EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

K-FORCE

SPECIAL MOBILITY STRAND

THE IMPORTANCE OF CONCRETE DURABILITY IN RC STRUCTURES

ERION LUGA, PhD

NOVI SAD 05.03.2019

Epoka University
Department of Civil Engineering

Lecture Outline:

- *Concrete*
- *Durability of Reinforced Concrete Structures*
- *Factors Governing Concrete Durability*
- *Processes Affecting the Durability of Concrete*
- *Case study*

Co-funded by the
Erasmus+ Programme
of the European Union

EPOKA UNIVERSITY

Co-funded by the
Erasmus+ Programme
of the European Union

Concrete is The Most Widely Used Construction Material

- *In many countries the ratio of concrete consumption to steel consumption exceeds ten to one.*

- *The total world consumption of concrete in one year is estimated at three billion tons. Man consumes no material except water in such tremendous quantities.*


(a)
(b)

Durability of Reinforced Concrete Structures

- *The durability of concrete is very important, because concrete should be capable to withstand the conditions for which it has been designed throughout the life of the structure*

- *Lack of durability can be caused by external agents arising from the environment or by internal agents within concrete*

Co-funded by the
Erasmus+ Programme
of the European Union

Durability of Concrete

Generally, concrete suffers from more than one causes of deterioration, which is generally seen in the form of:

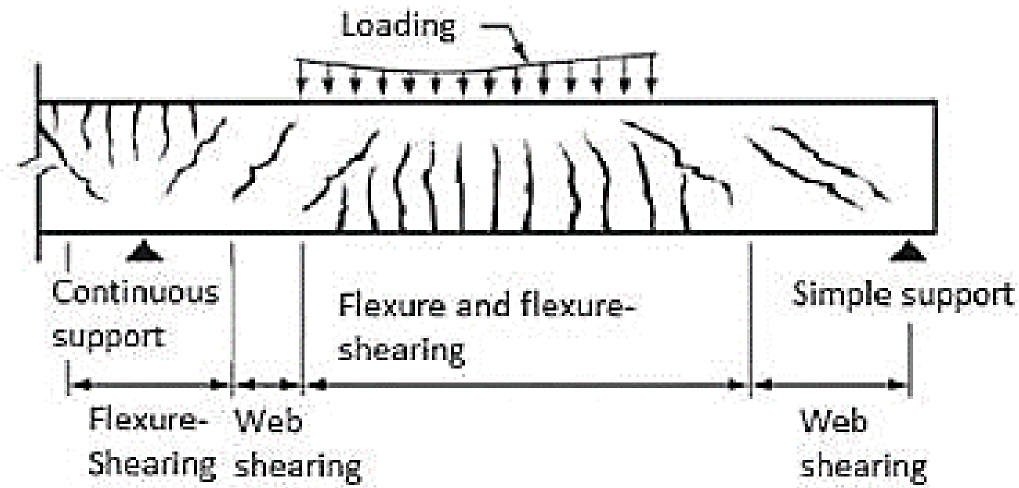
- *cracking,*
- *spalling,*
- *loss of strength, etc.*

It is now accepted that the main factors influencing the durability of concrete is its impermeability to the ingress of:

- *oxygen,*
- *water,*
- *carbon dioxide,*
- *chlorides,*
- *sulphates, etc.*

Cracks in Concrete

Concrete cracks when the tensile stresses > maximum tensile strength.

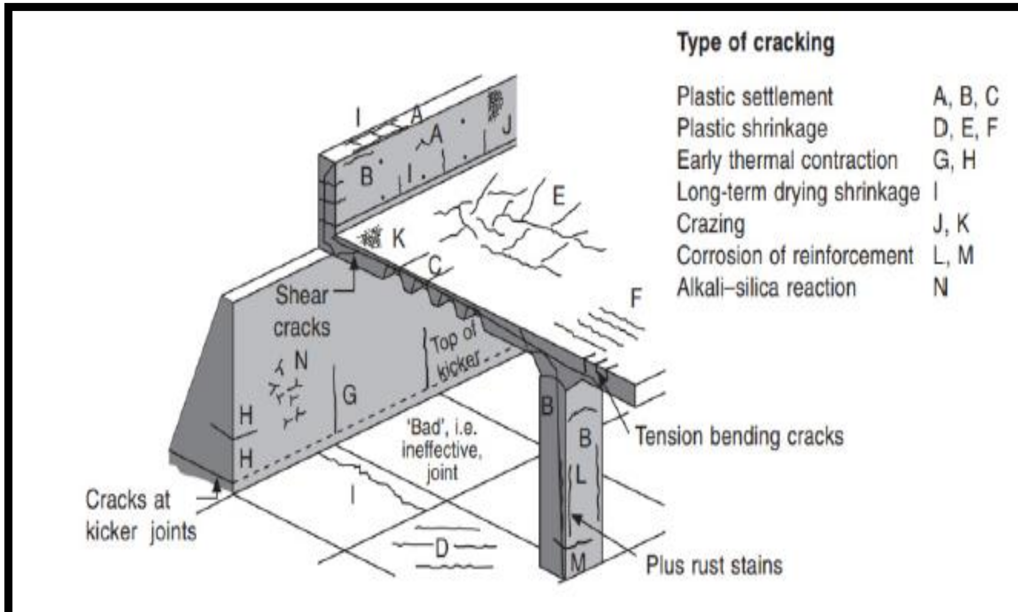


Influence of the cable´s layout on the shearing resistance of prestressed concrete beams, O. A. SOUZA JUNIOR, D. R. C. OLIVEIRA

Types of Cracks in RC structures

Cracks can occur in hardened or unhardened concrete and may be caused by some of the following conditions:

- *Plastic Shrinkage cracking*
- *Plastic Settlement cracking*
- *Structural cracking*
- *Rust cracking*
- *Thermally-induced cracking*
- *etc*

