Some Properties of Concrete Contains Waste Concrete as Fine Aggregate

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Abstract

In this research, experimental investigations have been carried out to assess the effect of partial replacement of fine aggregate by crushed concrete passed through a sieve size of No. 4.75 mm on workability, splitting tensile strength and compressive strength of recycled concrete at 7 and 28 days curing periods. Two sets of fine aggregate have been used, first set containing salts in conformity with the Iraqi Standard Specifications and another set not in conformity with the Iraqi Standard Specifications .The fine aggregate is replaced with crushed concrete in various percentage (25%, 50%, 75% and 100%), while 0% represents the control. Results showed that replacing 100% of crushed concrete after 28 days curing, the compressive strength has increased by 79% from the compressive strength of the control mix, while the splitting tensile strength has decreased, reaching 24% of the splitting tensile strength of the control mix.

Keywords: Crushed Concrete, Fine Aggregate, Compressive Strength, Tensile Splitting Strength.

بعض خواص الخرسانة المحتوية على مخلفات خرسانية كركام ناعم

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الخلاصة:

في هذا البحث تم اجراء تحريات عملية لدراسة تأثير الاستبدال الجزئي للركام الناعم بخرسانة مكسرة مارة من المنخل رقم 4.75 ملمتر على قابلية التشغيل، مقاومة الشد ومقاومة الانضغاط للخرسانة المعادة بعمر 7و28 يوم انضاج . تم استعمال مجموعتين من الركام الناعم، المجموعة الاولى تحتوي على نسبة املاح مطابقة للمواصفات العراقية واخر تحتوي على نسبة املاح غير مطابقة للمواصفات العراقية. تم استبدال الركام الناعم بخرسانة مكسرة بنسب مختلفة (25 %، 50 %، 75 %، 100 %) بينما نسبة (0 %) مثلت الخلطة المرجعية. بينت النتائج عند نسبة الاستبدال 100 % بخرسانة مكسرة وعند عمر 28 يوم انضاج فان مقاومة الانضغاط ازدادت بنسبة 79 % عن مقاومة الانضغاط للخلطة المرجعية بينما مقاومة الشد تناقصت وصولا الى 24 % من مقاومة الشد للخلطة المرجعية.

1. Introduction

Because of the rapid increase in population and the construction of buildings, Iraq is witnessing an ongoing reconstruction process. Include the continuous building demolitions and the ancient installations which have exceeded their design lifetime and all of this generates millions of tons of waste construction, which has become a major burden on the environment. According to information available from the Ministry of Municipalities and Public Works, this waste is increasing. Large quantities of sand in the southern region suffer from dissolved salts because this area was a sea in ancient times.

The process of recycling concrete has increased because of the growing awareness of the environmental risks of producing new concrete as well as the economic benefits of recycling, and through government regulations. This increase has led to some companies developing the means and advanced mechanisms for grinding concrete on site, including portable machinery for grinding concrete. Some mechanical methods have also been developed to remove the rebar from concrete to reduce the hard manual labor required to complete this process.

K. J. Mohammed et al. [3] were used steel slag as replacement of aggregate or stone in four group of concrete mixtures with (0, 25, 50, and 60%) by wt. of steel slag. Their results showed that, density of concrete and compressive strength, also flexural force, after 7 days and 28 days were increased by increased slag content. Johnson and Salam [4] presented the effect of recycled concrete aggregate (RCA) on the key fresh and hardened properties of concrete, they found at the age of 28 days, the concrete with 100% RCA provided 12.2% lower compressive strength and 17.7% lesser modulus of elasticity than the control concrete. Also, 100% RCA increased the permeable voids of 28-day old concrete by 8.2%. An attempt was made by Akbari et al.[5] to study the effect of recycled aggregate on the behavior of normal strength concrete, there experimental results showed up to 25% reduction in compressive strength, 23% reduction in flexural strength, 26% reduction in split tensile strength and a noticeable reduction in workability was observed with the increase in percentage of aggregate replacement. Umoh, A.A. [6] sought to utilize sandcrete blocks from demolition waste as an alternative material to fine aggregate in concrete, he concluded that crushed waste sandcrete block can be used as a supplementary aggregate material in concrete. Sonawane and Pimplikar [7] reported the basic properties of recycled fine aggregate and recycled coarse aggregate and also compared these properties with natural aggregates, they concluded that use of recycled aggregate up to 30% does not affect the functional requirements of the structure . Investigations and construction properties for using limestone as a lightweight course aggregate in concrete mixture instead of normal coarse aggregate were made by M. M. Jomaa'h [8], in his samples the normal coarse aggregate was replaced by 100% coarse srushed limestone. His results showed a suitable reduction in dead loads of structural elements and cost. Experimental investigations have been carried out by Monish et al. [9] to assess the effect of partial replacement of coarse aggregate by demolished waste on workability and compressive strength of recycled concrete for the study at 7 and 28 days, there test results showed that the compressive strength of recycled concrete up to 30% coarse aggregate replacement (C. A. R.) by demolished waste at the end of 28 d has been found to be comparable to the conventional concrete. The aim of the study conducted by Shinde et al. [10] was to determine the strength characteristics of recycled aggregate for application in structural concrete, which would give a better understanding of the properties of concrete, using the recycled aggregates as an alternative material to coarse aggregate in structural concrete, they concluded that significant decrease in compressive strength observed in concrete with recycled aggregate as compared to concrete with natural aggregate. S. A. Hameed [11] presented a study of mechanical properties of concrete made by using the demolished concrete as coarse aggregate in addition to steel fibers In the concrete mixes the ratios of concrete aggregate were(0, 25, 50, 75, and 100%) and the ratio of steel fiber was 6% of whole mix volume. His research shows that increasing recycle concrete aggregate will decrease the compressive strength and splitting tensile strength but adding steel fibers will increase these strengths.

