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Some Properties of No-Fines Concrete Produced by Using Demolished Concrete as Recycled Coarse Aggregate

Abstract- *This paper investigate some mechanical properties of no-fines concrete produced by using demolished concrete as coarse aggregate after crushing to different sizes. Different no-fine mixes were considered using Portland cement type I with two types of coarse aggregates, crushed natural gravel and crushed demolished concrete were used with two ratios by weight (1:5 and 1:7) cement/aggregate. Single size and graded aggregate were used with a maximum size of 20 mm. W /C ratio was kept as 0.4 for all mixes and supper plasticizer was used to keep the same flow and compaction factor value for all mixes . Using demolished concrete as coarse aggregate in no fine concrete led to decrease in the workability. As a comparison with natural coarse aggregate mixes, the average percentages of decreases for the flow, compaction factor and the fresh density were 2%, 2.3% and 6.4%, respectively. As well as the test results indicated that the compressive strength, splitting tensile strength, flexural strength and oven dry density for no fine made with crushed demolished concrete at age 28 days were decreased by about 29%, 22 %, 21% and 4% respectively as compared with no fine made by natural crushed aggregate.*

Keywords- *Compressive Strength, Demolished Concrete, Flexural Strength, No-Fine Concrete, Natural Aggregates, Splitting Strength.*

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1. Introduction

No Fine concrete is one of the methods of producing lightweight concrete by removes the fine aggregate from ingredients conventional concrete. This concrete is consisting of only coarse aggregate, cement and water [1]. Very often single sized coarse of aggregate, that passing through (20 mm sieve) retained on (10 mm sieve) is used. Because of some of the advantages it possesses over the conventional concrete made no fines concrete is becoming popular [1].

Large attention is being aimed to the environment and safeguarding of natural resources and recycling of waste materials. To reduce the problem of accumulated waste dumping, it is imperative that despoil materials should be used in an environmentally safe manner either as economic and beneficial purposes or as raw materials for other products. Because of a large development of the construction, techniques and methods of mixing, lightweight concrete become commonly used recently. There is a need to reduce the density of concrete productive because of its economic benefits and productivity of numerous productions. Moreover, the use of waste of construction or outputs from production processes for the purpose of manufacture of lightweight concrete can represent the double interest using this waste and clearness the environmental with production good concrete, which can be used for several purposes.

No fines concrete has many different names including zero-fines concrete, porous concrete and pervious concrete, obtained by eliminating the fine aggregate from the normal concrete mix .

The advantages of no fine concrete are have lower density, lower cost due to lower cement content, lower thermal conductivity, relatively low drying shrinkage, capillary movement of water and no segregation [2]. No fine concrete has the ability to allow water to permeate the material, which reduces the environmental problems associated with asphalt and conventional concrete pavements. The most common application for no fine concrete is in low traffic volume areas, such as parking lots, residential roads, driveways and footpaths [3].

Wen et al [4] studied the effect using of waste concrete as coarse aggregate in new concrete pavements on fresh and hardened concrete properties. Replacement of demolished concrete as coarse aggregate for natural coarse aggregate by up to (45%) by volume had no significant effects on any of the concrete properties. Results show that large quality from rubble concrete as aggregate can be used as a replacement for a portion of the natural coarse aggregates in new Portland cement concrete pavements.

Witchayangkoon et al [5] showed effect of using "recycle concrete aggregate as a replacement of natural coarse aggregate to produce concrete "paving blocks. Recycled concrete as coarse

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aggregate has been used at different proportions (50%), (70%) and (100%) as replacement of natural coarse aggregate. The mix concrete with design slump (100 ± 25mm) uses water/cement ratio (0.47). The average concrete strengths at 28days were (66.5, 45.6 and 35.0) MPa. This study showed possibility that can use recycled with full 100% replacement of coarse aggregate in concrete paving blocks .