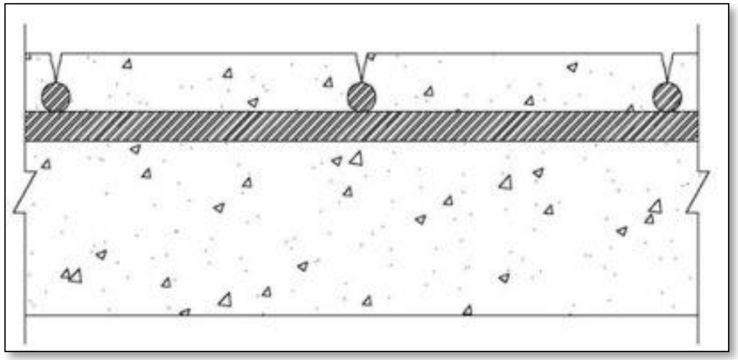


Types of cracks (Day, R. and J. Clarke, 2003)

Cracks in unhardened concrete

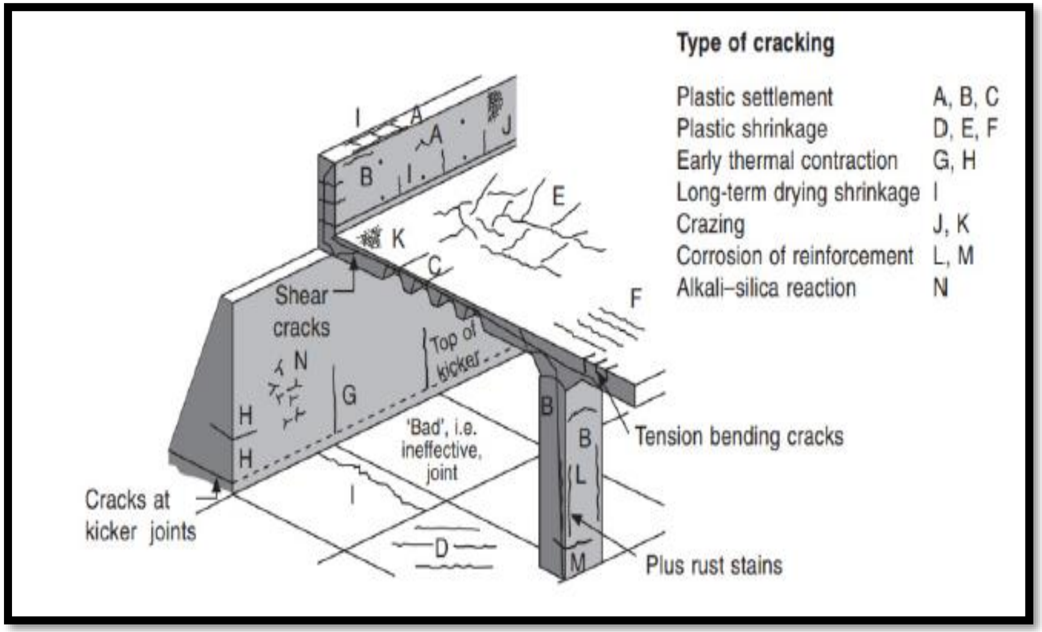
- *Plastic Shrinkage cracking*

- *Plastic Settlement cracking*



Types of Cracks in hardened concrete

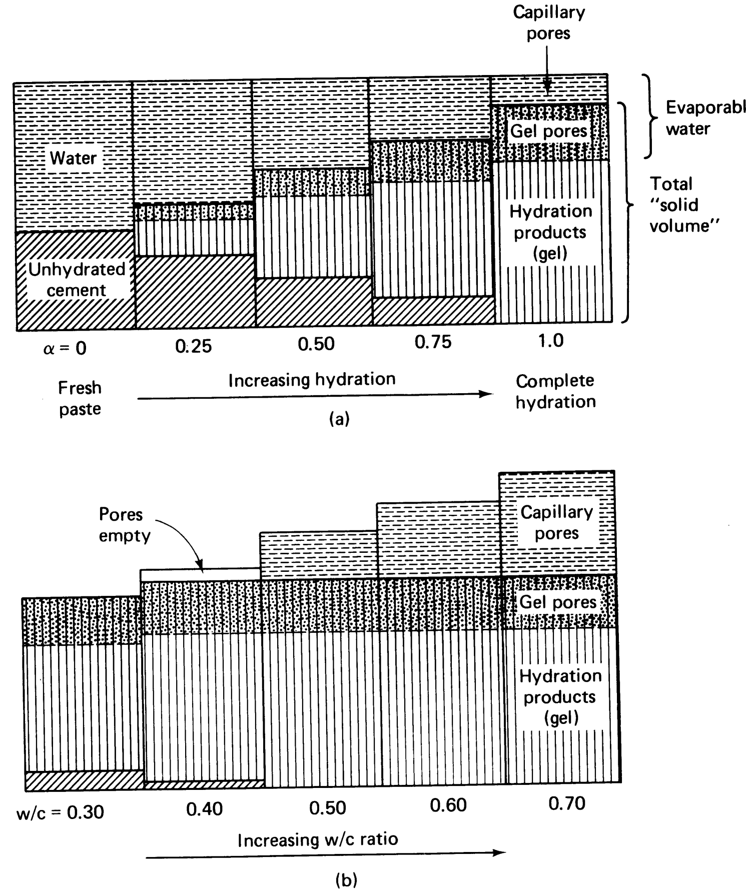
- *Structural cracking*
- *Rust cracking*
- *Thermally-induced cracking*
- *Etc.*



Types of cracks (Day, R. and J. Clarke, 2003)

Permeability of Concrete

- *Permeability is defined as the property that governs the rate of flow of a fluid into a porous solid.*
- *Amount of water migration through concrete when the water is under pressure, and the ability of concrete to resist penetration of any substance, be it a liquid, gas, or chloride ion.*
- *Designers of dams and other large hydraulic structures needed to know the rate at which water passed through concrete that was subjected to relatively high hydraulic pressures.*



