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PROPERTIES OF AGGREGATES IN DURABLE CONCRETE WORKING IN NORMAL AND AGGRESSIVE MARINE ENVIRONMENTAL CONDITIONS

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Abstract- The stability of durable concrete in normal and aggressive marine environmental conditions is important in the building structures of a coastal city. In this study, we focused on testing the influence of the properties of aggregates in concrete working in two different environmental conditions. This paper presents an analysis of *a* normal weight concrete of 45 MPa (NC 35/45) and marine durable concrete of 45 MPa (MC 35/45) compressive strength were cast and tested. This paper presents both properties of the (NC 35/45) and (MC 35/45) concretes of initial curing and subsequent exposure to humid (water tank and seaside) conditions for a period of 3 months. The chloride and sulphate concentrations in the two concretes are reported. It is concluded that the extent and amount of both chloride and sulphates in those two types of concretes can be considerably different due to condition ambient. Sulphate and chloride concentration in (MC 35/45) was only marginally higher than that in (NC 35/45). Overall, it is concluded that properly designed concretes of adequate strength and designed with water cement ratio lower than 0.40 are durable against chloride and sulphate penetration in severe humid exposure conditions.

Keywords: High Strength Concrete, Concrete Exposure Classes, Durable Concrete, Concrete Chloride Content.

1. INTRODUCTION

Durable concrete, in reality, is a highly versatile and a flexible family of construction material, which has performed extremely well in some of the most demanding and aggressive service and exposure conditions [1-5]. As a construction material it embodies high strength, high performance, heavy and normal weight, fiber-reinforced, polymer concrete and the list go on. If designed and constructed with proper care, concrete construction has often out-performed its design life [6-9]. Some of the more challenging concrete construction is in marine, off-shore and gravity platforms, etc. In marine and gravity structures durability against chlorides and sulphate rich waters and soils, and the self-weight of the concrete are often the overriding constraints [10-14]. Accordingly high strength structural concrete has emerged as a highly suitable material of construction in civil and marine structures. Structural durable concrete (SDC), of course, has well established advantages in comparison with normal weight concrete (NC) [15-20]. The mix proportions, strengths and modulus of elasticity development, and water/cement ratio, chloride and sulphate penetration are presented and discussed.

Portland cement is referred to as cement throughout this article. Concrete hardens through a process known as hydration when water and cement are combined to connect aggregate together. For the first two days, tricalcium silicate is mostly responsible for the strength. Because dicalcium silicate responds more slowly, it only helps to strength later in life. Tetra calcium aluminoferrite and tricalcium aluminate, two other important Portland cement components, also react with water [21-23]. These responses, however, are not taken into consideration because they have a minimal impact on strength. Strength can be indirectly impacted by the physical characteristics of aggregate from merit of how well can influence on the concrete workability. In case that aggregate makes unworkable the concrete, we can add water by increasing the water to cement ratio which weakens the concrete [24-28]. Additionally, it is crucial to make sure that the nominal maximum aggregate size for reinforced concrete is such that the concrete can be placed easily. Even the inclusion of admixtures could influence on the concrete strength. Furthermore, some other admixtures have made concrete more fluid where the level of water is lower. Super plasticizer is an admixture that influences workability. This influences on the incensement workability of concrete by using less water. The hydration process we addressed earlier has an important impact on the concrete strength. In reality, the most significant component affecting concrete's strength is the proportion of water to cement ratio. Thus, the porosity has been determined through the ration of the water in cement.

The strength is higher but workability is poor which result from low water to cement ratio. In case where the strength is lower, we can have very good workability with a high water to cement ratio. In this research work we will represent all variables that significantly affect the durability of concrete [1].

2. MATERIALS AND METHODS

In this research work, the specifics of the proposed experiment have been disclosed. The summary is provided below. Two types of concretes, one normal concrete and the other marine concrete, both of C 35/45 at 90-day compressive strength were designed. They are referred to (NC 35/45) and (MC 35/45), respectively. The raw material characteristics used for producing those types of concrete are represented as follow:

2.1. Cement

In this research work, Portland cement composition type CEM I 42.5 R has been employed from the company "Titan" cement ltd [29]. The cement class, chemical, physical and mechanical characteristics are tabulated in Tables 1, until 3.

