could be stripped 24 hours after pouring, for temperatures of 28 °C to 20 °C during the day and at night.

Figure 4.30,4.31,4.32- Precast self compacted concret elements after stripping (author photo)

After stripping, the precast elements made were maintained in natural marine environment (marine environment of the city of Constanta), CRH Concrete sample storage, for a period of 5 years. In the first 2 years, the prefabricated components were watered every 1 month with seawater taken from the Black Sea to simulate specific marine splash zone. After 5 years of analysis of prefabricated elements, degradation was not visible; although several items were subjected to freeze-thaw cycles, the action of wind, fog marine environment, etc. thus the self compacted concrete confirming its previously described properties.

In the next stage of the doctoral research we studied the behavior of self compacted concrete in practice, within the project "Expansion, renovation of Hotel Mamaia" and the project "Bridge construction over the Danube-Black Sea Channel, km 0 + 540".

In the first project, "Expansion, renovation of Hotel Mamaia", the components (pillars, reinforced concrete diaphragms) were intended to be very heigh, of about 4.5-5 m height. Initially, they tried by casting normal vibrated concrete using the conventional technology, concrete pump casting and vibrating.

Figure 4.33, 4.34- Construction elements poorly compacted due to large height of elements (photo author)

The results were unsatisfactory, the designer deciding these pillars demolition and rebuilding using self compacted concrete and specific technology for implementing its work. The solution adopted to use the self compacted concrete gave superior results compared to the traditional method, thus, the project was continued using only self compacted concrete.

In the second project studied, "Bridge construction over the Danube-Black Sea Channel, km 0 + 540", the designer adopted from the very beginning the solution for accomplishing the main pillars of the bridge using self compacted concrete. An optimized composition of self-compacted concrete, resistant to aggressive marine environment, was used, taking into account the influence on the specific behavioral parameters of self compacted concrete. Asfter stripping, no segregation or structural defects were found, elements having perfectly smooth sides. The better compactness of the self compacted concrete led to superior results as compared to normal vibrated concrete.

Figure 4.39- Elements before casting, in "Bridge over the Danube-Black Sea Channel, km 0 + 540" project (author photo)

All properties verified in the fresh self compacted concrete were within thelimits recommended by the European Guidelines for self compacted concrete, properties of high fluidity and resistance being achieved by increasing the overall amount of binder and next generation carboxilateter based superplasticising additives.

Regarding the determinations on hardened concrete, from the tests performed both on self compacted concrete and norrmal vibrated concrete, it was found that self compacted concrete has a better compression resistance than TVC, which can be explained by improved adhesion between the aggregate and hardened paste, in the case of SCC, as well as better compactness. Untill 90 days there were no visible degradation signs of the test specimens of concrete. Test pieces of concrete, submerged in water, have increased their mass compared to when they were introduced by waterlogging, more for TVC than for SCC, probably due to the denser pores in the structure of SCC. Self compacted concrete having the same amount of water/cement ratio, normally have an equal strength or even slightly higher compared to normal concrete, because of the suppression of vibration, resulting in improved adherence of aggregates and hardened paste. Studies show superior density of SCC compared to TVC, due also to its greater compactness.

CHAPTER 5. STUDIES AND RESEARCHES REALIZED BY THE CANDIDATE ON SELF COMPACTING CONCRETE FOR USING IT IN CONSTRUCTIONS MOUNTED IN THE BLACK SEA AREA

5.1. Use of cement resistant to marine agression in concrete composition

5.1.1 Mineral composition of cement

In the cement manufacturing process, raw ingredients are subject to various physical and mechanical processes, resulting in transforming rock into powder. Raw materials contained in cement can be made of natural minerals from limestone, clay, etc. but also from industrial products such as granulated blast furnace slag or fly ash.

Rock minerals used in the manufacture of cement can be grouped as follows:

- Carbonates, lime cement in component, such as the limestone rock, shale, chalk;
- Alumina silicate minerals and iron oxides which is the clay component of cement;
- Free silica, as correction material in cement composition.

5.1.2 Characteristics of aggregate cement

The main aggregate cement types are:

1. **Cement clinker with granulated blast furnace slag**

This type of cement is obtained by grinding the mixture in addition to Portland cement clinker, granulated blast furnace slag and gypsum in order to adjust the setting time. The addition of slag in the mixture generally varies between 15 and 50% but may reach 85%, depends on the quality of the slag and other factors. Mechanical resistance of cements with blast furnace slag varies between 42.5 and 51.6 MPa after 28 days.

2. Cement clinker with the addition of fly ash

The addition of fly ash varies depending on the quality of ashes, the fineness of grinding, in Romania, the addition of ash in cement is limited to 15% as per standard STAS 1500-78.

The addition of fly ash in cement gives high chemical stability, mainly by slightly reducing the content of calcium hydroxide of reinforced cement.