EPOKA UNIVERSITY

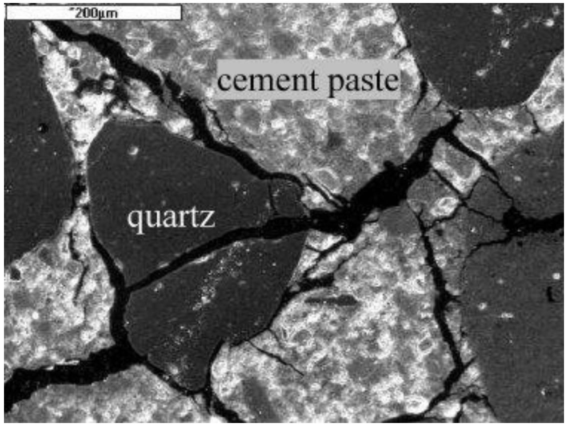
Co-funded by the Erasmus+ Programme of the European Union

Durability of Concrete

Durability of concrete

Factors Governing Concrete Durability

Processes Affecting the Durability of Concrete



Behaviour of cement concrete at high temperature, I. Hager

Adapting to a more aggressive policy environment, E. Cusworth

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Factors Governing Concrete Durability

Some of the factors that govern the durability of RC structures can be listed as:

- *Concrete mix design*
- *Structural design*
- *Reinforcement detailing*
- *Concrete cover*
- *Curing of concrete*
- *Supervision*
- *Quality of materials*

Co-funded by the
Erasmus+ Programme
of the European Union

Processes Affecting the Durability of Concrete

The behavior of concrete depends on several processes such as:

- *Physical processes*
- *Chemical processes*
- *Biological processes*

EPOKA UNIVERSITY

Co-funded by the
Erasmus+ Programme
of the European Union

Physical Causes of Concrete Deterioration

Physical Causes of Concrete Deterioration can be listed as follows:

- *Abrasion/Erosion*
- *Cavitation*
- *Freeze-thaw deterioration*
- *Deicer Scaling*
- *High temperatures*
- *Aggregate expansion*

EPOKA UNIVERSITY

Co-funded by the
Erasmus+ Programme
of the European Union

Deterioration from abrasion/erosion

When a material is repeatedly struck by particles from a harder body and the surface of concrete is unable to resist wear caused by rubbing and friction abrasion damage occurs:

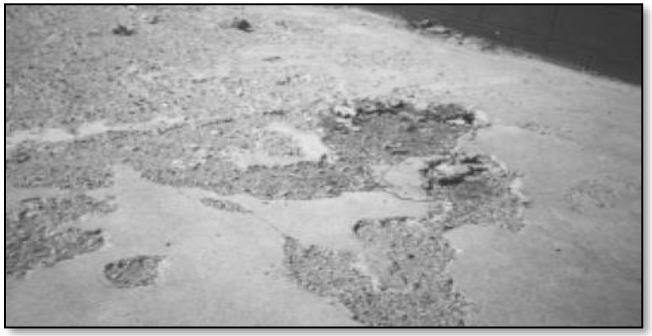
- *outer paste of concrete wears,*
- *fine and coarse aggregate are exposed*

abrasion and impact will cause additional degradation that is related to aggregate-to-paste bond strength and hardness of the aggregate.

Deterioration from abrasion/erosion

The most damaging forms of abrasion occur

- *on vehicular traffic surfaces,*
- *bridge piles,*
- *surfaces in contact with waves etc.*



Factors influencing abrasion resistance:

Some of the main factors affecting the abrasion resistance of concrete are:

- *Compressive strength;*
- *Properties of the aggregates;*
- *Nature of the finishing coat;*
- *Presence of areas which have been patched up;*
- *Condition of the surface.*

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Deterioration from Cavitation

- *Formation of bubbles or cavities in a liquid.*
- *The cavities form where the local pressure drops to a value that will cause the water to vaporize at the prevailing fluid temperature.*
- *Cavitation damage is produced when the vapor cavities collapse, causing very high instantaneous pressures that impact on the concrete surfaces, causing pitting, noise, and vibration.*

EPOKA UNIVERSITY

Co-funded by the
Erasmus+ Programme
of the European Union

Freeze-thaw Deterioration

- At temperatures below 0℃ cement does not hydrate
- Expands about 9% and produces pressure in the capillaries and pores of concrete.
- Exceeding the tensile strength of the concrete, the cavity will dilate and rupture.
- Successive freeze-thaw cycles and disruption of paste and aggregate can cause significant expansion and cracking, scaling, and deterioration.

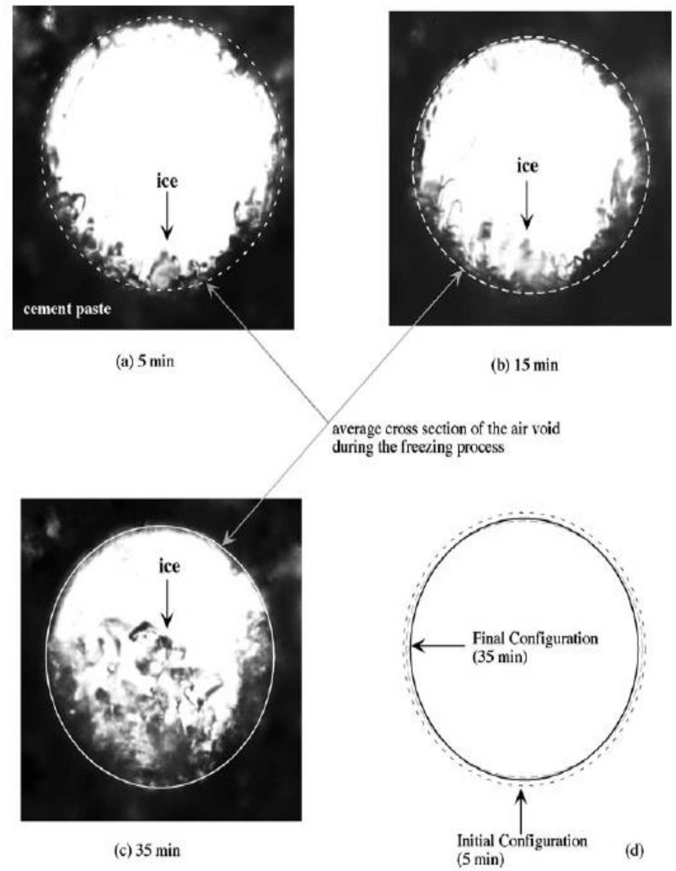


Figure 5-9 Sequence of ice propagation in an air-entrained void.
Concrete Microstructure, Properties, and Materials, P. Kumar Mehta, Paulo J. M. Monteiro