Qasrawi et al. [6] studied that effect of using recycled concrete aggregates (RCA) on properties for normal concrete. Results showed that the use of recycled aggregates effect on the workability of concrete. Such an effect can reduce by using plasticizers. Concrete strength has been reduced by (5% to 25%) depending on the percent of recycled aggregate replaced by normal aggregate and the W/C ratio. Rizvi et al. [7] this study showed the effect of using waste concrete as coarse aggregate instead of natural coarse aggregate in percentage (15%, 30%, 50% and 100%). The cylinders were used for compressive strength tested at (7, 14 and 28) day. Some of the cylinders were cut and tested for void content and permeability. For all the batches slump was zero, but the entrained air and unit weight with (15% recycle concrete aggregate), specimens were very similar to the control mix. However, there was a big drop in entrained air and unit weight for the samples with (30%, 50% and 100%) recycles concrete aggregate. The samples with (15% recycle concrete aggregate) had very similar to the strengths for control specimens.

Berry et al. [8] investigated the effect of using recycle concrete aggregate on density and compressive strength of pervious concrete. Recycled concrete as coarse aggregate has been used at different proportions (50%, 70% and 100%) as replacement of natural coarse aggregate. For mix, designs with (0% to 50 %) recycle concrete aggregate replacement were found to have densities within the same general range. Nevertheless (100%) recycle concrete aggregate replacement resulted in reduction in density. Mix designs incorporating low amounts of recycle concrete aggregate (0% to 20%) gave highest compressive strength values, while pervious concrete with (100%) recycle concrete aggregate replacement gave lowest compressive strength values. The recycling of concrete process provides the following:

- Less the use of the natural resources.
- Less the cost of production and transfer of these raw materials.
- Less the material transferred to landfills.

It was focus to use locally material to maintain the economic side and provide an incentive encouraging for using no fine concrete in practical applications.

2. Experimental work

I. Material used; cement

Ordinary Portland cement type (I) manufactured in Iraq with a commercial name of (Karasta) was used for no-fine concrete mixes throughout the present work. Table 1 and 2 present the physical properties and chemical analysis for cement. Results indicated that the cement was conformed to the Iraqi Standard IQS No.5/1984 [9].

II. Coarse aggregate

Two types of coarse aggregate were used in this work to produce no-fine concrete, they were:

a) Natural Crushed Coarse Aggregate

Natural crushed coarse aggregate of 20mm nominal grading and single size, brought from (Al-Soddor source) region. The grading and properties of natural crushed coarse aggregate conforms to the Iraqi specification No.45/1984 [10], as shown in Table 3 and 4.

b) Demolished Concrete Aggregate:

A demolished concrete was used as coarse aggregate. It was brought from waste found in the university laboratories and used as recycled materials. To produce aggregate from the demolished concrete, the following procedure was followed:

1. The demolished concrete was crushed into smaller sizes manually by a hammer to obtain the required sizes.
2. The crushed old concrete was sieved on a standard sieve according to Iraqi specification IQS. No.45/1984 [10], to produces aggregate with 20mm maximum size, single and grading similar to that of natural aggregate used in this study.

III. Admixture

The super plasticizer used in this work was considered high range water reducing admixture. It is commercially know as (Glenium 54), Table 5 shows the typical properties of it. This admixture is complying with the requirement of the ASTM C494-03 [11] type F.

IV. Water

Ordinary tap water was used for washing, mixing and curing throughout this study.

Table 1: Chemical composition of main compounds of the cement

Oxide	Content %	IQS No. 5, 1986 [9]
CaO	66.11	-
SiO_2	21.93	-
Al_2O_3	4.98	-
Fe_2O_3	3.10	-
MgO	2.0	<5
SO_3	2.25	< 2.8
Insoluble Residue I.R	1.29	<1.5
Loss on ignition L.O.I	2.39	<4.0
Lime Saturation Factor, L.S.F	0.93	0.66-1.02
Main Compounds (Bogue's equations)		
C3S	64.57	-
C2S	14.15	-
C3A	7.95	>3.5
C4AF	9.43	-

