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Production of conventional concrete using sustainable fine aggregate as an alternative to natural fine aggregate

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Abstract - In this paper, we dealt with the study of the effect of two types of sustainable fine aggregates, the first type is crushed gravel that passes through a 5 mm sieve when crushing gravel to graded sizes, and the second type is recycled concrete as fine aggregate from the demolition of old buildings (concrete rubble) , which are considered wastes that are difficult to dispose of . Ordinary concrete was produced with a mixing ratio (1:2:4) and the replacement of natural fine aggregate in three proportions for each type of sustainable aggregate: 100%, 75% and 50%, with a reference mix containing 100% natural fine aggregate (Kanhash sand) . For comparison we have 7 mixtures and it was found that mixture No. 6 which contains 50% natural sand and 50% crushed gravel powder is the best according to the results of compression, splitting and flexural strength

Index Terms *– sustainable aggregates, crushed gravel, crushed rubble, compression strength, splitting strength, flexural strength, etc.*

INTRODUCTION

Nowadays, it is very important to make concrete economical by searching for alternatives to its basic components such as fine aggregate (river sand), the importance of replacing fine aggregate with sustainable fine aggregate generated from rock crushing residues in block and tile production factories . Or of the rubble resulting from the cracking of the debris of destroyed concrete buildings, for several reasons, the most important of which is that river sand is a natural wealth that must be preserved as much as possible, in addition to the fact that the process of obtaining river sand constantly works to raze the edges of the rivers and change their natural features and lead to damages in the surrounding areas. There is a need to search for other alternatives, such as crushed gravel and concrete rubble that can be converted into sustainable fine aggregates for use as a complete or partial substitute for natural fine aggregates .

The experimental work of this study was carried out on concrete in the laboratory of the Technical College of Engineering in Mosul. The work was planned and carried out to provide detailed information on economically producing concrete using locally available types of fine aggregates. The test program included some measurements and tests required for this study, namely compressive strength, splitting strength and bending strength. In addition to describing the general characteristics of the different materials used in conventional concrete for this paper.

LITRATURE REVIEW

Mrs. Roopa G Sindigi, Mr. Devaraja R , Mr. Paramesh G A 2018: It is examined how building and demolition debris can be used in M20 grade concrete. The fine aggregate in the concrete is replaced with recycled aggregate in percentages of 25%, 50%, and 100%. (crushed concrete). These blends' new properties, such as slump change, are investigated. The specimens were evaluated at 3, 7, and 28 days to see how compressive strength, split tensile strength, and flexure strength changed .

Amit Kumar Singh, Vikas Srivastava, V.C. Agarwal 2015 : An experimental program was carried out in this study to investigate the workability and compressive strength of concrete built with stone dust as a partial replacement for fine aggregate in the range of 10% to 100%. For referral concrete, M25 grade concrete was built with Portland pozzolana cement (PPC). Workability and compressive strength were assessed at various fine aggregate replacement levels compared to referral concrete, with compressive strength determining the best replacement level. In comparison to all other replacement levels, the results showed that by replacing 60% of fine aggregate with stone dust, concrete with the highest compressive strength may be formed .

B.Basavaraj, Ravichandra Honnalli, Sagar N S, Praveen Ashok M, Shwetha K C 2017 : Stone crusher powder appears to have similar features and performance to river sand, according to the research. The purpose of this article is to look at the possibility of replacing sand with stone crusher powder. The behavior of concrete when fine aggregates are replaced with stone crusher powder in various quantities is addressed. The strength test findings are also examined, and the values are compared to those of standard concrete .

Rameshwar S. Ingalkar, Shrikant M. Harle 2017 : at 40% to 50% crushed sand replacement, the maximum compressive strength is attained. The highest tensile strength of concrete is achieved when natural sand is replaced with crushed sand to the extent of 60% to 70%. Because crushed sand has greater properties than natural sand, concrete with crushed sand performed better than concrete with natural sand .