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Freeze-thaw Deterioration

How to prevent Freeze-thaw Deterioration:

- *Use **air entraining agent**.*
- *Entrained air voids act as empty chambers in the paste for the freezing and migrating water to enter, thus relieving the pressure in the capillaries and pores and preventing damage to the concrete.*
- *Low permeability concrete also performs better when exposed to freeze-thaw cycles.*
- *The permeability of concrete is directly related to its water-to-cement ratio*

Deicer Scaling

- *Deicing chemicals, such as sodium chloride, can aggravate freeze-thaw deterioration.*
- *Osmotic and hydraulic pressures in excess of the normal hydraulic pressures produced when water in concrete freezes.*
- *Salt absorbs moisture, it keeps the concrete more saturated, increasing the potential for freeze-thaw deterioration.*

Aggregate Expansion

- *Some aggregates absorb too much water, expand and increase hydraulic pressure during the freezing of water.*
- *Also aggregates such as CaO expend about 2.5-3 times in the presence of moisture.*
- *Concrete disintegrates if these are in high quantity.*
- *If it is near the surface of the concrete, it can cause a pop out.*

Portland Cement Association, Types and Causes of Concrete Deterioration

High Temperature

The behavior of concrete at high temperatures is influenced by several factors such as:

- *Rate of temperature rise and the*
- *Aggregate type and stability.*
- *Moisture level*

Fast temperature changes can cause cracking and spalling due to thermal shock, and aggregate expansion can also produce distress within the concrete.

High Temperature

High temperatures also affect the compressive strength and stiffness of concrete.

- *Above 100° C, the cement paste begins to dehydrate (loses chemically combined water of hydration), which gradually weakens the paste and paste-aggregate bond*

The effect of high temperatures on concrete is destructive.

- *The reinforcement rods resist at temperatures of up to 500°C, while concrete resists at up to 650°C. The thicker the concrete, the longer it takes for the reinforcement rods to reach their failure temperature of 500°C*

Chemical Causes of Concrete Deterioration

The Chemical Causes of Concrete Deterioration can be listed as follows:

- *Acid attack*
- *Sulphate attack*
- *Alkali aggregate reaction*
- *Carbonation*
- *Corrosion*
- *Leaching*

Co-funded by the Erasmus+ Programme of the European Union

Acid Attack

- *Portland cement concrete is not resistant to acids or solutions with a pH of 3 or lower.*
- *It may resist to some weak acids if the exposure is occasional.*
- *Acids react with the calcium hydroxide of the hydrated Portland cement.*
- *It forms water-soluble calcium compounds, which are then leached away by aqueous solutions.*

Portland Cement Association, Types and Causes of Concrete Deterioration

Sulphate *Attack*

- *Sulfates of sodium, potassium, calcium, or magnesium are sometimes found in soil or dissolved in groundwater.*
- *React with aluminate compounds, calcium and hydroxyl of hardened Portland cement forming ettringite and gypsum.*
- *In the presence of sufficient water, these reactions of delayed ettringite formation cause expansion of concrete leading to irregular cracking.*
- *The cracking of concrete provides further access to penetrating substances and to progressive deterioration.*

civilblog.org

Alkali Silica Reaction

Alkalis react with silica containing aggregates and not with cement.

Free alkalis present in cement dissolve in the mixing water and forming a caustic solution, which attack the reactive silica in the aggregate.

The alkali silica gel so formed swells in the presence of moisture, and exerts osmotic pressure on the concrete internally.

- *Alkalies + Reactive Silica → Gel Reaction Product*
- *Gel Reaction Product + Moisture → Expansion*

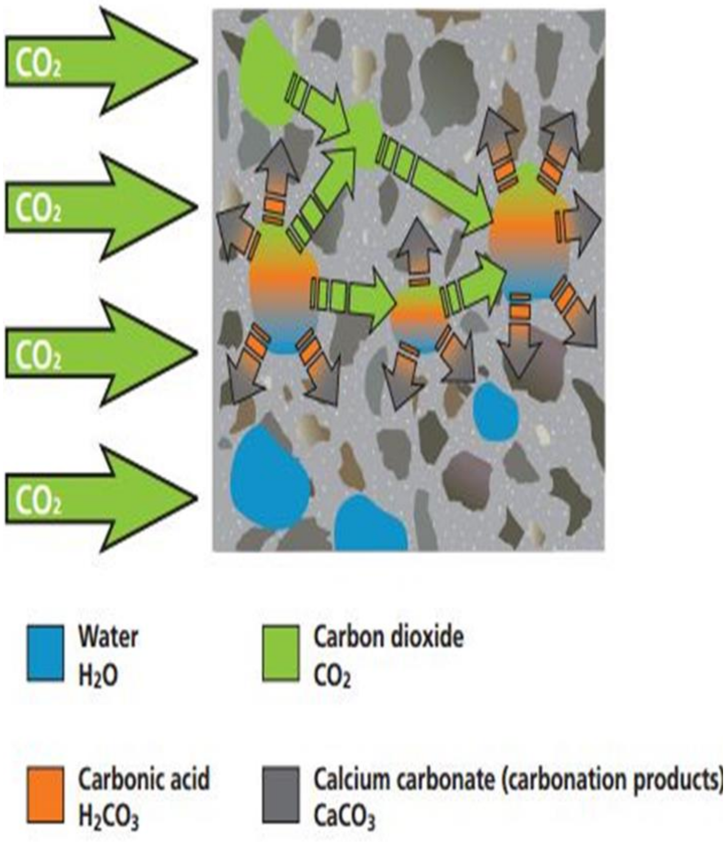
Portland Cement Association, Types and Causes of Concrete Deterioration

Carbonation

- *The pH of the fresh cement paste is at least 12.5. The pH of a fully carbonated paste is about 7.*
- *The concrete will carbonate if CO2 from air or from water enters the concrete according to:*

Ca(OH)2 + CO2 -----------> CaCO3 + H2O

When Ca(OH)2 is removed from the paste hydrated CSH will liberate CaO which will also carbonate. The rate of carbonation depends on porosity & moisture content of the concrete.