Table 1. Portland Cement Composition [29]

No.	Composition	Results (%)	Amount limit (%)
1	Al_2O_3	4.58	-
2	Fe_2O_3	2.69	-
3	SiO_2	18.01	-
4	SO_3	2.67	3.5
5	CaO	61.23	10.0
6	I.R	0.3	5.0
7	(Cl)	-	0.1
8	MgO	1.80	5.0

Table 2. Portland cement, physical properties [29]

No.	Physical characteristics	Units	Results	Standard limit
1	Standard consistency	%	28	-
2	Expansion	mm	0	≤10 mm
3	Specific density	g/cm^3	-	± 50
4	Final setting time	min	-	-
6	L.O.I	%	-	≤5%
7	Surface (Blaine)	cm^2/g	3842	± 200
8	Initial setting time	min	2h:30min	60

Table 3. Portland cement, mechanical properties [29]

No.	Mechanical characteristics	Units	Test results		
			Day 2	Day 28	Standard limits
1	Compression strength	MPa	26	48	Day 2 > 20 MPa Day 28 ≥ 42.5
2	Flexural strength	MPa			

2.2. Aggregates

For this study were used coarse aggregates from Mat River (Milot) and quarry units from Kruja mountain. The usage of aggregate maximum size varied 5-25 mm where specific gravity varied from 2.6-2.7 kg/m^3. River and mountain coarse aggregates were part of the experiments. Figures 1 and 2 represents particle size distribution of coarse aggregates. Furthermore, through this study were used fine aggregates - sand from the location of Mat River (Milot) and quarry units from Kruja mountain. Aggregate size varied from 0-5 mm where specific gravity varied from 2.68-2.7 kg/m^3. River and mountain fine aggregates were both used for the experiments. In the Figures 3 and 4 and Table 4 are depicted the particle size distribution of fine aggregates.

Table 4. PSD test results obtained from coarse and fine aggregates used in production durable concrete

Sieve	Particle size distribution [g]			
Openings	River sand	Crashed sand	River gravel	Crashed gravel
[mm]	0/5mm	0/5mm	5/25mm	5/25mm
40	0.00	0.00	0.00	0.00
31.5	0.00	0.00	0.00	0.00
22.4	0.00	0.00	156.80	678.00
16	0.00	0.00	284.20	325.60
11.2	0.00	0.00	1466.10	18745.00
8	0.00	0.00	3630.30	3785.20
4	3.12	5.23	277.70	302.60
2	410.48	512.30	92.30	112.30
1	479.44	621.30	0.00	0.00
0.5	611.50	654.20	0.00	0.00
0.25	552.24	587.00	0.00	0.00
0.125	185.64	210.00	0.00	0.00
Bottom	45.06	83.92	12.30	32.56
Total	2287.48	2673.95	5919.70	23981.26

Sieve	Cumulative passing [g]			
Openings	River sand	Crashed sand	River gravel	Crashed gravel
[mm]	0/5mm	0/5mm	10/25mm	10/25mm
40	2287.48	2673.95	5919.70	23981.26
31.5	2287.48	2673.95	5919.70	23981.26
22.4	2287.48	2673.95	5762.90	23303.26
16	2287.48	2673.95	5478.70	22977.66
11.2	2287.48	2673.95	4012.60	4232.66
8	2287.48	2673.95	382.30	447.46
4	2284.36	2668.72	104.60	144.86
2	1873.88	2156.42	12.30	32.56
1	1394.44	1535.12	12.30	32.56
0.5	782.94	880.92	12.30	32.56
0.25	230.70	293.92	12.30	32.56
0.125	45.06	83.92	12.30	32.56

Sieve	Cumulative passing [%]			
Openings	River sand	Crashed sand	River gravel	Crashed gravel
[mm]	0/5mm	0/5mm	10/25mm	10/25mm
40	100.00%	100.00%	100.00%	100.00%
31.5	100.00%	100.00%	100.00%	100.00%
22.4	100.00%	100.00%	97.35%	97.17%
16	100.00%	100.00%	92.55%	95.82%
11.2	100.00%	100.00%	67.78%	17.65%
8	100.00%	100.00%	6.46%	1.87%
4	99.86%	99.80%	1.77%	0.60%
2	81.92%	80.65%	0.21%	0.14%
1	60.96%	57.41%	0.21%	0.14%
0.5	34.23%	32.94%	0.21%	0.14%
0.25	10.09%	10.99%	0.21%	0.14%
0.125	1.97%	3.14%	0.21%	0.14%