Iveta Nováková , Karel Mikulica 2016 : Recycled concrete aggregates (RCA) can be used to substitute natural aggregates in concrete manufacturing, thereby conserving natural resources and reducing the quantity of demolition trash that must be landfilled. Precast manufacturing produces a certain amount of defective elements, which are hauled away and repurposed with other demolition waste. Defected elements are recycled individually into RCA with advantageous qualities and used directly in fresh precast element mixes in this investigation. The results of RCA testing and incorporation into new concrete compositions are discussed. It has been demonstrated that replacing raw aggregates with RCA up to 20% has no negative impact on the physico-mechanical properties of concrete .

MATERIALS

1 - Cement : Ordinary Portland cement (OPC) produced by Badoosh cement factory was used in this study. The physical properties and chemical compositions of cement are mentioned in Table (1). Both physical and chemical properties are with compliance to Iraqi standard specification "IIS: 5/1984 .

Physical properties	Test results	Limits of Iraqi specification No.5/1984
Specific surface area, Blain‟s method, m²/kg	290	≥ 230
Soundness, Autoclave‟s Method, %	0.03	< 0.8
Setting time, Vicat‟s method Initial setting hr:min Final setting hr:min	 1:49 3:25	 ≥ 45 min ≤ 10 hours
Compressive strength 3 days N/mm² 7 days N/mm²	 22 30	 ≥ 15 ≥ 23

Table (1) : Physical and mechanical properties of ordinary Portland cement

2 - Fine aggregate (three types)

A - Natural fine aggregate : It obtained from Kanhash region (Mosul) . This type of sand is conforming to British standard (B.S.) 882:1992. Its sieve analysis is shown in Table (2) .The grading limits with compliance to ASTM C33-02 .

Sieve size (mm)	Total limit	Percentage passing Of the sand used
4.75	89 – 100	100
2.36	60 – 100	72.23
1.18	30 – 100	53.82
0.600	15 – 100	29.87
0.300	5 – 70	9.73
0.150	0 - 15	2.79

Table (2): Sieve analysis of the natural sand

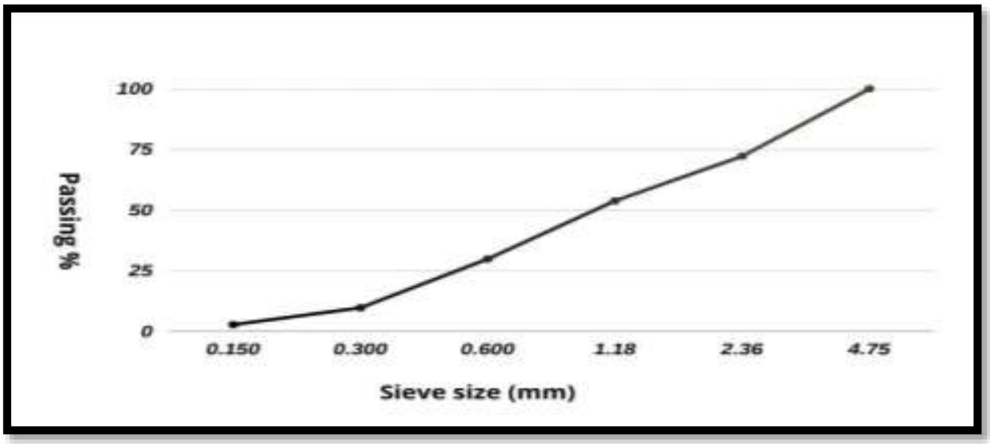

Figure (1): Sieve analysis of the natural sand

B - Crushed gravel : It is obtained from the Kukjali block and tile production plant located in the east of Mosul city, where large rocks are broken and passed on a number of sieves to take the required sizes remaining on each sieve to produce blocks and tiles . Passing through a **5 mm** sieve is considered fine aggregate, which is why we use it in concrete as an alternative to natural aggregate. The sieve analysis is shown in Table (3). Classification limits are in accordance with ASTM C33-02 .