3. Cement clinker with the addition of tuff (trass)

Cement clinker with the addition of tuff is characterized mainly by low shrinkage, low heat of hydration and stability to chemical aggression. The addition of trass in clinker cements with added tuff is off 5% as per STAS 3011 - 83.

Resistances of these types of cement develop very slowly but final resistances are approximately the same as Portland cement without additives.

4. Sulphate slag cements

These types of cement are obtained by activating sulfated slag, and the composition of approx. 75-90% of blast furnace slag, 5-20% calcium sulphate and up to 8% baric substances (lime clinker, calcined dolomite).

Slag sulphate cements are characterized by good stability to the action of aggressive water for which reason they can be successfully used to achieve massive underground or underwater constructions, sewer pipes and constructions located in areas involving aggressive action of water.

In 2012, in order to highlight the development of hydration heat of cement in concrete, we conducted a comparative study on IIAV42,5 R cement, cement with fly ash added with high initial resistance, and III A42,5N-LH cement, resistant to chemical aggression and has reduced of hydration heat, with lower initial resistance, both produced by SC Lafarge Ciment (Romania), factory of Medgidia. The objective was to highlight the importance of using reduced hydration cements for construction works on the Black Sea coast, to limit or even eliminate pathways for the penetration of aggressive substances in concrete cracking, resistance to frost-thaw, permeability, etc.

In this chapter I will syntheticaly present the results of compression strength on 10 series of mortar cement samples obtained with cement IIAV42,5R and 10 normal vibrated concrete compositions made with the same type of cement, consequently, in the next section I will present the results for IIIA42,5N-LH cement and concrete compositions made with this type of cement as well as a comparative study on the development of compression strength on the two types of cement respectively on the two normal vibrated concrete compositions. Normal vibrated concrete recipe designed for the study was class C30 / 37 in both cases, the maximum aggregate size was of 16 mm with a cement dosage of 360 kg / m³.

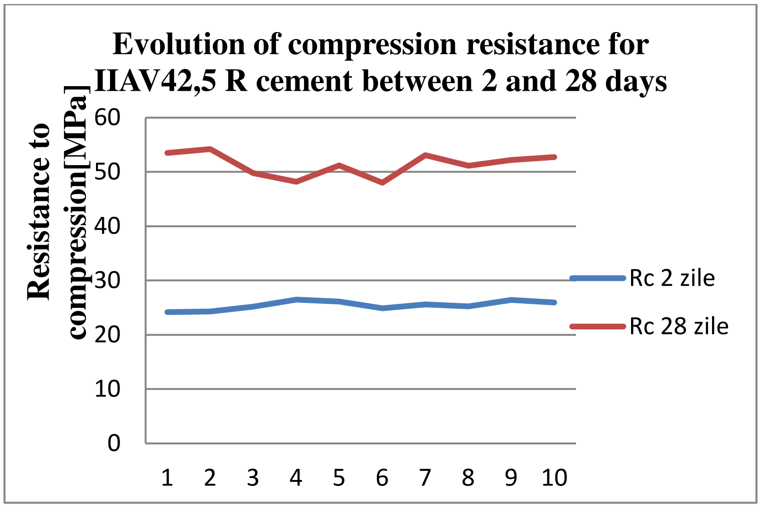


Figure 5.1- Evolution of resistance to compression of IIAV42,5R cement, 2-28 days

5.1.3 Characteristics of cements resistant to marine environmental aggression

Aggressive environments are those liquid and gases environments containing free CO_2, sulphates, chlorides, organic substances (fats, animal and vegetable oils) such as ground, sea and ocean water, the residual and humid gas with or without SO_2, H_2S, Cl_2 [102].

Cements are divided into 3 categories, according to the research conducted by Solacolu, from the point of view of stability to aggressive marine waters, depending on the content of C3A:

- Very stable cements, characterized by M_{Al} <0.64
- Stable cements, where 0.7 < M_{Al} <1
- Acceptable cements characterized by 1 < M_{Al}<1.4, usable only in case of low impact of water.

In this thesis, we will use a cement with a high content of slag, between 36-65%. The main feature of this type of cement is resistance to sulphate attack (XA_1, XA_3) and the attack given by seawater. It is also characterized by a low hydration heat, the hydration heat developed by this type of cement in 7 days is <= 220 J / g and lower initial resistances.

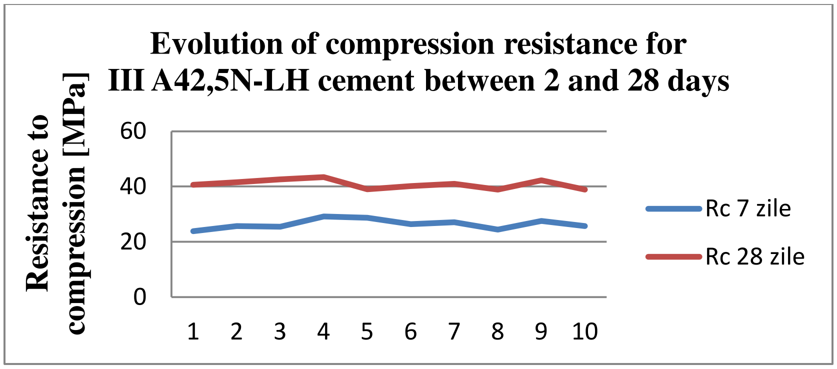


Figure 5.3- Evolution of compression resistance for III A42,5 N-LH cement, 2-28 days