Table 2: Physical properties of cement

Physical properties	Test results	Limit of Iraqi specification (No. 5-1984)
Specific surface area (Blaine method), m^2/kg	376	≥230
Setting time (Vicate apparatus),	1:05	≥45 min.
Initial setting time, hrs:min	4:00	≤ 10 hrs
Final setting time, hrs:min		
Soundness (Autoclave) method, %	0.12	≤0.8

Table 3: Grading and physical properties of single size coarse aggregate

No	Sieve size (mm)	Percentage passing	
		% Passing	(Limit of Iraqi specification No. 45, 1986) [10]
1	20	100	85-100
2	10	14	0-25
3	5	1	0-5
4	2.36	-	-
Sulfate content (%)		0.08	≤ 0.1%
Specific gravity		2.69	
Absorption (%)		0.55	

Table 4: Grading and physical properties of coarse aggregate

No.	Sieve size (mm)	Percent passing %		
		Natural aggregate	Demolished aggregate	IQS No. 45, 1984 [10]
1	20	100	100	85-100
2	10	30	30	30-60
3	5	0	0	0-10
4	2.36	-	-	-
Sulfat content (%)		0.08	0.08	≤0.1%
Specific gravity		2.69	2.48	
Absorption (%)		0.55	4.5	

Table 5: Technical description of high range water reducing admixture

Technical properties T 25 ºC	
color	Dark Brown
Specific gravity	1.21@ 25±2ºC
Chloride content	Nil
Flash point	N/A
PH	6.6
viscosity	128+/-30cps@ 25±2ºC

3. Experimental Program

Trail mixes were adopted to check the required properties of no fine concrete with suitable amount of w/c ratio and converge on the influence of changing aggregate type on mechanical properties of concrete. Table 6 gives the details of all mixes used in this study. Mixing was don using 0.1m3 pan tilting mixer, then cast the mix in oiled steel molds and mechanical compaction by simple Roding (25 blows) to avoid any segregation of the mix. All simples were covered with nylon sheet for (24±2) hours to prevent evaporation of water from the surface and to avoid plastic shrinkage cracking, after that, they were demolded and immersed in water tank up to date of test.

4. Fresh Concrete Tests

I. Flow test

This test was conducted for giving the index of the cohesion of the no-fine concrete produced and to show the extent of their tendency to segregation according ASTM C124 [12]. The increase in the flowing percentage of concrete gives an indication to its higher consistency.

II. Compacting factor test

Compacting factor test is used according to BS 1881: Part 103: 1993[13] .The specimen falls from the initial cone and is captured in a second cone. It is then allowed to fall into a test cylinder.

III. Fresh density

The measurement of concrete density was carried out according to ASTM C138-01 [14] in which the average of three cylinders with (100*200) mm masses was considered to determine the fresh concrete density.

5. Hardened Concrete Tests

I. Dry density (oven dry density)

The test is performed in accordance with ASTM C567-10 [15] using cylinders samples of size (100 * 200) mm and the average of three samples were taken for each mix.

II. Compressive strength

Compressive strength test was executed by according to British Standard BS 1881 part 116:1983 [16] using cubical samples size (100x 100x100) mm and taking the average result of three samples at 7, 28 days age for each mix.

III. Splitting tensile strength

Splitting tensile strength test was executed by according to ASTM C496-04 [17], using cylinder samples size (100x 200) mm and taking the average result of three samples at 28-day age for each mix .

IV. Flexural test

Flexural test was carried out according to ASTM C78-02 [18], this test method covers the determination of the flexural strength of concrete by the use of a simple prism samples (100x100x400) mm, with third-point loading. The average result of prisms specimens were calculated at 28 days age for each mix.