Figure (2) : Fine aggregate (crushed gravel) from the Kukjali blocks and tiles production plant

Sieve size (mm)	Total limit	Percentage passing Of the sand used
4.75	89 – 100	100
2.36	60 – 100	73.36
1.18	30 – 100	47.93
0.600	15 – 100	23.56
0.300	5 – 70	10.14
0.150	0 - 15	2.89

Table (3): Sieve analysis of (crushed gravel) as fine aggregates

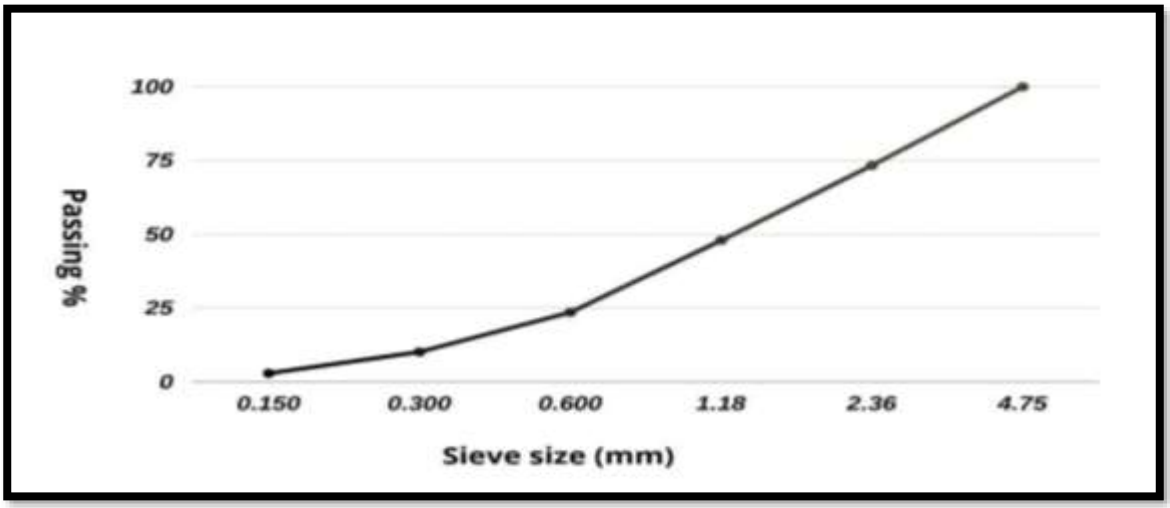

Figure (3): Sieve analysis of (crushed gravel) as fine aggregates

C - Recycled concrete as fine aggregates : Concrete rubble resulting from the demolition of old buildings or as a result of wars and bombing generates a large amount of rubble that is difficult to dispose of as it is broken into standard sizes and to be used by backfilling in some projects and it can be used as a fine aggregate material in concrete . Its sieve analysis is shown in Table (4) .The grading limits with compliance to ASTM C33-02 .

Figure (4) : Concrete rubble and crushed into fine aggregate

Sieve size (mm)	Total limit	Percentage passing Of the sand used
4.75	89 – 100	100
2.36	60 – 100	77.93
1.18	30 – 100	58.89
0.600	15 – 100	45.51
0.300	5 – 70	19.77
0.150	0 - 15	8.71