The high contens of slag in IIIA42,5N-LH cement helps the formation of fine dispersed hydrosilicates and hydroalumina. They reduce the overall porosity of the concrete matrix with favorable effects on the durability of concrete. By increasing the amount of slag in the cement composition, the amount of calcium hidroxid available for the reaction with the atmospheric carbon dioxide with calcium carbonate that is formed reduces.

Further, we analyzed the evolution of class C30/37 concrete strengths produced with CEM IIIA 42,5N-LH cement, and then compared them with those of ready mix concrete prepared with CEM IIAV42,5R.

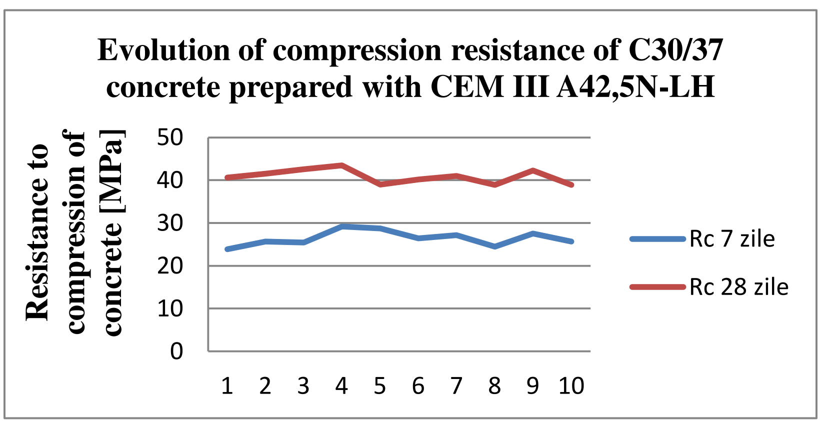
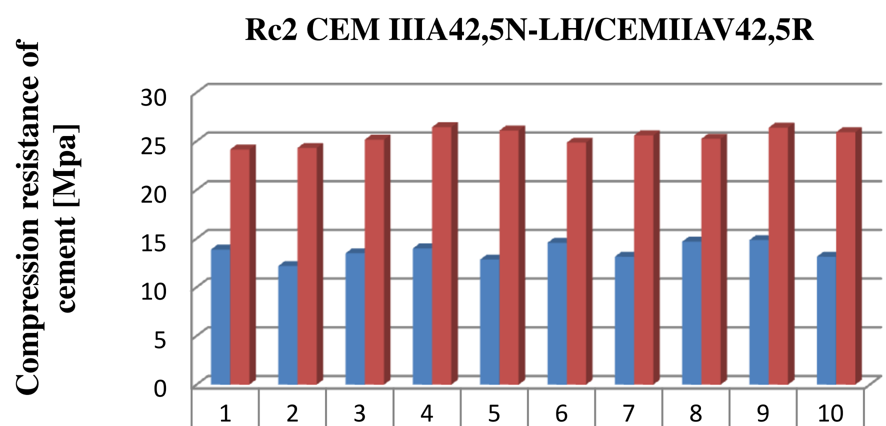


Figure 5.4- Evolution of compression resistance of C30/37 prepared with CEM III A42,5N-LH, 7-28 days

Increasing the dosage of slag in IIIA42,5N-LH cement leads to a less permeable cement stone that offer less risk of diffusion of chloride ions in sea mist. Research has shown that cements containing more than 36% in slag composition have a pore diameter less than 0.01 µm compared to no added cements where the majority of pores is more than 0.1 µm.

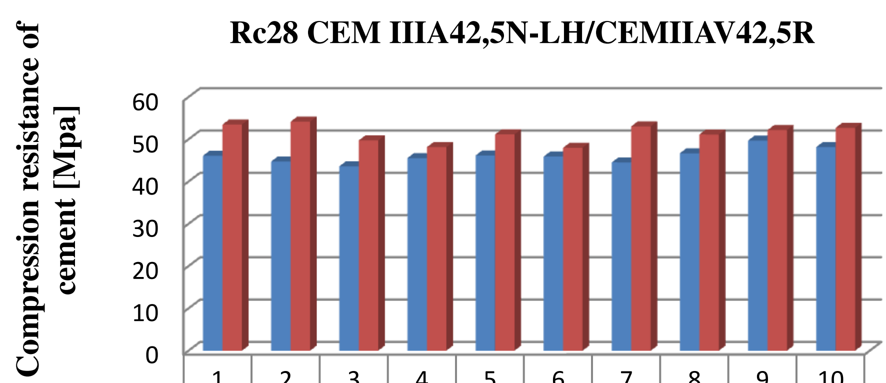
Cement with granulated blast furnace slag presents high chemical stability to sulphate, carbonate and chloride ions, comparable to a Portland CEM I cement.