Carbonation

Measuring of carbonation depth with Phenolphthalein solution

Corrosion

What is corrosion?

- *It is the main cause of deterioration in concrete.*
- *Rust occupies a greater volume than steel.*
- *Steel is thermodynamically unstable under normal atmospheric conditions and will release energy and revert back to its natural state*

Corrosion of the reinforcement in RC structures is classified as:

- *Atmospheric Corrosion*
- *Chloride Ion on Corrosion*
- *Galvanic Corrosion*
- *Electrochemical Corrosion*

Leaching

*The process of dissolving and transporting substances out of concrete is called **Leaching.***

- *Calcium hydroxide $Ca(OH)_2$*
- *Other soluble salts*

Biological Causes of Concrete Deterioration

The metabolic activity of microorganisms causes liberation of many acids as well as hydrogen sulfide and other corrosive reagents into environment.

- *Algae*
- *Fungi*
- *Bacteria*
- *etc*

Concrete Hub

Marine Environment

Seawaters contain 3.5% soluble salts and their pH varies from 7.5 to 8.4. Concrete deteriorates from the combined effects of chemical and physical processes :

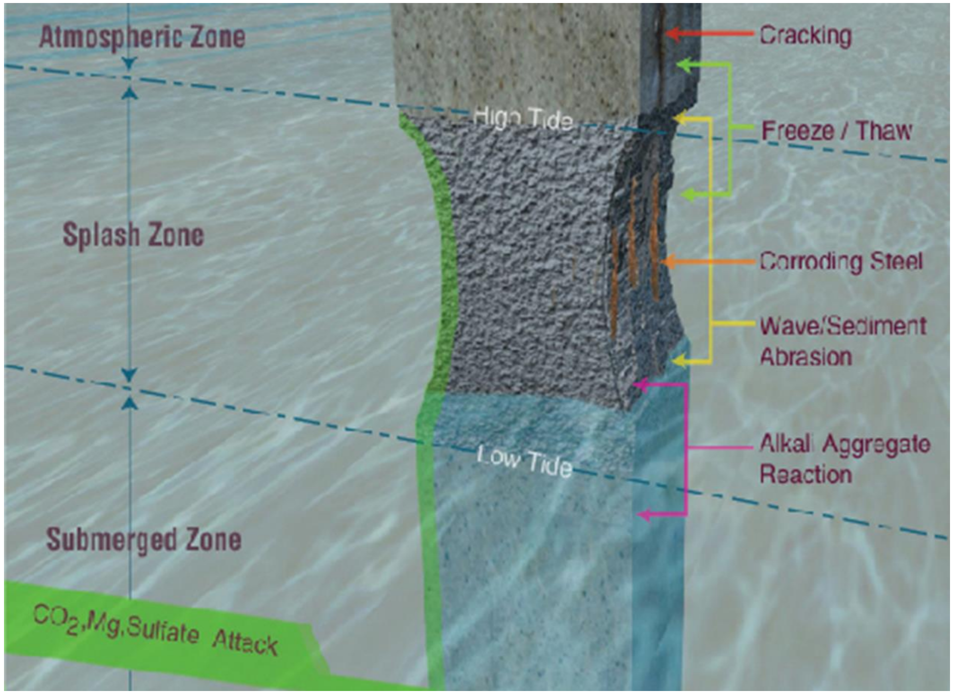
- *Sulfate attack*
- *Biological attack*
- *Leaching of lime (calcium hydroxide)*
- *Alkali-aggregate expansion*
- *Salt crystallization from alternate wetting and drying*
- *Freezing and thawing*
- *Corrosion of embedded reinforcing or pre stressing steel*
- *Erosion and abrasion from waves*

EPOKA UNIVERSITY

Co-funded by the
Erasmus+ Programme
of the European Union

Marine Environment

- *Submerged Zone, continuously covered by seawater,*
- *Splash Zone, subject to continuous wetting and drying*
- *Atmospheric Zone, subject to occasional seawater spray concrete.*



EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Severity of environment

As a general classification exposure conditions can be classified as:

- *Mild/Negligible or Low*
- *Moderate*
- *Severe*
- *Very severe*

Whereas EN 206-1 classifies the exposure conditions in more details

Table 1 – Exposure classes

Class designation	Description of the environment	Informative examples where exposure classes may occur
1 No risk of corrosion or attack		
X0	For concrete without reinforcement or embedded metal: All exposures except where there is freeze/thaw, abrasion or chemical attack	
	For concrete with reinforcement or embedded metal: Very dry	Concrete inside buildings with very low air humidity
2 Corrosion induced by carbonation		
Where concrete containing reinforcement or other embedded metal is exposed to air and moisture, the exposure shall be classified as follows: NOTE The moisture condition relates to that in the concrete cover to reinforcement or other embedded metal, but in many cases, conditions in the concrete cover can be taken as reflecting that in the surrounding environment. In these cases classification of the surrounding environment may be adequate. This may not be the case if there is a barrier between the concrete and its environment.		
XC1	Dry or permanently wet	Concrete inside buildings with low air humidity Concrete permanently submerged in water
XC2	Wet, rarely dry	Concrete surfaces subject to long-term water contact Many foundations
XC3	Moderate humidity	Concrete inside buildings with moderate or high air humidity External concrete sheltered from rain
XC4	Cyclic wet and dry	Concrete surfaces subject to water contact, not within exposure class XC2
3 Corrosion induced by chlorides other than from sea water		
Where concrete containing reinforcement or other embedded metal is subject to contact with water containing chlorides, including de-icing salts, from sources other than from sea water, the exposure shall be classified as follows: NOTE Concerning moisture conditions see also section 2 of this table.		
XD1	Moderate humidity	Concrete surfaces exposed to airborne chlorides
XD2	Wet, rarely dry	Swimming pools Concrete exposed to industrial waters containing chlorides
XD3	Cyclic wet and dry	Parts of bridges exposed to spray containing chlorides Pavements Car park slabs
4 Corrosion induced by chlorides from sea water		
Where concrete containing reinforcement or other embedded metal is subject to contact with chlorides from sea water or air carrying salt originating from sea water, the exposure shall be classified as follows:		
XS1	Exposed to airborne salt but not in direct contact with sea water	Structures near to or on the coast
XS2	Permanently submerged	Parts of marine structures
XS3	Tidal, splash and spray zones	Parts of marine structures
5 Freeze/thaw attack with or without de-icing agents		
Where concrete is exposed to significant attack by freeze/thaw cycles whilst wet, the exposure shall be classified as follows:		
XF1	Moderate water saturation, without de-icing agent	Vertical concrete surfaces exposed to rain and freezing
XF2	Moderate water saturation, with de-icing agent	Vertical concrete surfaces of road structures exposed to freezing and airborne de-icing agents
XF3	High water saturation, without de-icing agent	Horizontal concrete surfaces exposed to rain and freezing
XF4	High water saturation, with de-icing agent or sea water	Road and bridge decks exposed to de-icing agents Concrete surfaces exposed to direct spray containing de-icing agents and freezing Splash zones of marine structures exposed to freezing
6 Chemical attack		
Where concrete is exposed to chemical attack from natural soils and ground water as given in table 2, the exposure shall be classified as given below. The classification of sea water depends on the geographical location, therefore the classification valid in the place of use of the concrete applies. NOTE A special study may be needed to establish the relevant exposure condition where there is: - limits outside of table 2; - other aggressive chemicals; - chemically polluted ground or water; - high water velocity in combination with the chemicals in table 2.		
XA1	Slightly aggressive chemical environment according to table 2	
XA2	Moderately aggressive chemical environment according to table 2	
XA3	Highly aggressive chemical environment according to table 2	

Co-funded by the Erasmus+ Programme of the European Union

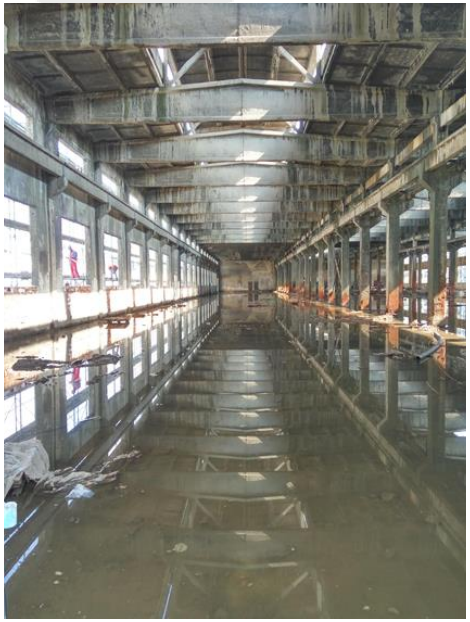
Case study

- To be emphasized is the fact that the durability of concrete is a main factor for the performance of the concrete structure.
- This fact can directly influence the bearing capacity of the structure and the safety of the entire structure overall

Importance of Investigation

- For that reason, it is often necessary to test concrete structures after the concrete has hardened to determine whether the structure is suitable for its designed use.
- The tests available for testing concrete range from:
  - completely non-destructive tests, where there is no damage to the concrete,
  - through those where the concrete surface is slightly damaged,
  - to partially destructive tests, such as core tests and pull-out and pull-off tests, where the surface must be repaired after the test.

Aim of Study



- The objective of this investigation is to give results related to the actual material properties state of the plain Reinforced Concrete structural elements of a formerly built structure. For this reason:
- visual assessment,
- non-destructive and destructive tests were performed.
- In order, not to affect the structural performance, the steel samples were taken from non-structural elements.

Methodology

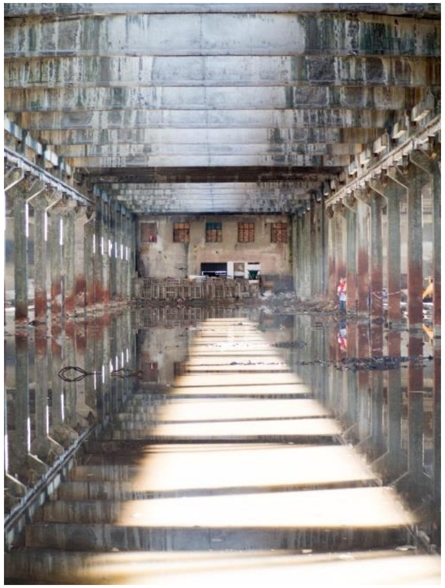
1. *General Information*

a. A state protected building, “Ish NISH GOMA” in Durres, Albania;

b. The construction is made in 1974;

c. 43 years old;

d. Composed of two main warehouses.



Methodology

2. Visual Inspection

a) The structural elements - precast reinforced concrete produced in the construction site or in the precast production sites.

b) The roof elements - beams with two different directions, covered by precast reinforced concrete plates.

c) The problems noticed are:

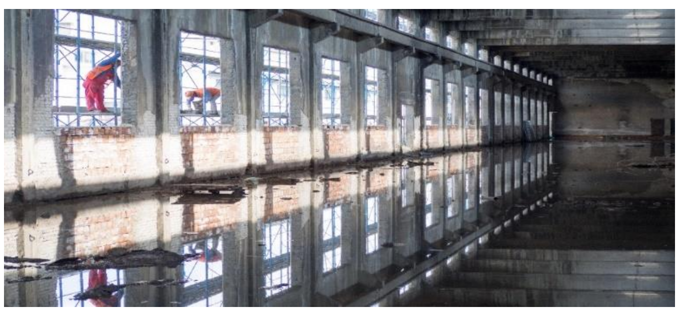
- Technological problems of the concrete cover;
- Carbonation phenomena;
- Moisture and water presence;
- Lack of technical conditions and knowledge during construction;
- Exposure class;
- Lack of maintenance conditions of the inspected object.