Table (4): Sieve analysis of Concrete rubble as fine aggregates

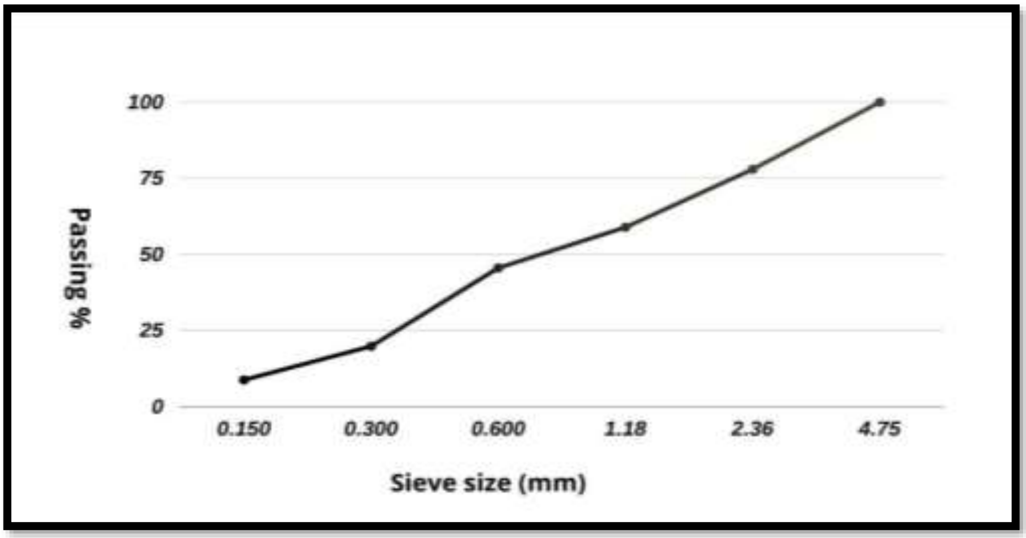

Figure (5): Sieve analysis of Concrete rubble as fine aggregates

3 - Coarse aggregate : It is obtained from the outskirts of the city of Mosul in Iraq and we used in the first stage of conventional concrete with a size of **19 mm** . Its sieve analysis is shown in Table (5) .The grading limits with compliance to ASTM C33-02 .

Sieve size (mm)	Weight passing (%)	Total limits (ASTM C33-2)
19	100	90 -100
12.5	51.8	35 - 80
9.5	33.2	20 - 55
4.75	9.4	0 - 10
2.36	3.7	0 - 5

Table (5): Sieve analysis of the natural coarse aggregates

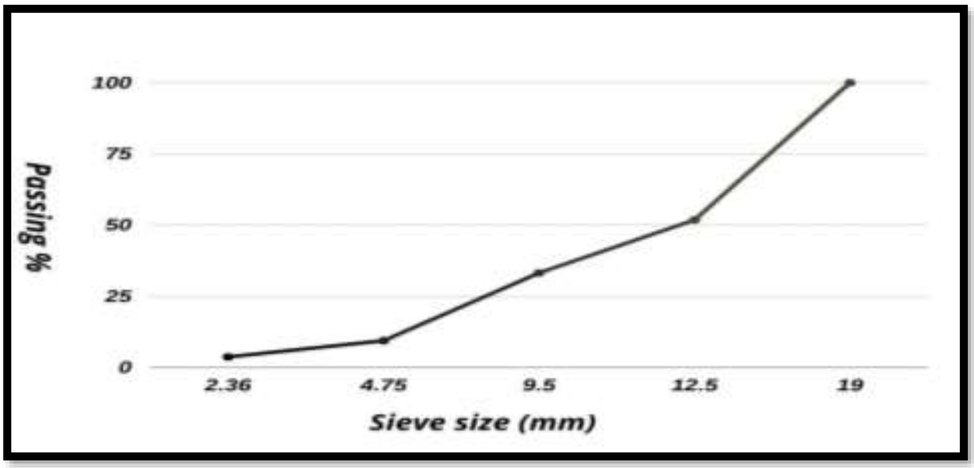

Figure (6): Sieve analysis of the natural coarse aggregates

4 - Water : Tap water was used in this research for both mixing and curing the concrete specimens in accordance with ASTM C1602 .

EXPERIMENTAL PROGRAM

In this paper, seven concrete mixtures were used in a proportion of **[1: 2: 4]** with a slump of **50** to **80 mm** fig 3 , without any Chemical Admixtures . The maximum size of the coarse aggregate was **19 mm**, while the fine aggregate was substituted for each type of sustainable aggregate. In three proportions: the first being a **100%** total replacement, the second **75%**, the third **50%**, and a reference mix using Kanhash sand (river sand) as fine aggregate was used **100%** for comparison .