	1	2	3	4	5	6	7	8	9	10
Rc 2 zile IIIA42,5N/LH	13,87	12,18	13,49	13,99	12,85	14,57	13,14	14,68	14,85	13,14
Rc 2 zile IIAV42,5R	24,15	24,31	25,16	26,45	26,1	24,85	25,6	25,25	26,4	25,92

Figure 5.5- Evolution of cement compression, III A42,5 N-LH/IIAV42, 5-2 days

From the results presented, it is noted that CEM 42.5 N-LH IIIA cement develops initial resistance lower than other types of cement, in this case compared to cement IIAV42,5R, which significantly reduces the risk of cracking and thus penetration of aggressive substances in the concrete.



	1	2	3	4	5	6	7	8	9	10
Rc 28 zile IIIA42,5N/LH	46,13	44,76	43,62	45,57	46,18	45,93	44,55	46,71	49,7	48,16
Rc 28 zile IIAV42,5R	53,51	54,19	49,75	48,15	51,16	48,02	53,08	51,15	52,19	52,73

.

Figure 5.6- Evolution of cement compression, III A42,5 N-LH/IIAV42, 5-28 days

5.2 Analisys of aggregates ractivity for their use in preparing concrete exposed to marine conditions

5.2.1 General

In the preparation of concrete subjected to the action of the marine environment, besides the aggressive action should that may affect the cement stone, one should also consider the aggressive action on the aggregates used in the preparation of concrete. Therefore, in the preparation of concrete subject to marine aggressiveness one should consider the formula of aggregate concrete, such as sand and gravel from the river, aggregates quarry whose base material is quartz or sand and coarse aggregates obtained from volcanic rocks by breaking. Aggregates obtained by granite, diabase, andesite, basalt, sandstone and other rocks crushing, can be safely used in acid medium and in alkaline conditions at low temperatures [44]. River sands, generally if the relevant technology of washing and equipment comply, contain less harmful materials, the maximum permissible clay being of 3%. The presence of clay in the sand and implicitely in the concrete has a detrimental effect on it, because it tends to wear particles thus preventing direct binding of cement.

5.2.2 Granulometric analysis

The main factors that characterize the granulation of the aggregate are:

- Total area of the particles
- The relative volume occupied by the aggregate
- Workability of mix
- The trend of segregation

There is a unique grading curve, the trend is towards a compromise between the physical and economic conditions. Most often, the concrete is made of local materials, which can be obtained cheaply.

There is no limitation on the maximum size of the aggregates used in self compacted concrete composition, but in most cases the aggregate size used is of maximum 16 mm.

To emphasize the importance of using self compacted concrete in the completion of the construction exposed to aggressive marine conditions, for the rehabilitation of historical buildings where the possibility of vibrating the concrete are doubtful or would endanger the safety of the structure, following this thesis I realized a study of a self compacted concrete composition grained 0-8 in two versions. We have proposed a SCC composition of aggregate limestone taken from the Balcescu career, in Constanta county, solution proposed to rehabilitate the ancient fortresses on the Danube, Pacuiul lui Soare, Capidava, but also those in the neighborhood, Adamclisi, Histria and so on. A second SCC solution proposed is for a composition grained to 0-8, from aggregate of granitic rock taken from Turcoaia career, Tulcea, solution proposed for the rehabilitation of Casino Mamaia walkway and historical buildings in the historic area of Constanta.

5.2.3 Alkali-aggregate reaction

The need to verify alkalii- aggregate reaction is required in situations where concrete comes in constant or alternatively contact with water or a wet environment.

Checking aggregate reaction alkali - aims:

- Assess the reactivity and potential harmfulness of aggregates containing silicon dioxide forms of low crystallisation with cements alkali
- Check the possible use of these aggregates with cement able to mitigate or neutralize the harmful effects of reaction (low alkali content cements, pozzolan cements, etc.) [139].

To determine the alkali-aggregate reaction between the two types of units used in the preparation of both self compacted concrete compositions, we have made use of the determination of the chemical method of alkali-aggregate reaction, according to the SR 5440-2009. Alkali-aggregate reaction chemical study was performed in the Grade I CRH Ciment (Romania) SA Laboratory. The study of reaction in the research laboratory consisted of two main stages:

- Reducing the concentration of NaOH, where the samples provided in the fineness of grinding as per SR5440-2009 were treated with NaOH solution, and then the operation was carried out by titration with phenolphthalein and methyl orange
- Determination of SiO_2 dissolved in the solution of NaOH, method described in detail in SR 5440-2009.

The results obtained are shown below in tabular and graphic supported by images captured during the making of the determination.

Calcareous rock samples are noted C1 and C2 while granitic rock samples, G1 and G2.