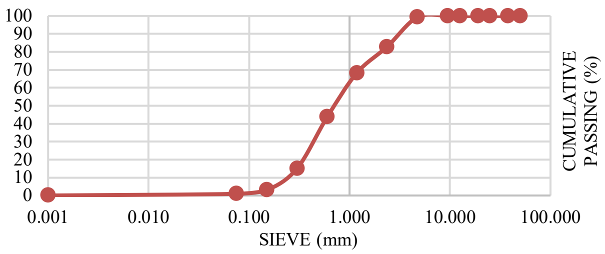

Figure 1. Natural River gravel PSD graph

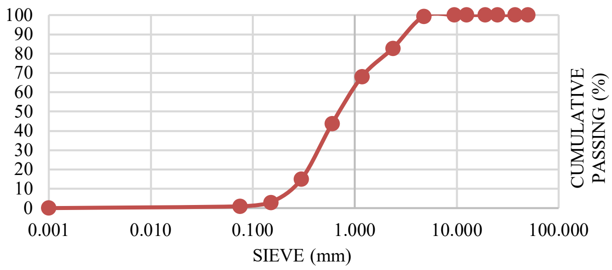

Figure 2. Natural crashed mountain gravel PSD graph

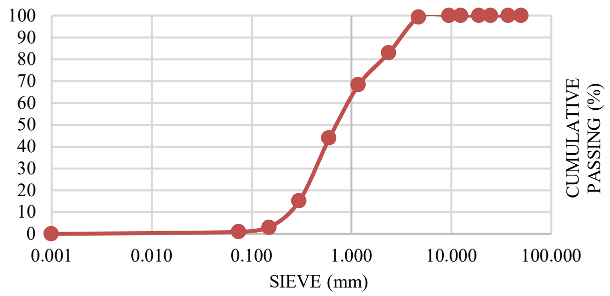

Figure 3. Natural crashed river sand PSD graph

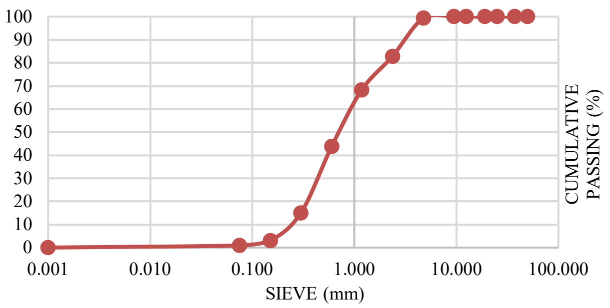

Figure 4. Natural Mountain sand PSD graph

2.3. Water

As can be seen in Table 5, the laboratory's potable tap water was utilized for the concrete's mixing and curing.

Table 5. Characteristics of water used in production of durable concrete

No.	Properties	Units	Results	Standard limits [31]
1	Hardness ($CaCO_3$)	mg/l	2.56	-
2	pH value	-	7.23	≥4
3	Odor	-	-	-
	Water resource	-	Potable	-
4	Density of the water @1900C	kg/l	1.0032	0.9982
5	Color	-	Transparent	-
6	Solids dissolved @1800C	mg/l	3.24	≤4
7	Sulphate content	mg/l	986	≤2000
8	Chloride content	mg/l	645	≤1000
9	Salts content	mg/l	42	≤100

2.4. Admixture

Type Chryso fluid Premia 180 admixture is used for producing concrete class C 30/45 for this project study. The used admixture chemical properties in concrete are shown in the Table 6.

Table 6. Physical and chemical characteristics of super plasticizing admixture used in durable concrete

Chryso fluid Premia 180 admixture product	
Appearance	Liquid
Color	Brown
Density according to ISO 758	1.26g/cm^3 (@ +20˚C)
Dry content according to EN 480-8	23.65%
Principal action	Increased and extended workability and reduction of water content
Classification [32]	Set retarding, high-range reducing, super plasticizing
Alkali content [32]	<0.1%
pH according [33]	5.3 (@ +20˚C)

2.5. Durable Concrete Mix Design

The mix quantities used and some characteristics of the durable concretes produced for normal and aggressive environmental ambient are shown in Tables 7 and 8. In this particular study, river and mountain raw materials were used to produce durable concrete class C30/45. The standards of EN 206-1 are the foundation upon which all mix designs are built.