6. Test Results

I. Fresh properties (flow and compacting factor)

The results of the fresh properties of all no fine concrete mixes (flow and compacting factor) are indicated in Table 7. The results showed that it is possible to have a homogeneous mix using demolished concrete as replacement of coarse aggregate with cement/aggregate (C/A) ratios of 1:5 and 1:7 and w/c ratio of 0.4. Super plasticizer was used for mixes with C/A ratio of 1:7 to keep the flow and impact factor nearly the same for all no fine concrete mixes. It was noticed that the effect of super plasticizers on the fresh no-fines concrete is limited, i.e., using more than 1% of this admixture does not improve the concrete workability but causes segregation of the mix. This might be due to the nature of this type of concrete that has deficiency in fine particles of aggregate. The result indicated that using demolished concrete as coarse aggregate cause slight reduction in compaction factor and flow test compared with natural crushed aggregate. This is due to harsh surface of recycle aggregate. The aggregate/cement ratio had a significant effect on the flow test and compaction factor, in which increasing the aggregate/cement ratio increased both test results. The type of aggregate size (single or graded) of the used aggregate had significant effect on compaction factor and flow test of mixture productive. Using single size aggregate led to a reduction in flow and compaction factor more than grading size.

II. Density test results

The results of the fresh and oven dry density at (1 and 28) day of all no fine concrete mixes were indicated in Table 8. Where fresh density gives an early expectation of all the hardened properties of concrete, which gave indicated if the mix will satisfy the requirements of no fines concrete to be used as structural or insulation members. Beside it gives an early solution to overcome any unsatisfactory property. The fresh density ranges between (1680-1950) kg/m3 for all mixes.

The demolished concrete as coarse aggregate no-fine concrete exhibits a reduction in unit weight (fresh and oven dry densities) compared with natural crushed aggregate no-fine concrete. This reduction of fresh density attributed to the demolished concrete aggregate which require large amount of water to get suitable workability which was avoided by using S.P. Hence the porous nature of recycle concrete aggregate produce mixes with lower density compared with natural crushed coarse aggregate. In addition the harsh nature of the demolished concrete particles required higher water to overcome the friction problem between the particles leading to more voids and lower density. The mixes with cement/ aggregate C/A ratio of 1:7 present lower fresh density as compared with 1:5.

Table 8 also indicates the result of oven dry density at (1 and 28) days for all no-fine concrete specimens. In no-fine concrete the oven dry density would be more importance because the concrete sample contain large amount of voids and pores that detention of water (mixing water + curing water) inside of them.

Table 6: Constituents of no-fine concrete mixes

No	Mix description	Mix Details	Mix proportion by volume cement: aggregate	w/c	S.P
1	NSA5	Natural single size aggregate	1:5	0.4	-
	RCSA5	Recycled concrete single size aggregate	1:5	0.4	-
2	NSA7	Natural single size aggregate	1:7	0.4	0.36
	RCSA7	Recycled concrete single size aggregate	1:7	0.4	0.36
3	NGA5	Natural grading size aggregate	1:5	0.4	-
	RCGA5	Recycled concrete grading size aggregate	1:5	0.4	-
4	NGA7	Natural grading size aggregate	1:7	0.4	0.36
	RCGA7	Recycled concrete grading size aggregate	1:7	0.4	0.36

Table 7: Fresh properties of all no fine concrete mixes

Set No	Mix	C/W	S.P.by cement wt. (%)	Flow (%)	Compacting Factor
1	NSA5	1:5	0	61	0.88
	CCSA5	1:5	0	60	0.85
2	NSA7	1:7	0.35	64	0.87
	CCSA7	1:7	0.35	62	0.86
3	NGA5	1:5	0	63	0.89
	CCGA5	1:5	0	61	0.87
4	NGA7	1:7	0.35	65	0.90
	CCGA7	1:7	0.35	64	0.88

Table 8: Fresh density and oven dry density of all no fine concrete mixes

Set No.	Mix	Fresh density kg/m^3	Oven dry density at 1days kg/m^3	Oven dry Density at 28 days kg/m^3
1	NSA5	1850	1740	1790
	CCSA5	1735	1650	1705
2	NSA7	1780	1685	1730
	CCSA7	1680	1610	1660
3	NGA5	1950	1800	1860
	CCGA5	1800	1710	1768
4	NGA7	1835	1720	1775
	CCGA7	1735	1680	1710

II. Density test results

The results of the fresh and oven dry density at (1 and 28) day of all no fine concrete mixes were indicated in Table 8. Where fresh density gives an early expectation of all the hardened properties of concrete, which gave indicated if the mix would satisfy the requirements of no fines concrete to be used as structural or insulation members. Beside it gives an early solution to overcome any unsatisfactory property. The fresh density ranges between (1680-1950) kg/m3 for all mixes.