Sample G1	grams	Sample G2	grams
Empty crucible	30.8112	Empty crucible	30.4957
Filter A+B	30.8130	Filter A+B	30.4558
Treatment with hydrofluoric acid evaporation	30.8037	Treatment with hydrofluoric acid evaporation	30.4307
After calcination	30.8003	After calcination	30.4292
	0.0127		**0.0266**

Table 5.9- Primary data, samples G1, G2


Figure5.14, 4.15- Sample filtering with vacuum pump

Sample		NaOH 0.05N solution							Rc	R'c	A1	A2	Sc
		V1	V2f	V2m	V3f	V3m	V'2	V'3					
T84	C1	20,00	29,52	3,64	28,88	3,04	55,40	54,72	-35	-37	0,01016	0,00688	10,9224
	C2	20,00	27,36	4,80	28,88	3,04	49,92	54,72	82	259	0,02128	0,00688	47,952
T85	G1	20,00	17,80	12,24	28,88	3,04	23,36	54,72	599	1695	0,0292	0,00688	74,3257
	G2	20,00	18,20	14,44	28,88	3,04	21,96	54,72	577	1771	0,0588	0,00688	172,894

Table 5.13 –Results obtained for reducing NaOH concentration and SiO_2 dissolved in hydroxide solution

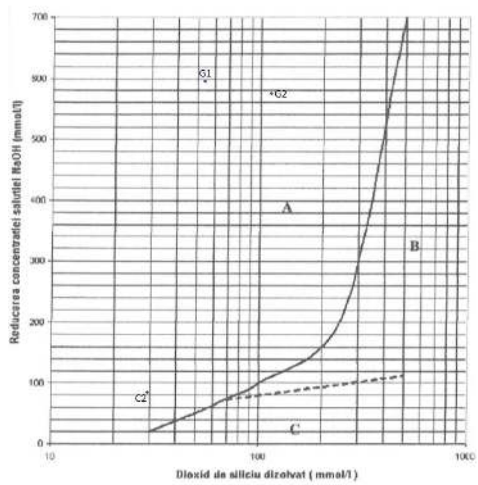


Figure 5.19- Interpretation of results for determining the reactive potential of aggregates in alkali-aggregate reaction

The results for G2, C1 and C2 are inserted in the diagram showing the reduction of the concentration of sodium hydroxide function of dissolved silicon dioxide, sample G1 was missed. The position of these points on the chart, their location in the A favorable area, allow us to use these aggregates in concrete preparation, as they do not appear as potential reagent. Favorable location in the limestone rock area recommends caution in using this rock in the humidity and sea aggression conditions, Thus, following the studies and research carried out, I recommend the practical use of this rock in self compacted concrete 0-8 grained composition, for the rehabilitation of ancient sites in Dobrogea, subject that I will present in a more detailed study in the next chapter. Putting the two samples of granitic rock in the A favourable area, recommends the use of this type of rock in the composition of the self compacted concrete in works on the Black Sea coast, in the rehabilitation of historical buildings in the peninsular area of Constanta, at the rehabilitation walkway Casino Mamaia

5.3 Case study. Modern techniques for the rehabilitation of historical monuments using self compacting concrete

5.3.1 Rehabilitation of Casino Mamaia walkway

The last part of the hereby doctoral researches, a stydy was carried out on Mamaia Casino walkway and the ancient citadels of Dobrogea, the results materialized in proposals for rehabilitation and consolidation.

Areas were identified where concrete and reinforcement were fully expelled, in these cases it is necessary to produce formworks, installation of fittings and totally replacing the damaged reinforced concrete (reinforced concrete).

As main methods of consolidation recommended in the less affected areas are the use of reinforced concrete guniting, reinforced concrete plastering clothing, building with metal profiles or total replacement of deteriorated concrete to retrieve efforts [49]. In all these situations it is advisable to use self compacted concrete with resistance to marine aggression, as this type of concrete is characterized by the best cohesion and filling capacity, best linking capacity with old degraded concrete, and not least because of its durability. For areas where spraying is adopted, it is advisable to use self compacted concrete of 0-8 grain; for columns, beams, belts, self compacted concrete of 0-16 grain is recommended; for the other elements, foundations, caissons, etc. it is recommended to use self compacted concrete of 16 to 22.5 granulation.

Figure 5.20, 5.21- Damage of concrete elements on Casino Mamaia walkway (author photo)

Among the main causes that led to the premature degradation of the concrete there is the use of aggregates such as limestone that have a low resistance to chemical aggression, not recommended for such applications. Regarding the source of cement used, it is supposed that it is Portland Superpod cement manufactured at Cernavoda, the only source in the area at the time.

It is recommended that this building of historical significance is rehabilitated using the guniting techniques, and restoring the structural elements using self compacted concrete given its very good behavior in the aggressive marine, the ease of commissioning works and good behavior of all of the others parameters analyzed in this thesis.