No. Mix	The proportions of the types of fine aggregates
Mix1	Natural fine aggregate(River sand) **100 %**
Mix2	crushed gravel as sand **100 %**
Mix3	recycled concrete as sand **100 %**
Mix4	River sand **25 %** + crushed gravel as sand **75 %**
Mix5	River sand **25 %** + recycled concrete as sand **75 %**
Mix6	River sand **50 %** crushed gravel as sand **50 %**
Mix7	River sand **50 %** + recycled concrete as sand **50 %**

Table (6) : Classification of mixtures depends on the type and proportion of fine aggregates

A mechanical tilting mixer with a **125-liter** capacity was used. Before placing the materials, the internal surface of the mixer was cleaned and wet. ASTM C192 was followed for mixing and casting. Curing was carried out in accordance with ASTM C511.

Concrete was poured with **6 cubes** with dimensions of **150 mm** to test the compressive strength, **6 cylinders** with a diameter of **100 mm** and a height of **200 mm** to test the splitting strength, and **6 prisms** with a cross section of **100 mm** and a length of **400 mm** to test flexural strength .

Figure (7) : Description of slump for concrete mixes

RESULTS

No. Mix	7 days	28 days
1	**18.8**	**29.5**
2	**19.6**	**29.2**
3	**18.3**	**23.9**
4	**18.9**	**31.6**
5	**17.1**	**30.6**
6	**18.1**	**32.3**
7	**17.5**	**31.1**

Table (7) : Results of Compressive strength (MPa)

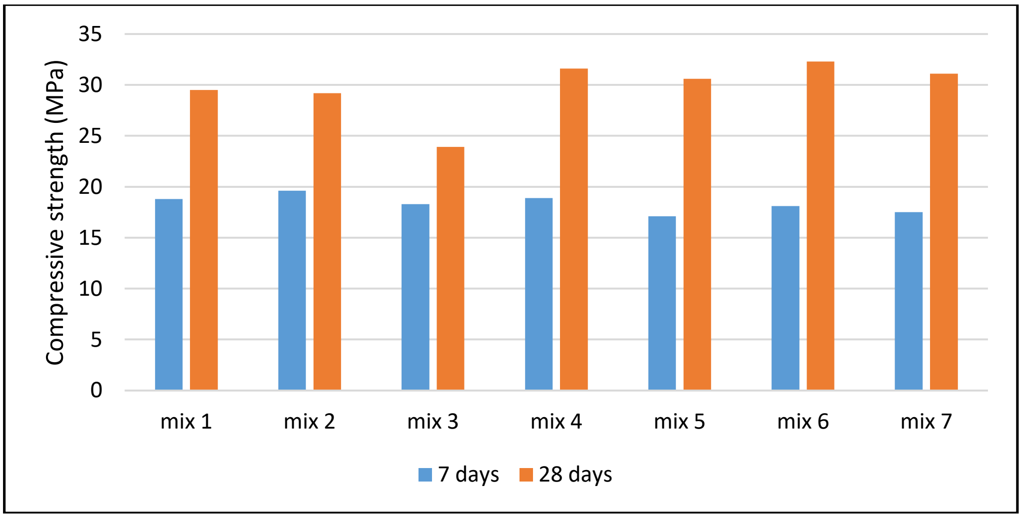

Figure (8) : Results of Compressive strength (MPa)

No. Mix	7 days	28 days
1	2.08	3.03
2	1.69	2.81
3	1.57	2.52
4	1.93	3.06
5	1.73	2.55
6	1.98	3.13
7	1.76	2.64

Table (8) : Results of Splitting strength (MPa)