The demolished concrete as coarse aggregate no-fine concrete exhibits a reduction in unit weight (fresh and oven dry densities) compared with natural crushed aggregate no-fine concrete. This reduction of fresh density attributed to the demolished concrete aggregate, which require large amount of water to get suitable workability, which was avoided by using S.P. Hence, the porous nature of recycle concrete aggregate produce mixes with lower density compared with natural crushed coarse aggregate. In addition, the harsh nature of the demolished concrete particles required higher water to overcome the friction problem between the particles leading to more voids and lower density. The mixes with cement/ aggregate C/A ratio of 1:7 present lower fresh density as compared with 1:5.

Table 8 also indicates the result of oven dry density at (1 and 28) days for all no-fine concrete specimens. In no-fine concrete the oven dry density would be more importance because the concrete sample contain large amount of voids and pores that detention of water (mixing water + curing water) inside of them.

II. Compressive strength test results

Table 9 illustrates the average compressive strength result at age of (7 and 28) days for all no-fines concrete mixes. The result show that the compressive strength increased with the age, due to hydration process with time that led to decrease the voids and porosity becoming denser. The compressive strength of no fine concrete containing demolished concrete as coarse aggregate was less than concrete made of natural crushed aggregate. This is due to less density and high absorption of no-fine concrete made of demolished concrete as coarse aggregate in addition the weakness in properties of demolished concrete aggregate cause that reduction in compressive strength of no-fine concrete. Figure 1 shows the relationship between C/A ratio and compressive strength, which indicate that the compressive strength increases with decreases percentage of coarse A/C ratio .This is mainly due to the high mortar content and the low porosity. The cement content also has a significant role in compressive strength ,where concrete mix with high cement content exhibit higher compressive strength than concrete mix with low cement content due to increase cement paste around aggregate particles leads to improve cohesive strength and bond between aggregate particles and cement paste.

Figure 2 shows the effect of aggregate type (single size and graded) on compressive strength. The graded aggregate particles led to increase in compressive strength compared with single aggregate type. This is caused by good compaction for graded aggregate and less voids.

Table 9: Average strengths result for all mixes of no-fines concrete

Set No.	Mix	Compressive strength (MPa)		Splitting tensile strength (MPa)	Flexural strength (MPa)
		7 days	28 days	28 days	28 days
1	NSA5	6.80	8.10	0.9	1.40
	CCSA5	4.80	5.70	0.65	1.10
2	NSA7	6.65	7.85	0.7	1.23
	CCSA7	4.55	5.50	0.5	0.93
3	NGA5	7.30	8.70	1.1	1.50
	CCGA5	5.10	6.30	0.87	1.20
4	NGA7	7.10	8.60	0.89	1.30
	CCGA7	4.80	6.10	0.7	1.00