5.3.2 Rehabilitation of the antique sites in Dobrogea

Most of the ancient sites of Dobrogea, especially those located along the Danube suffered deep degradation, caused by temperature changes, wind action, biological factors, degradation caused by water flowing through variations in level of the watercourse and, consequently, partial or complete flooding of the city walls. In this context it is necessary to strengthen early intervention and restoration of these walls and further work where they were stopped. Based on these considerations we conducted a research in situ on the state of degradation of ancient citadels in Dobrogea and started building measures using modern building techniques using self compacted concrete. Research results show the advantages of self compacted concrete to drywall restoration of the ancient cities of Dobrogea.

Gross stone masonry usually degrades via openings vertical joints and cracks in stone. Water and other destructive agents ingress through these cracks, causing local peeling of rough stone masonry binder.

In this study we investigated degradation of rough stone walls of ancient citadels Capidava, Păcuiul lui Soare, Adamclisi, the first two in the immediate vicinity of the Danube River, the third about 50 km far from it.

Research carried out at the three ancient cities shows visible degradation, local detachment of the binder of masonry stone, spacings of joints of appx. 5 cm and collaps of walls in contact with water.

Figure 5.35, 5.36- Rehabilitation of Capidava Citadel walls using conventional concrete (author photo)

Figure 5.37-Construction element of self compacted concrete at Capidava Citadel (author photo)

The results were clearly in favor of self compacted concrete, perfectly smooth sides being obtained in this case, compact and therefore of higher permeability and freeze-thaw resistance compared to the elements restored with conventional concrete where cracks are visible along the masonry since the start of implementation of the project. Following the research conducted, we identified two important benefits for the propose scope, that of restoration of the historic objectives located in areas with natural aggressiveness.

- By using self compacted concrete to refurbishing historical monument, the vibration equipment needed for vibrating fresh concrete is eliminated, thereby eliminating the possibilities to deploy the rehabilitate concrete element from the initial position. It is imperative to use this type of concrete, especially in refurbishing historic area affected by Black Sea aggression, located in the peninsular zone of Constanta, where because of concrete vibration, these sites are in very advanced stages of degradation, that could lead to the collapse.

Figure 5.38, 5.39-Historical monument in an adanced degree of degradation, located in the peninsular area of Constanta (author photo)

- The use of limestone filler in self compacted concrete composition enhances its capability to be used as a binder to restore masonry stone on historic objectives;

6.CONCLUSIONS. APPLICATIONS OF THE RESEARCH RESULTS

6.1 Conclusions

The objectives in developing the doctoral thesis were met by studiea and researches made in laboratories in Romania, as well as in the Great Britain, in accordance with the proposed scope of work, and the conclusions, interpretations, correlated with the results obtained before starting the research program, and also with the results gathered during the studies realized in Romania and Great Britain. Conclusions to be drawn from the research conducted are:

- Self-compacted concrete studied for use in the marine environment will be such as to satisfy the conditions of exploitation: the use of cements resistant to aggressive marine, with a high content of slag, up to 65%, MAL <0 64 and reduced heat of hydration, <220J / g, the use of added limestone filler, fly ash or dust extracted in order to increase statbility and use of non-reactive aggregates to achieve self-compacted concrete compositions. This result obtained answers abundantly to coastal marine environment of the Black Sea coast, where the environment aggression manifests not only by the Black Sea salinity (approx. 1.8%) and the salinity of lakes in the area: Techirghiol (8%) , Nuntasi (3.7%), Sinoe, Costineşti (2.6%) , in particular that the research we've conducted between 2011 to 2016 have shown that there is a tendency of seawater acidifying, an increase of water pH Black Sea, from 7.87 in 2011 to 8.46 value obtained in 2016;
- Use self compacting concrete is favored by the fact that investment in contact with the marine environment does not always allow compacting, by self-compacted concrete fulfilling this function its very composition to fulfilling this function, no vibration necessary. In this context, submwrged concrete elements poured into the area, walkways, embankments and civil engineering can be made of concrete with modern technology, thus avoiding defects of structure and the areas of vulnerability to marine aggression;
- Use self-compacted concrete constructions in the marine area, with or without direct exposure, brings an important contribution to increasing sustainability over the lifetime of

constructions or intervention works because vulnerable areas identified in normal concrete disappear, while capillary absorption, diffusion, ionic transport is very limited to aggressive substances attacking self-compacted concrete;