Methodology

2. Visual Inspection

Columns of Existing Structure

Joints of columns with beams



Existing Structural Beams

Existing Structure Cover

EPOKA UNIVERSITY

Co-funded by the
Erasmus+ Programme
of the European Union

Methodology

3. Quality Control with Non-Destruction Method

3.1. Schmidt Rebound Hammer

Used in the **vertically overhead** or **vertically downward** positions and in addition at any middle of the edge, given that the hammer is opposite to the surface under test. Before leading any estimations, we did the **cleaning process**. The distance from each **test point is 2 cm**. Were taken **10 values** and then were proceeded with the same steps for all the columns.

Methodology

Metal Detection

Finds in which section is the **steel located** inside the columns. After the detection of the steel, the zone where **the sample** would be taken was marked.

Methodology

Core Drilling

a) Based on standard **S SHEN 13791.**
b) After **concrete inspection**.
c) First the **machine is fixed** in the column with screw.
d) After, is proceed with the **taking of the sample** through drilling.
e) In this study **11 cylindrical samples** were taken from the columns. The diameter of the core drill was 75 mm and all this test was performed with reference to EN 12504-1:2008.

Process of Core drilling test

Methodology

Testing for Carbonation

a) The depth of the carbonation was found using **1% phenolphthalein** that was prepared by dissolving 1gm phenolphthalein 90cc in ethanol.

b) Then the solution obtained was **added to the extent 100cc with distilled water** and after that the solution was **sprayed on the surface** of the samples.

c) The solution became on a **pink color** indicating the depth of carbonation.

d) Later, the **carbonation depth** was measured using calibrated tool and some record for each of the sample was done.

e) The average depth of carbonation is 22.43 mm.

Co-funded by the Erasmus+ Programme of the European Union

Methodology

Testing for Carbonation

The samples provided from the case study building

Performing carbonation test through phenolphthalein solution

Visual results after applying phenolphthalein

Measuring the depth of carbonation

Methodology

Preparing the samples for testing

a. The samples were **cut in the same length**. They should have a regular shape in the top and in the bottom part.

b. The **diameter** for each of the samples were recorded, to use them for **compressive strength calculation**.

Co-funded by the
Erasmus+ Programme
of the European Union

Methodology

Preparing the samples for testing

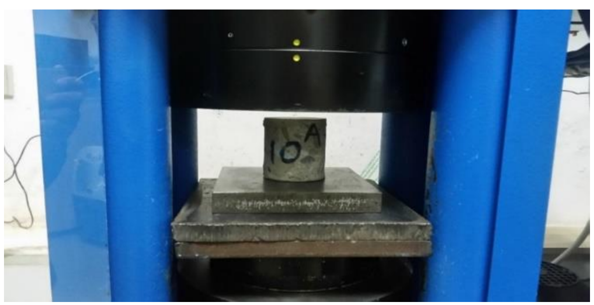
c. The **diameter** for each of the samples were recorded, to use them for **compressive strength calculation**

d. Samples **ready for compressive strength test**

Methodology

Compressive Strength Test

a) Reference to the standard **SSH EN 12390-1-2000**.
b) The specimens were **centrally placed** in the testing machine in such a way that the **load** would be applied to the **opposite sides-position** of the specimen mold.
c) A load was applied until the specimen went **failure**.
d) The **maximum load** corresponding to specimen failure and **strength** was recorded by the **computer software** and written down for each of the samples.



Testing procedure

Results in testing procedure

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Methodology

Testing the Steel in Tensile Strength

•Reference to the standard **SSH EN 9892-1:2009**.

•The **steel samples** were taken from **non-structural elements**.

•Three samples each of **diameters 10 and 20mm** respectively.

Samples of steel for tensile strength test.

Testing the steel rebar

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Results and Discussion

RESULTS OF SCHMIDT HAMMER

Distinctive signs	Date Of production	Date Of Tests	X average [N/mm²]	Compresive Strength [N/mm²]
Column C-2	Year 1974	22.10.16	**36.31**	**34**
Column A-10	Year 1974	22.10.16	**39.31**	**39.2**
Column D-7	Year 1974	22.10.16	**34.76**	**30.2**
Column A-23	Year 1974	22.10.16	**36.95**	**35.7**
Column C-10	Year 1974	22.10.16	**43.85**	**47.9**
Column B-13	Year 1974	22.10.16	**44.80**	**49**
Column B-4	Year 1974	22.10.16	**33.87**	**29.5**
Column C-15	Year 1974	22.10.16	**38.01**	**36.2**
Column B-1	Year 1974	22.10.16	**35.28**	**32**
Column B-5	Year 1974	22.10.16	**31.05**	**25.7**

Results of Schmidt Hammer Method

- Concrete class that is used as the initial project was 20- 25 N/mm2 (class of concrete).

Results and Discussion

RESULTS OF COMPRESSIVE STRENGTH

Distinctive signs	Date of Production	Date of Testing	Diameter of sample [mm]	Length of sample [mm]	Weight of sample [g]	Force [kN]	Compressive Strength [N/mm²]
Department : Section 1 and 2 (04.11.2016)							
Column C-2	Year 1974	18.11.2016	75.38	82.98	890	131,626	29.49
Column A-10	Year 1974	18.11.2016	75.35	79.17	849	132,031	26.84
Column D-7	Year 1974	18.11.2016	75.20	78.77	852	164,555	37.10
Column A-23	Year 1974	18.11.2016	75.57	80.69	864	108,805	24.27
Column C-10	Year 1974	18.11.2016	75.43	81.59	884	212,907	47.66
Column B-13	Year 1974	18.11.2016	75.55	75.02	806	218,764	48.83
Column B-4	Year 1974	18.11.2016	75.45	76.53	791	149,461	33.44
Column C-15	Year 1974	18.11.2016	75.33	79.52	830	101,842	24.86
Department : Section 3 (04.11.2016)							
Column B-1	Year 1974	18.11.2016	75.34	77.49	812	140,207	31.65
Column B-5	Year 1974	18.11.2016	75.49	67.77	726	141,644	31.66

