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Performance Evaluation Analyses of Recycled Concrete in Albania by using Ultrasonic Pulse Velocity

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ABSTRACT

This paper is focused on investigation of the possibility of using recycled aggregate in concrete mixes instead of natural aggregate. Our research included the preparation of concrete mixtures with recycled aggregate of concrete and natural fine aggregate. It has been focused on evaluation of compressive strength of old and new concrete, granulometric distribution analysis of recycled concrete, density of new and old concrete, water permeability in concrete, and measuring of Ultrasonic Pulse Velocity (UPV) for our samples. According to experimental results, the use of recycled aggregate in concrete mixes as an alternative to natural aggregate is possible. The experimental results demonstrate that recycled aggregates of concrete can achieve higher durability.

Keywords: Recyclable concrete; fine aggregate; compressive strength; granulometric distribution; ultrasonic pulse velocity.

1. INTRODUCTION

Recently the use of recycled concrete as a structural material, instead of natural aggregate, has shown increasing interest in use. Recyclable of concrete aggregates can cost 20% to 30% less than natural aggregates. Albania is a small area with an average population of 3,000,000 inhabitants. Disposal of construction and waste in Albania is one of the biggest environment problems and it will get worse in the future, due to the lack of open land and the limited size of landfills that deposit large amounts of raw construction waste.

This research aims to reduce the environmental problems generated by the dumping of construction and demolition waste. Utilizing recycled aggregate is certainly an important step towards sustainable development in the concrete industry and management of construction waste. Recycled aggregate is a viable alternative to natural aggregate, which helps in the preservation of the environment. Quality of the recycled aggregate is influenced by the quality of materials being collected and delivered to the recycling plants [1, 2]. Quality and availability of recycled aggregate are the main factors towards stable use and introduction of recycled aggregate to the construction industry [2, 3]. The applications of recycled aggregate in construction have started since end of World War II by demolished concrete pavement as recycled aggregate in stabilizing the base course for road construction [4].

The main objectives of this research work are as follows:

- to study the physical and mechanical performance of recyclable aggregates used in concrete mix instead of natural aggregate;
- to consider the possibility of using recycling in concrete mixing aggregates;
- to study mixtures that can be added to improve the bond between the recycled aggregate and cement on one side.

2. MATERIALS

Aggregates are making up 60-75% of the total volume of concrete, so their selection is important because they control the quality and the concrete. Therefore, the selection and pro-portions of the aggregate should be given attention. Since recycled aggregates have a large amount of porosity and can potentially undergo a higher degree of deformation and are weaker than cement paste, therefore, this may affect the mechanical and physical properties of concrete [5]. Materials that we have used in our study have been prepared from Portland cement, aggregates, and sand. Specific weight, aggregate absorption and volume weight are important values in determining aggregate volume in mixed selection production. Table 1 shows the specific weight values of the fine sand aggregate to be used in the mixed selection.

Table 1. Properties of finest aggregate

Specific weight	2.65	g/cm^3
Absorption	1.5	%
Dry volumetric weight	1530	kg/m^3

The specific weight was performed in accordance with ASTM C 127, ASTM C 128 standards, and was calculated under two different conditions, dry and water saturated [6]. Table 2 depict the fine aggregate sieves and shows the maximum and minimum limits where the material is in accordance with ASTM C33 standard [7].

Table 2. Evaluation of the sieve passing of the finest aggregate

Sieves dimensions	**Lower passing limit**	**Upper passing limit**
mm	**[%]**	**[%]**
9.5	100	100
4.75	95	100
2.36	80	100
1.18	50	85
0.6	25	60
0.3	5	30
0.15	2	10
0.075	0	3

The use of single parameter as a function of the granulometric curve, describes the degree of uniformity of the material is desirable. The granulometric modulus (Fineness Modulus, FM) is such that the parameter can be defined: FM = Σ cumulative residue in the sieves: (4.75 ÷ 0.15) mm / 100, the granulometric modulus for the finest aggregate must be between 2.3 ÷ 3.1, to assure a uniform mixture. In this study, we have used the sand of the Fan River in Rreshen Albania.

The results of granulometric distribution of sand are shown in table 3. The parameters of the sand are in compliance with ASTM C33 standard and at the same time its FM = 2.73 which is within the technical specifications 2.3 ÷ 3.1, thus usage of the sand as a fine aggregate is within the technical conditions for mixing with thick materials [7].

Table 3. Granulometric distribution of sand

Sieves dimensions	Lower passing limit	Upper passing limit	Actual curve of the sand	Conformity according to ASTM
mm	[%]	[%]		
9.5	100	100	100	+
4.75	95	100	100	+
2.36	80	100	84	+
1.18	50	85	66	+
0.6	25	60	48	+
0.3	5	30	23	+
0.15	0	10	6	+

Recyclable aggregates of the maximum size is about D_{max} = 25 mm, dust and dirt, such as bricks, asphalt, glass, wood, etc., were not presented after the recycled material [8]. The granulometric distributions of recycled aggregate are shown at Table 4.