- We found that the normal concrete used in the restoration of historical monuments, namely the research we have carried out to achieve restoration work on the fortress Capidava had a poor behaviour, cracks being observed since the start of the restoration works. Archaeological sites are usually subject to weather, atmospheric factors, freeze-thaw phenomena, at Capidava Citadel, the constructive elements of the city being subject to high humidity because the archaeological site is located in the immediate vicinity of the Danube River. By comparison, in the same site, using self-compacted concrete to build the new tourist information center of the archaeological site Capidava showed superior results compared to conventional concrete used in restoration, in terms of mechanical properties and durability (freeze-thaw resistance, permeability) and also special finishing characteristics. The use of self compacted concrete in the constructions operated in aggressive marine environment solves the freeze-thaw issue in that the resistance is 30% - 40% higher for self-compacted concrete compared to normal vibrated concrete; after 150 cycles of freezing - thawing the losses in compressive strength ranging between 5.71% -8.28% (CSO98 samples; CSO99; CSO122) for normal vibrated concrete, up from 3.07% -4.9% (samples DR52, DR53, DR54) for self compacted concrete;
- Another very important conclusion that has emerged from the research program carried out, is that self-compacted concrete offers a much better resistance to erosion, applicable to the construction of coastal embankments, walkways, which are in direct contact with the sea and subject to waves and marine force aggressiveness. Given that resistance to erosion of the concrete largely depends on the quality of the concrete expressed by its compression strength, the studies I've done on class C25 / 30 a self-compacted concrete compared to normal concrete of the same strength class, sowed that self-compacted concrete has a much better erosion resistance compared to normal vibrated concrete, as its mechanical strength increases of 20-30% when compared to normal vibrated concrete. This recommends self compated concrete for constructing breakwaters where the wind

direction and wave breaking force are very strong, as conventional breakwaters made of normal concrete at the moment are ubder an accentuated process of erosion;

- Use self-compacted concrete isan optimal solution for realizing the buildings located in the area of marine Black Sea coast aggression; researches I have made concluded that the use of cements resistant to marine aggression, with a low heat of hydration, the use of reactive aggregates, use of additives based on carboxilateter compatible to the cements resistant to marine aggressiveness, give self-compacted concrete special properties such as resistance to chemical attack, high permeability, high fluidity, which greatly recommends it for the buildings located in the Black sea coastline. Compatibility studies of different types of additives to mineralogical composition of cement resistant to marine aggressiveness determine the reactive potential of the aggregates, from the point of view of the reaction of alkali-aggregates, determinations carried out in Chapter 5 of this thesis, entitle me to say that the use of a composition of self-compacted concrete prepared with strongly reducing water additives -based on polycarboxylate ether, Glenium, Auracast 200, which is a cement resistant to marine aggressiveness and granitic crushed rock aggregates is the best solution for achieving sustainable constructions in the coastal area of the Black Sea.

6.2 Applications of research results

The research results were utilized in part for the study of the behaviour of self compacted concrete in the two works, Agigea Bridge and Rennovation of Mamaia Hotel, by extending the scope to the rehabilitation of Casino Mamaia walkway, the proposal to include them in Guide of Regulations for the use of self compacted concrete in aggressive chemical environments and overall contributions to update these technical regulation. The research results will be promoted in the next period to achieve the rehabilitation of the Tomis port and special works aimed at the Peninsular area. Part of the research results were presented at the conference entitled "**Theory and practice in civil engineering**", held at Ovidius University, the Faculty of Civil Engineering, The theme presented was "**Optimization of self-consolidating concrete composition for higher performances in marine environement**" .Also, in the Doctoral School of Applied

Sciences, of Ovidius University, two research reports were held: on June, 2012 - **"Influence of the marine environment aggressiveness over concrete durability. Comparative analysis of self compacted concrete properties and normal vibrated concrete"** and June, 2013 – "**Optimization of self-consolidating concrete composition for higher performances in marine environement"**. The research results were disseminated and in international publications and conferences listed below:

- **"The advantages of using self compacting concrete for reinforced concrete structures in an aggressive marine environment", Cîinoiu Marian Nicolae,** Grămescu Ana Maria,- **Indian Journal of applied Research**, ISSN No. 2249-555X, February 2016, **BDI**, Index Copernicus (IC) Value:74.5, Impact Factor: 3.919;
- **''Mechanism degradation of concrete structures located in the aggressiveness area of Black Sea Coast. Rheabilitation of affected structures using self compacting concrete.", Cîinoiu Marian Nicolae**, Grămescu Ana Maria,-16th International Multidisciplinary Scientific Geoconference SGEM 2016, Book 6 , Nano, Bio and Green-Technologies for a Sustainable Future, Conference Proceedings, Vol. II, ISSN 1314-2704, July 2016, **ISI Web of Knowledge**, Thomson Reuters;
- **"Compactness concrete influence on its mechanical strength. Tensile strength studies on self compacting concrete compared with traditional vibrated concrete", Cîinoiu Marian Nicolae**, Grămescu Ana Maria, International Journal of Scientific Researh,, Volume 5 , Issue9, ISSN No.2277-8179, **BDI**, Index Copernicus IC Value : 69.48
- **"The ancient fortress rehabilitation from Dobrudja, Romania, using modern tehnics – Self compacting concrete tehnics" , Cîinoiu Marian Nicolae ,** Grămescu Ana Maria **,**The Bulletin of the Polytechnic Institute of Jassy, Construction. Arhitecture Section, ISSN 1224-3884, e-ISSN : 2068-4762**,** under publication, B+.