Table 7. Durable concrete mix designs laboratory data for river materials

Mix Design					
Code: R1					
Laboratory name: KIBE1 Laboratory					
Concrete class: C 35/45					
Exposure class: XS1; XS2; XS3					
Standard uncertainty projection: 7 MPa					
Durable Concrete Ingredients					
No.	Miloti raw materials	Descriptions	Results		
1	Cement	CEM I	-		
		42.5 R	-		
2	Water	"TITAN"	-		
3	Aggregates (Miloti)	Crashed	Density (kg/m³)	Quantity (kg/m³)	Amount [%]
	Sand (0/5 mm)	River	2.631	915	48.1
	Gravel 5/10 mm	River	2.681	294	15.4
	Gravel 10-25 mm	River	2.712	695	36.5
4	Additive	Type	CHRYSO premia 180		
		Dosage	1.20%		
		Reduce	30 %		

Ingredients						
No.	Aggregates	Quantity for 1m^3 (kg)	Quantity for 0.027 m^3 (kg)	Humidity (%)	Absorption (%)	Corrected quantity (kg)
1	Sand 0/5 mm	915	24.71	9.0	0.46	26.93
2	Gravel 5/10mm	294	7.94	2.5	0.36	8.14
3	Gravel 10/25 mm	695	18.77	2.5	0.59	19.23
5	Cement	380	10.26			10.26
7	Water	151	4.08	2.89	1.41	2.60
8	Additive ml/m^3	4.56	123.1			117
9	Total	2440				

Fresh concrete properties			
No.	Characteristics	Units	Results
1	Concrete temperature	ºC	15.0
2	w/c	ratio	0.40
3	Slump	cm	20
9	Fresh concrete density	kg/m³	2440

Table 8. Durable concrete mix designs laboratory data for crashed mountain materials

Mix Design						
Code: R2						
Laboratory name: KIBE1 Laboratory						
Concrete class: C 35/45						
Exposure class: XS1; XS2; XS3						
Standard Uncertainty Projection: 7 MPa						
Durable Concrete Ingredients						
No.	Miloti raw materials	Descriptions	Results			
1	Cement	CEM I	-			
		42.5 R	-			
2	Water	TITAN	-			
3	Aggregates (Miloti); (Fushe Kruje)	Crashed	Density (kg/m³)	Quantity (kg/m³)	Dosage (%)	
	Sand 0/5 mm	Crashed + river	2.631	915	48.1	
	Gravel 5/10mm	Crashed/River	2.681	294	15.4	
	Gravel 10-25 mm	Crashed/River	2.712	695	36.5	
4	Additive	Type	CHRYSO premia 180			
		Dosage	1.20%			
		Reduce	30%			
Ingredients						
No.	Aggregates	Quantity for 1m^3 [kg]	Quantity for 0.027 m^3 [kg]	Humidity [%]	Absorption [%]	Corrected quantity [kg]
1	Sand 0/5 mm	915	24.71	9.0	0.46	26.93
2	Gravel 5/10 mm	294	7.94	2.5	0.36	8.14
3	Gravel 10/25 mm	695	18.77	2.5	0.59	19.23
5	Cement	380	10.26			10.26
7	Water	151	4.08	2.89	1.41	2.60
8	Additive ml/m^3	4.56	123.1			117
9	Total	2440				
Fresh Concrete Properties						
No.	Characteristics	Units	Results			
1	Concrete temperature	ºC	15.0			
2	w/c	ratio	0.40			
3	Slump	cm	20			
9	Fresh concrete density	kg/m³	2440			

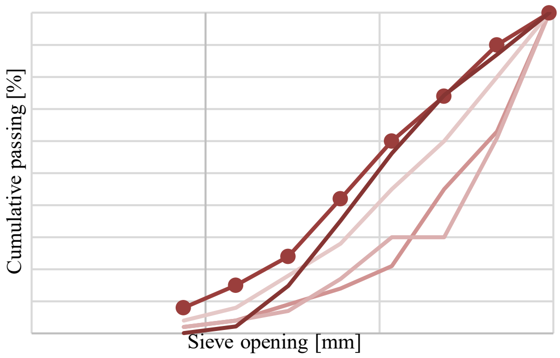

Figure 5. Curve reference of the grain maximal diameter = 30 mm [30]

3. RESULTS

For the creation of durable concrete, elements from rivers and mountains have been used. 150×150×150mm specimens are treated in both a normal and an aggressive context. After 90 days curing age, compressive strength, water depth penetration, and chloride content are evaluated. The test results are shown in Tables 9 and 10.