Table 4. Granulometric distribution of recycled aggregate

Sieves dimensions	Lower passing limit	Upper passing limit	Actual curve of recycled aggregate	Conformity according to ASTM
mm	[%]	[%]		
37.5	100	100	100	+
25	100	100	100	+
19	85	100	86.9	+
9.5	20	55	29.2	+
4.75	0	10	7.8	+
2.36	0	5	4.9	+

Table 5. Physical properties of recycled aggregate

Dry Specific weight	2.34	g/cm3
Saturated specific weight	2.42	g/cm3
Absorption	5.2	%
Dry volumetric weight,	1370	kg/m3
Saturated volumetric weight	1441	kg/m3

3. EXPERIMENTAL METHODOLOGY AND RESULTS

In this study, the design mixtures were prepared in accordance with ACI 211.1. The two target groups of samples selected in this study were C20/25 and C25/30. Twelve samples were prepared for each concrete class: two samples were prepared for 7-day compressive test and two for 28-day compressive test, two samples for indirect traction test, two samples for water permeability test, two samples for volume weight and two samples for bending test [9].

Concretes that contain recycled aggregates have the same steps of the mix design process as concretes made with natural aggregates. Concrete mixing operation for all samples was realised with mixer in accordance with ASTM C192 [9]. The mixes were designed with an S3 slump (100-150) mm and designed for the same 0.015 air content per unit volume. The water and cement used in both mixes is the same, the recycled aggregates and sand are in the same portion, and 60% recycled aggregate and 40% sand [10-12]. The proportions used in the preparation of the two different mixes. Table 6 gives the mix design used for this study per cubic metre of concrete, the control mix with sand from FAN River, recycled aggregate and cement. Also, gives compressive strength (Figure 1), hardened density, ultrasonic test and penetration water under pressure results for mix design of the existing concrete, mix design C 20/25 and mix design C 25/30.

Furthermore, Table 7 shows slump test, temperature of test, density of fresh concrete for fresh concrete properties for two mix design use in this study for mix design C 20/25 and Mix Design C 25/30 [13].

Table 6. Trial mix designs (per cubic meter of concrete)

Materials	**Mix Design C 20/25**	**Mix Design C 25/30**
Sand from FAN river, kg	736	720
Recycled aggregate, kg	1104	1079
Cement, kg	300	349
Water/ l	180	192
Ratio Water Cement, w/c	0.6	0.55

Table 7. Fresh Concrete Properties

Mix Design	**Properties**	**Value**
Mix Design C 20/25	Slump Test (mm)	105
	Temperature of test (0C)	22.2
	Density of fresh concrete (Kg/m3)	2270
	Air Content (%)	1.46
Mix Design C 25/30	Slump Test (mm)	140
	Temperature of test (0C)	22.4
	Density of fresh concrete (Kg/m3)	2300
	Air Content (%)	1.50

Considering that for the Portland cement concrete the compressive strength (Figure 1) continues to increase with time (with the years) [14]. The durability of our mix design results satisfactory (after 28 days) and can achieve or overcame even higher that the existing concrete (aging time 23 years) as can be seen in Table 8 and Figure 1.

Table 8. Mean Compressive Strength, Hardened density, Ultrasonic test and Penetration of water under pressure

		Age of test		
Mix Design	**Properties**	**7 Days**	**28 Days**	**23 years**
Existing concrete	Compressive strength (MPa)			33.3
	Hardened density (Kg/m^3)			2396
	Ultrasonic pulse velocity (km/s)			4.2
	Penetration of water under pressure (mm)			16
Mix Design C 20/25	Compressive strength (Mpa)	18.8	26.6	
	Hardened density (Kg/m^3)	2252	2265	
	Ultrasonic pulse velocity (km/s)		3.8	
	Penetration of water under pressure (mm)		28	
Mix Design C 25/30	Compressive strength (Mpa)	20	28.5	
	Hardened density (Kg/m^3)	2295	2302	
	Ultrasonic pulse velocity (km/s)		3.9	
	Penetration of water under pressure (mm)		22	