Doctoral internship and benchmarking made in 2010 in labs, sites and production units of SC Lafarge UK gave me the opportunity to develop and transfer knowledge from the UK to Romania so I helped the research team to achieving high performance concrete materialized in using material for Agigea Bridge, Mamaia Hotel and other works. It is the product of research results and knowledge transfer expressing conditions and aims to increase the sustainability of the construction elements and reducing operating expenses during the service.

Application of results also aimed user benefits. This aims to increase competitiveness, economic development and income progress. These issues are related in particular to the development of the construction industry in the Dobrogea region, the perspective of development in the area, especially those located in the coastal area. In this context, the massive investment to be made in the next period in Tomis Port was taken into consideration, so that the management policy of the companies that provide this material should consider the use of this material as an important economic gain, function of location, degree of exposure, etc.

An important aspect of the valorification of results is the contribution to specialized literature, publishing outcomes research articles and books, continuous information released to the construction interested public by organizing workshops, benchmarks but also by publishing magazine articles with relevant impact in construction. An important action which aims at making the results of research applicable is to improve the regulations on concrete by introducing new parameters, updating the norms referring to self compacted concrete corrosion, extending the field of application to hydraulic structures, slope settlement constructions for ensuring the safety of urban areas, old buildings with heritage value.

6.3 **Contribution of the candidate, originality and applicability, criteria for continuing the researches**

The originality of this thesis lies primarily in the fact that it address a current theme promoted internationally in the 2006s, when investigations were only at the begginig, then being thoroughly checked in international laboratories, while in Romania, research was in its early stage, at the start of applying the results obtained in foreign laboratories. Nothing was known about its applicability in aggressive environments, its behavior and how it will interact with destructive factors. What was very well known were the superior parameters of the composition and its great resistance in constructions. There were no regulations in Romania to cover this material and its application technology. The only regulations applicable in Romania were the standards introduced in 2010 after a year of my enrollment in the Doctoral School, which is a translation of European standards. Later, in 2012, the Research Institute for Construction Equipment and Technologies has developed a research report (normative), with the Ministry of Regional Development and Tourism as beneficiary.

Second, the originality lies in analyzes, in-depth investigations, initiated for this material, in order to more accurately quantify the parameters that can be adjusted to the environmental conditions. In this context, the research program studied with maximum responsibility the conditions in the marine environment in our area, in conjunction with the analysis of behavior in time of constructions made both in contact with sea water, as well as those located in the area of marine environment influence. From this research we have outlined the actions in concrete behanior analysis to meet environmental requirements offered to improve durability, increase operational safety, reduce operating costs, in a word to increase the effectiveness of this new material.

The originality lies in the methodology and applicability of this material in the existing buildings located under marine environment influence, through consolidation, rehabilitation, growth of behavioral parameters. A very important component of originality of the thesis is that the studies and research on the use of the material in new buildings can be extended to a new area of engineering concern namely for solutions for the rehabilitation of historical monuments located in this area, to solutions for the valorification of ancient ruins, relics, ancient citadels of

Dobrogea located in the marine environment. Lastly, part of the originality of the thesis is the contribution to the field, by the elaboration of own standards, technical regulations, which will contribute to the progress of science and construction technology in Romania.

The contributions of the doctoral candidate materialized through:

- Expanding the specific database, aknowledge and promoting the material on the domestic market of construction materials and especially on the local coastal areas of the Black Sea. Studies constitute a starting point for new research directions;
- Testing different types of additives that ensure compatibility of the cement resistant to chemical aggression with the proper additive;
- After achieving concrete composition in laboratory, testing it by manufacturing of prefabricated elements to highlight the reliability, ease of commissioning work and obtain perfectly smooth sides;
- Produce different self compacted compositions of concrete where the addition used were limestone filler, expanded ash and tuff, one at a time;
- Conducting comparative studies on the mechanical properties of self compacted concrete with normal concrete.
- Laboratory studies but also those made for Casino Mamaia walkway on the destructive effect of seawater on concrete, loss of mass of concrete under the destructive action of waves and sea water, ionic analysis of sea water in which the control samples were maintained and ionic analysis of distilled water distilled water in which samples of the same material were maintained.
- Documentation through studied bibliography on timeliness, the current state of development and use.

The originality of the thesis primarily consists of the subject whch is the behavior of self-compacted concrete in the marine aggressive environment.

Through studies and researches we have developed and actions proposed, thus responding to the research plan and objectives while identifying new issues in this new field of research. New issues regarding the correlation between the durability of constructions and the opration duration and the characteristic environment, marine environment, as well as the expansion of optimized composition of the self compacted concrete and other operating conditions, ie constructions that are subject to dynamic factors, forced vibrations.

The doctoral thesis opens up new directions for further research, such as:

- The application of self compacted concrete to sthe consolidation of historic constructions by studying the buildings and compatibility of technical parameters to the existing old materials;
- Studies and research on the development of a special binder material but with similar parameters as self compacted concrete that could be used in the future to restore the natural stone vestiges. Current investigations have been initiated at Capidava Fortress.

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