Table 9. Concrete test results obtained from river materials

No.	Water in normal curing condition (River aggregates)			Water in aggressive curing condition (River aggregates)		
	Compressive strength	Water depth penetration	Chloride content	Compressive strength	Water depth penetration	Chloride content
1	47.56	13.6	0.019	45.12	14.8	0.024
2	48.23	13.5	0.022	46.13	15.2	0.022
3	48.25	13.5	0.022	46.28	15	0.023
4	49.00	13.2	0.023	45.53	14.5	0.025
5	49.06	13.2	0.034	47.00	14.3	0.032
6	50.02	13.0	0.021	47.09	13.8	0.023

Table 10. Concrete test results obtained from mountain crashed materials

No.	Water in normal curing condition (Mountain aggregates)			Water in aggressive curing condition (Mountain aggregates)		
	Compressive strength	Water depth penetration	Chloride content	Compressive strength	Water depth penetration	Chloride content
1	41.357	22.4	0.032	39.032	23.0	0.038
2	49.337	20.3	0.033	46.737	21.2	0.042
3	49.510	20.0	0.036	43.240	22.0	0.045
4	41.615	24.3	0.034	33.647	24.6	0.045
5	49.250	20.1	0.041	47.005	20.0	0.036
6	50.370	19.3	0.036	38.140	24.8	0.045

The relationship between strength and chloride concentration for durable concrete built from river materials is depicted in Figures 6 and 7 for two environments: normal and marine.

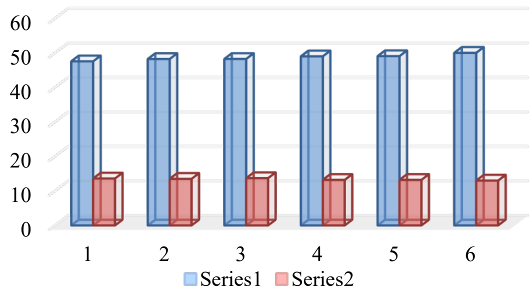

Figure 6. In normal environment

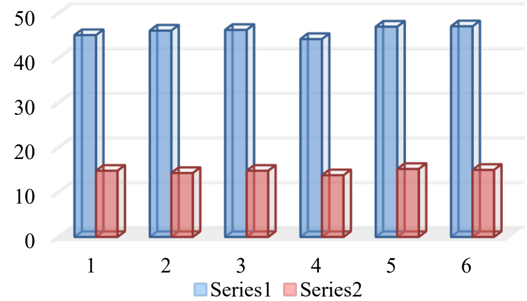

Figure 7. In marine environment

The relation between strength and the chloride content, for durable concrete made with mountain crashed materials is depicted in Figures 8 and 9, for two environments: normal and marine.

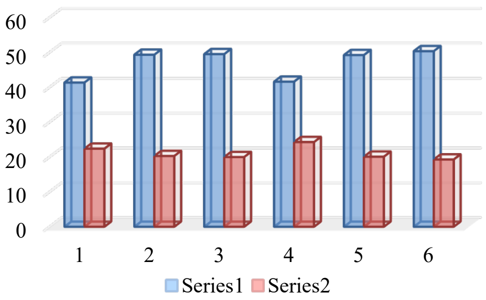

Figure 8. In normal environment

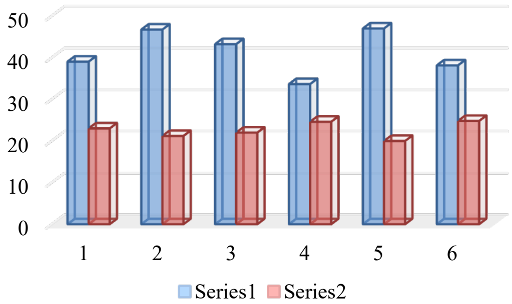

Figure 9. In marine environment

Figure 10 depicts the relation between strength and the depth of water penetration, in normal, for durable concrete made with river materials.