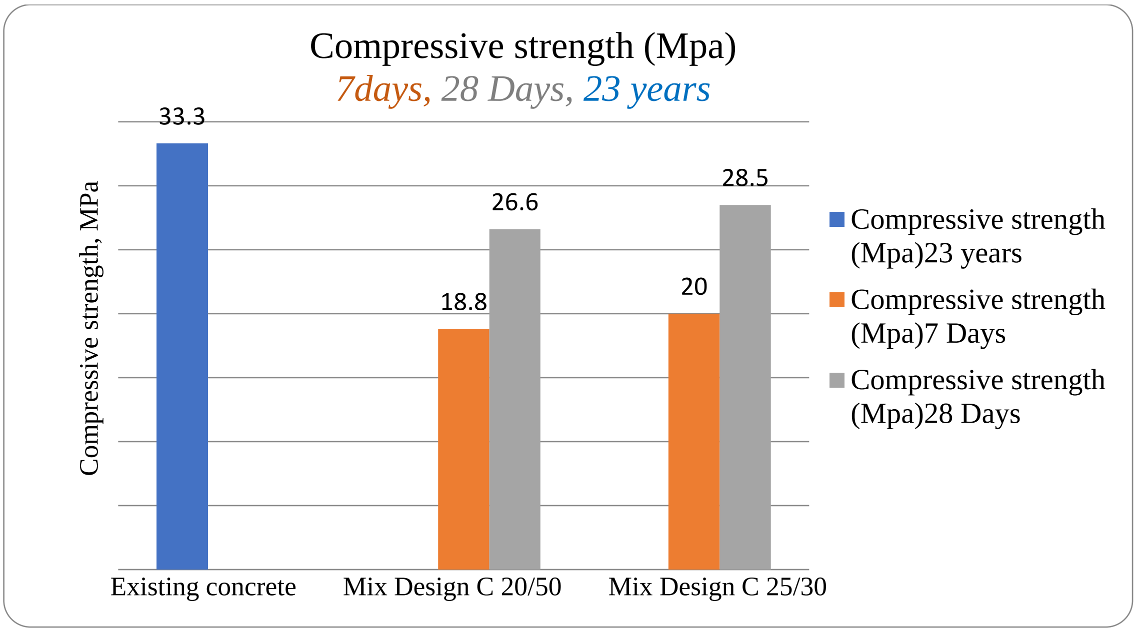
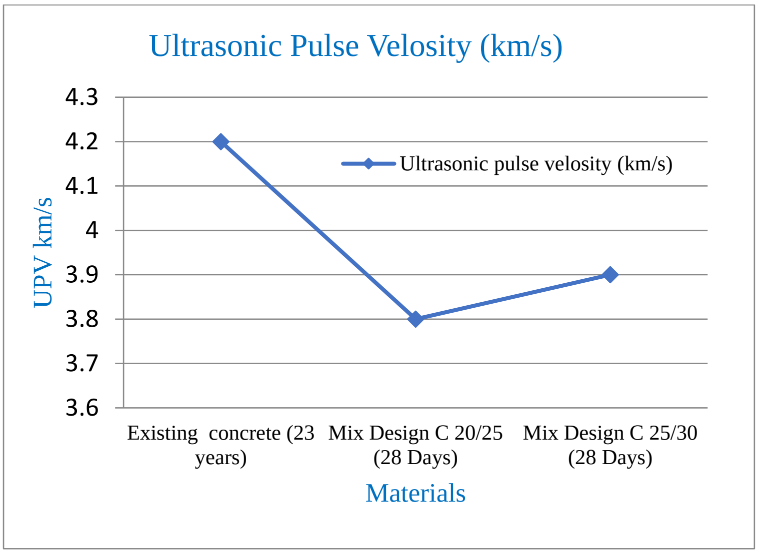


Figure 1. Compressive strength of exists concrete.

Ultrasonic pulse velocity technique is one of the most used non-destructive techniques used in the assessment of concrete properties. This test is done to assess the quality of concrete by ultrasonic pulse velocity method. The UPV technique consists of measuring the travel time of an ultrasonic pulse passing through the height of the concrete samples being evaluated [15, 16]. Referring to the standards, comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity, absence of internal flaws, cracks and segregation etc. [17]. Figure 2 depict the results of Ultrasonic pulse velocity (UPV) and comparison of UPV for existing concrete, mix design C20/25days and mix design C25/30days [17].

(a)



(b)

Figure 2. (a) Ultrasonic pulse velocity results – UPV, (b) Comparison of UPV for existing concrete, mix design C20/25days, mix design C25/30days

The measurement results of UPV existing concrete (23 years) show very good quality with UPV = 4.2 versus mix design C 25/30 28days with UPV = 3.9, and mix design C 20/25 28days with UPV= 3.8.

4. CONCLUSION

In this research work we have investigated the possibility of using recycled aggregate in concrete mixes instead of natural aggregate. Also, we have briefly described the preparation of concrete mixtures with recycled aggregate and different natural properties of fine aggregate and evaluation of the properties of fresh and hardened concrete. Further analyses have been focused on the evaluation of compressive strength of old and new concrete, granulometric distribution analysis of recycled concrete, density of new and old concrete, water permeability in concrete and air content. According to experimental results, the use of recycled aggregate in concrete mixes as an alternative to natural aggregate is possible.

From our experimental work the uses of recycled aggregates of concrete it can conclude that can be realised through recycled aggregate. The durability of our mix design results satisfactory (*after 28 days*) and can achieve or overcame even higher that the existing concrete (*aging time 23 years*). In the light of the global environmental situation the promotion regarding the use of recycled concrete waste should be widely supported.

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CONFLICT OF INTERESTS

The authors would like to confirm that there is no conflict of interests associated with this publication and there is no financial fund for this work that can affect the research outcomes.

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