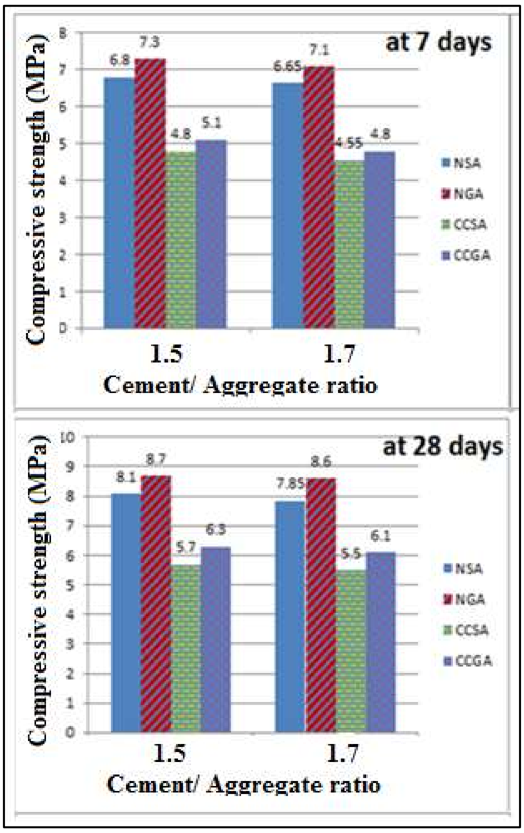

Figure 1: Compressive strength with cement/ aggregate ratio and compressive strength at 7 and 28 days age

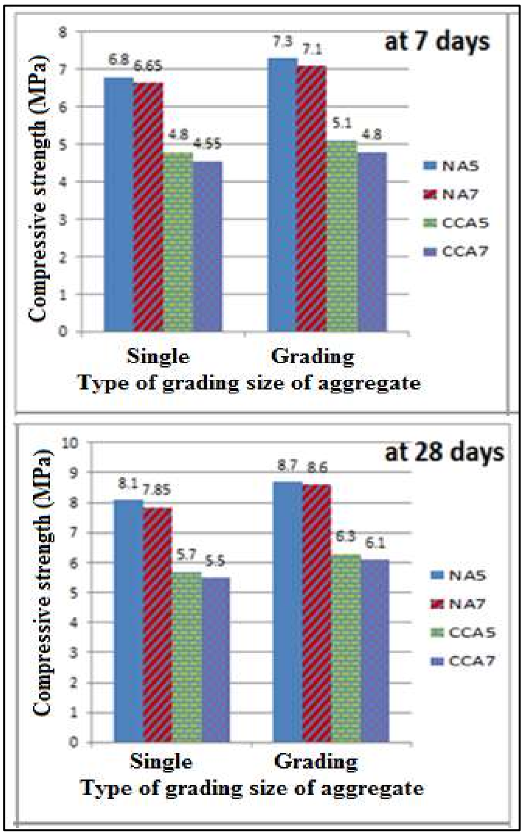

Figure 2: Effect of type aggregate (single and graded) on compressive strength at 7 and 28 days age

III. Splitting Tensile Strength And Flexural strength

The average results of splitting tensile strength and flexural strength for all no fine concrete mix at 28 days are presented in Table 9. The results showed that the splitting tensile strength for no fine concrete containing demolished concrete as coarse aggregate were lower than no fine concrete made of natural crushed coarse aggregate. The same behavior was indicated for flexural strength of no fine concrete containing demolished concrete as coarse aggregate. This reduction was due to the same reason that led to the decrease in compressive strength test .Where less density and high absorption of no-fine concrete made of demolished concrete in addition the weakness in properties of recycle concrete aggregate that cause a reduction in strength results.

Figure 3 and 4 show the relationship between C/A ratio and average splitting tensile strength and flexural strength at 28 day respectively. The results indicated that the splitting tensile strength and flexural strength increases with decreases percentage of coarse A/C ratio .This is mainly due to the high mortar content and the low porosity. The cement content also has a significant role in splitting tensile strength and flexural strength, where concrete mix with high cement content exhibit higher splitting tensile and flexural strength than concrete mix with low cement content due to increase cement paste around aggregate particles leads to improve cohesive strength and bond between aggregate particles and cement paste.

Figure 5 and 6 show the effect of aggregate type on splitting tensile strength and flexural strength. Using graded aggregate type led to increase in splitting tensile strength and flexural strength as compared with single aggregate type. The percentage increase was (14.3-16.7) % for natural crushed aggregate mixes (1:5 and 1:7) respectively, but for demolished concrete as coarse aggregate mixes (1:5 and 1:7) was (10-12.5)% respectively.