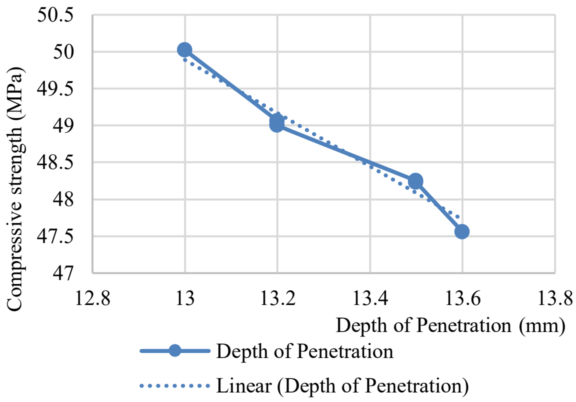

Figure 10. Relation between depth penetration and compressive strength of river materials, in Normal environment

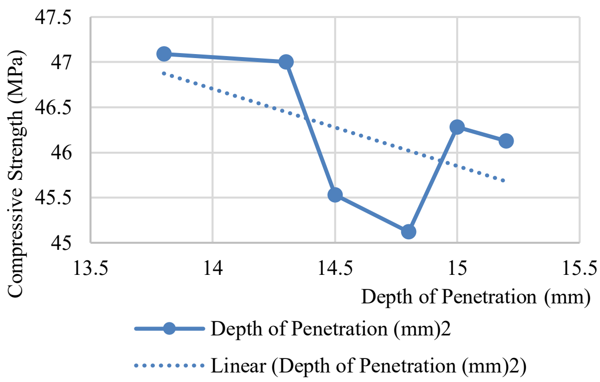

Figure 11. Relation between depth penetration and compressive strength of river materials, in Marine environment

In a maritime environment, the relationship between strength and the depth of water penetration for long-lasting concrete built from river components is depicted in Figure 11 [34, 35]. The relation between strength and the depth of water penetration, in normal environment, for durable concrete made with mountain crashed materials, are shown in Figure 12. The relation between strength and the depth of water penetration, in marine environment, for durable concrete made with mountain crashed materials, are shown in Figure 13.

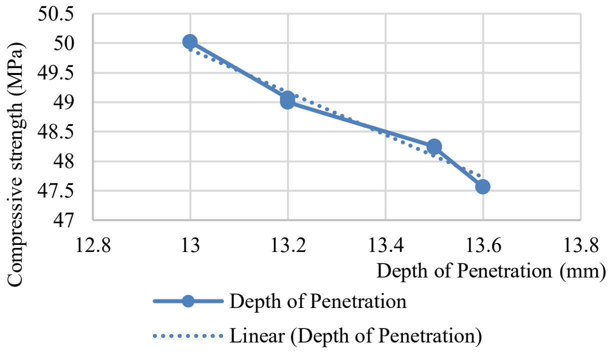

Figure 12. Relation between depth penetration and compressive strength of river materials, in Normal environment

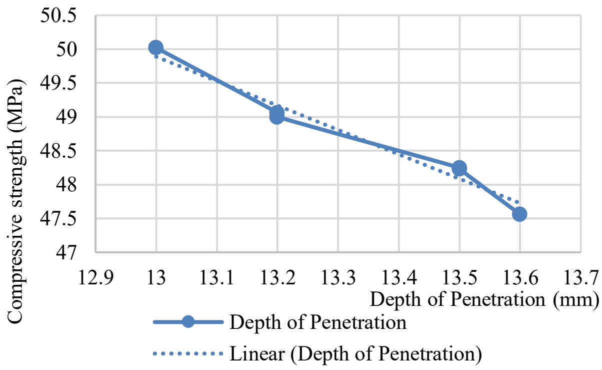

Figure 13. Relation between depth penetration and compressive strength of river materials, in Marine environment

4. CONCLUSIONS

The characteristics and ratio of the ingredients which compose in concrete have a significant impact on its durability. The river aggregates, which are denser, are expected to be appropriate for generating durable concrete in order to assure adequate durability of maritime structures. It is obvious that even a slight increase in the water to cement ratio may significantly improve the permeability of concrete. Once more, because it regulates the flow of corrosive salt-ions into the concrete, permeability is the key factor in determining the long-term durability of reinforced concrete exposed to saltwater. In our situation, all mix designs created are based on a ratio of 0.4. When comparing test results from durable concrete made from mountain and river materials, it is clear that durable concrete produced with mountain crashing materials and treated in abrasive environments indicates significant degrees of water depth penetration. Rivers form in materials with high compressive strengths and low water penetration rates.

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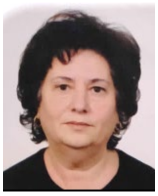
BIOGRAPHIES



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