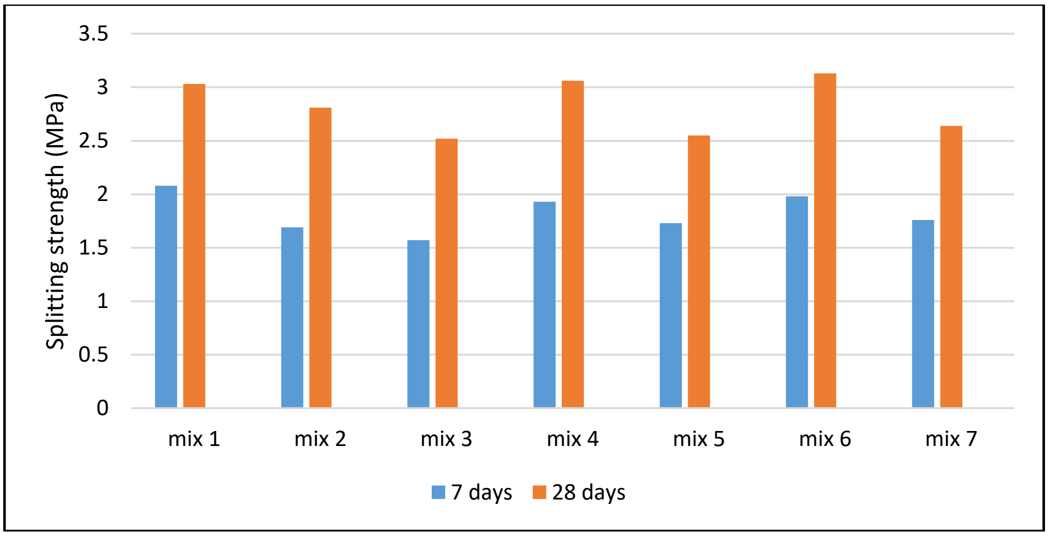

Figure (9) : Results of Splitting strength (MPa

No. Mix	7 days	28 days
1	3.22	3.88
2	2.84	3.46
3	2.52	3.05
4	2.87	3.64
5	2.61	3.27
6	2.94	3.69
7	2.72	3.36

Table (9) : Results of Flexural strength (MPa)

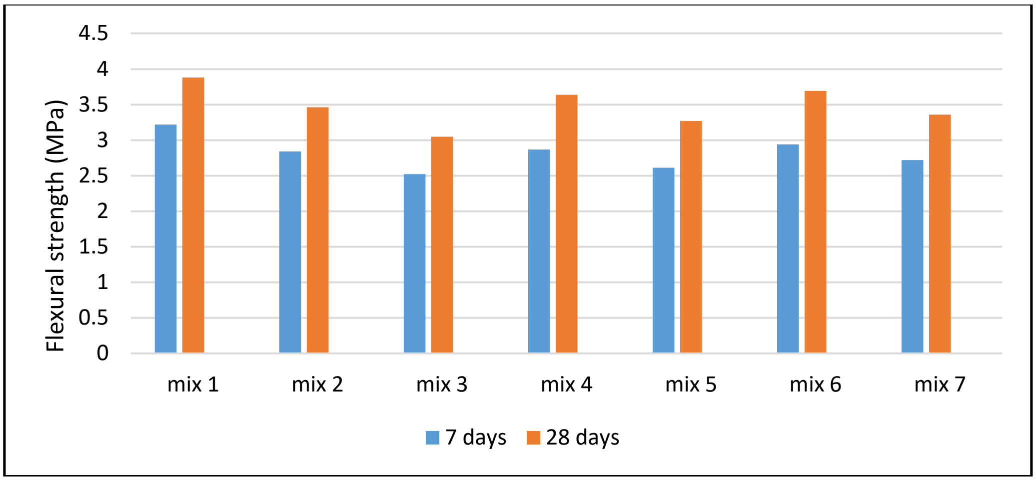

Figure (10) : Results of Flexural strength (MPa)

CONCLUSION

Based on the results we obtained in this study, we conclude :

1 - The optimum mixture between mixtures is **Mix 6**, which contains **50%** of natural fine aggregate (**kanhash sand**) and **50%** of sustainable fine aggregate of crushed gravel, which enhances the mechanical properties of concrete such as increasing the compressive strength by **9.5%** and increasing the splitting strength by **3.3%** for the reference mixture **,** While there was a decrease in flexural strength by **4.9%** for the reference mixture.

2 - In general, partial replacement ratios of **50%** and **75%** of sustainable fine aggregate, whether as a result of crushed gravel or crushed concrete aggregate, improved the mechanical properties of concrete relative to the reference mixture with better results than the total replacement of **100%** .

3 - The mixtures that used fine aggregates resulting from crushing concrete rubble needed more W/C ratio than other mixtures to obtain the same workability .

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