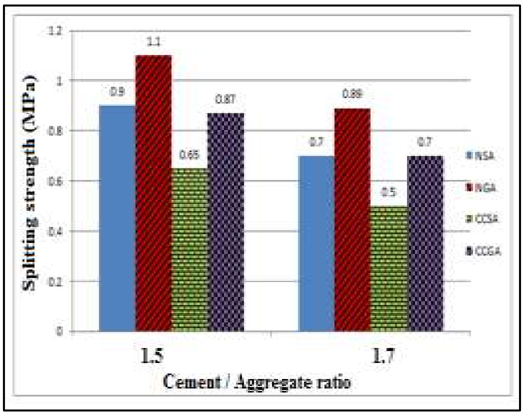

Figure 3: Splitting tensile strength with cement /aggregate ratio at 28 days age

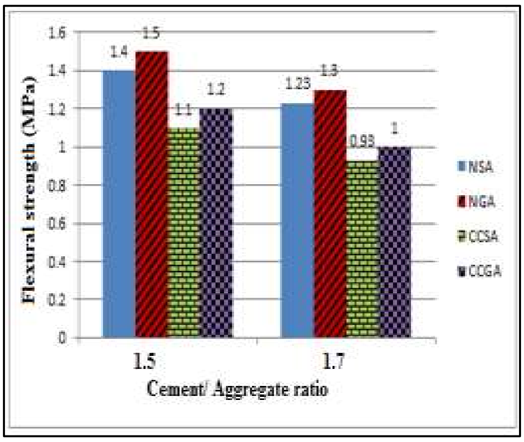

Figure 4: Flexural strength with cement/ aggregate ratio at 28-day age

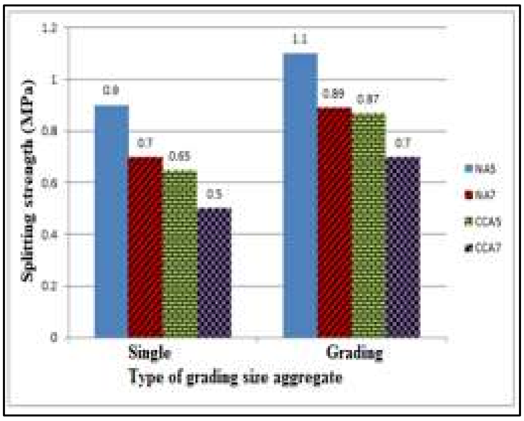

Figure 5: Splitting tensile strength with type gradation size of aggregate (single and graded) at 28 days age

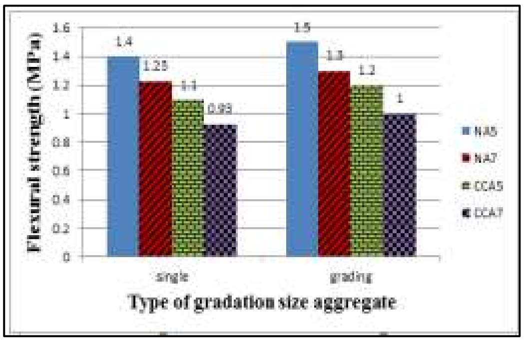

Figure 6: Flexural strength with type of gradation size aggregate (single and graded) at 28 days age

7. Conclusions

Based on the results of this research, the following conclusions may be drawn:

a. The workability of no fine concrete produced by demolished concrete as coarse aggregate is less than the workability of no fine produced by natural crushed aggregate. The flow test and compaction factor of no fine concrete produced with C/A ratio of 1:5 was less than no fine concrete produced with 1:7. The results of flow test and compaction factor of no-fine concrete produced with single aggregate type is less than that of no-fine concrete produced by graded aggregate by about 2% .

b. The hardened properties (compressive strength, splitting tensile strength, flexural strength and oven dry density) for no-fine concrete produce by demolished concrete as coarse aggregate are less than that of no fine produced by natural crushed aggregate. The hardened properties for no-fine concrete produced with C/A 1:5 were higher than no fine concrete produced with C/A 1:7. The harden properties for no fine concrete produce by single aggregate size was less than no fine produced by graded aggregate.

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