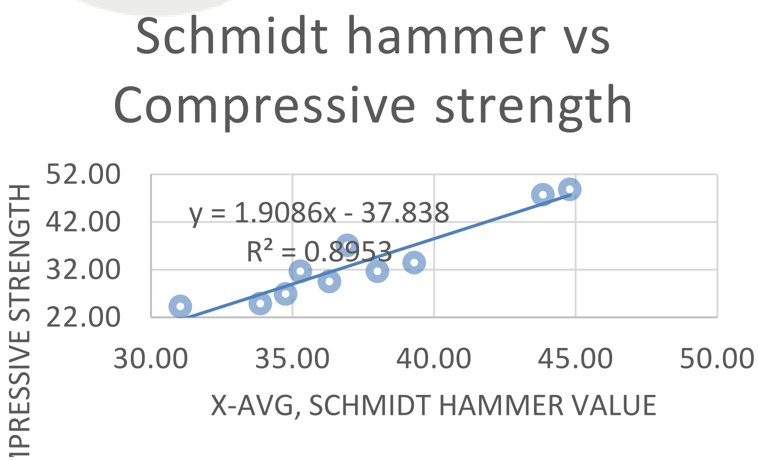
Results of the Compressive Strength test

- Compressive strength is over 24.27 MPa that shows a good concrete, a well compacted one.
- In the initial project the concrete grade was: for the columns 20/25 MPa and for the beams 25/30 MPa concrete class.
- The concrete is in a good condition adapting them with the initial project.

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Results and Discussion



The correlation between Schmidt Hammer Values and the Compressive Strength

- Coefficient is obtained R^2=0.8953 from which the correlation coefficient **R=0.9462**.
- if R<0.2- correlation is very weak (interdependence will not exist)
- if 0.2<R<0.4 - correlation is weak (interdependence will be weak too)
- if 0.4<R<0.7 - correlation is average (average interdependence)
- if 0.7<R<0.9 - correlation is strong (strong interdependence)
- **if R>0.9 - very strong interdependence**

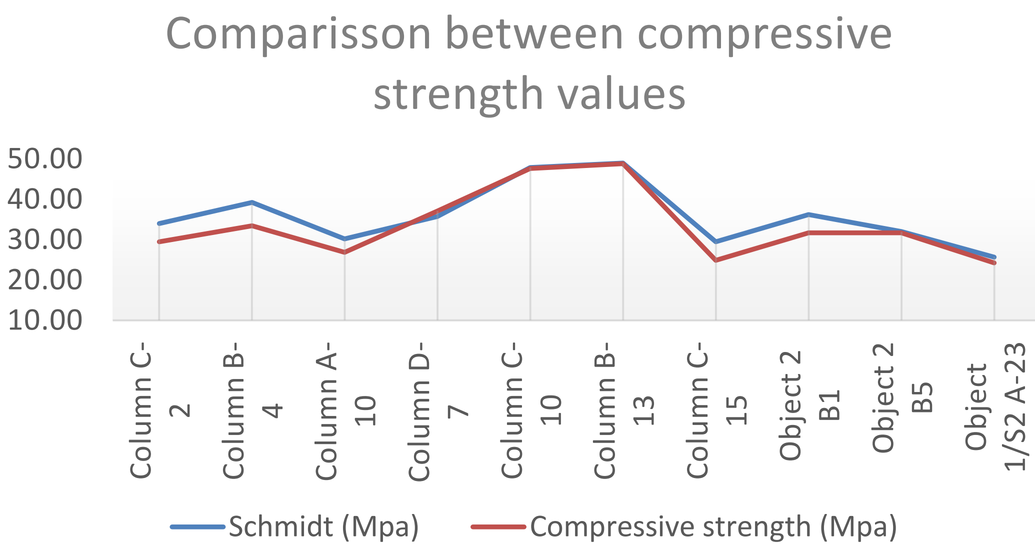
$$Y=1.9086 * X – 37.838$$

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Results and Discussion

RESULTS OF COMPRESSIVE STRENGTHS



- The chart shows the comparison between Schmidt hammer compressive strength and the compressive strength of the cored drilled concrete samples.
- There is a slight difference between the values given from the Schmidt Hammer and the core drilled compressive strength
- 5.8 MPa higher in favor of the Schmidt hammer values.

The comparison of the Schmidt Hammer compressive strength and the Compressive Strength for each structure elements.

EPOKA UNIVERSITY

Co-funded by the Erasmus+ Programme of the European Union

Results and Discussion

RESULTS OF TENSILE STRENGTH OF STEEL

Distinctive signs	*Nominal Diameter*	*Actual linear mass*	*Effective size*	*Among the fluidity*	*Among the rapture*
	[mm]	[Kg/m]	[mm²]	fy[N/mm²]	ft[N/mm²]
The round steel	10	0,5968	76,0438	473,411	578,614
		0,5952	75,8460	461,461	606,492
		0,5988	76,2957	471,848	579,325
Steel	20	2,5722	327,736	366,148	561,427
		2,5479	324,6366	385,049	585,274
		2,5573	325,8268	383,639	576,994

Results of tensile strength test

EPOKA UNIVERSITY

Co-funded by the
Erasmus+ Programme
of the European Union

Conclusion

- The tests were made and run with the samples and specimens taken from the observed and inspected building.
- The concrete, used of the case study building, is in a good condition.
- The carbonation of concrete and other aggressive agents from the environment have had an extensive corrosive effect on the steel reinforcement.
- The core concrete was in good conditions regarding the aggressive environment of the industrial area.
- Further investigations must be made and also the further interventions must also be taken in consideration.

Co-funded by the Erasmus+ Programme of the European Union

K-FORCE

Co-funded by the
Erasmus+ Programme
of the European Union

Thank you
for your attention

Contact info about the presenter:
eluga@epoka.edu.al

Knowledge FOr Resilient soCiEty