2. Experimental Programme

The cement used is, Sulphate Resistant Portland cement, which is identical to the Iraqi Standard Specifications No.5 (1984) [2]. Two types of coarse aggregate were used: the first type contained the proportion of salts in conformity with the Iraqi Standard Specifications No.45 (1984) [1] and was coded with symbol A. And the other contained the proportion of salts as identical to the Iraqi Standard Specifications and was coded symbol B. Aggregates of both types A and B ranged from size 5 to size 40 as shown in **Table (1).** Also, two types of fine aggregates were used: the first one contained the proportion of salts in conformity with the Iraqi Standard Specifications No. 45 (1984) [1] and was coded symbol A. And the other contained the proportion of salts as identical to the Iraqi Standard Specifications and was coded symbol B. Fine aggregate of both types A and B is within the area of gradient No. 2 as shown in **Table (2).** Concrete Waste was collected from building demolition sites. The concrete was crushed manually and sieved with a 4.75 mm size sieve, as shown in **Figure (1).**

Mixing ratio used is (1:1.5:3) and the water- to- cement ratio used is (0.55). Two types of steel molds were used in this research: the first is cube-shaped with dimensions (150 × 150 × 150) mm to check out compressive strength and the second type is cylindrical with dimensions (100 × 200) mm to be used in the examination of splitting tensile strength. Six cubic molds and three cylindrical molds were cast for reference mix and for each mix A and B, where the replacement ratios were cast.

Fig .(1): Crushed aggregate passing sieve 4.75 mm

Table .(1) Physical Properties of Coarse Aggregate

Sieve size (mm)	Percent passing % A	Percent passing % B	IOS 45 : 1984 Nominal size , (5-40mm)
37.5	100	100	95-100
20	64.6	68.73	35-70
14	35.96	51.27	-
10	14.83	32.24	10-40
5	0.72	3.77	0-5
2.36	0.08	1.32	-
Properties	Test result A	Test result B	IOS 45 : 1984 Limits
so_3	0.06	0.18	≤ 0.1

Table (2): Physical Properties of Fine Aggregate

Sieve size (mm)	Percent passing % A	Percent passing % B	IOS 45 : 1984 Limits , zone 2
4.75	94	96.72	90-100
2.36	87.2	83.61	75-100
1.18	75.4	68.99	55-90
0.60	52.8	45.23	35-59
0.30	15.4	16	8-30
0.15	6.6	3.59	0-10
Properties	Test result A	Test result B	IOS 45 : 1984 Limits
so_3	0.45	1.11	≤ 0.5

3. Discussion of Results

Mix (A) containing fine aggregate identical to the Iraqi Standard Specifications and mix (B) the fine aggregate not in conformity with the Iraqi Standard Specifications and all proportions of replacement (0%, 25%, 50%, 75%, 100%) and the encoded symbols (A, A1, A2, A3, and A4) for mix (A) and the encoded symbols (B, B1, B2, B3, and B4) for mix (B) were studied.

Figure (2) shows the relationship between the values of slump and the proportion of W / C (0.6, 0.55, 0.5, 0.45, 0.4) for all replacement ratios.

It was observed at replacement percentages (25%, 50%) that there was a slight negative effect on slump and workability was decreased . This effect becomes more pronounced at the high ratios of replacement (75%, 100%) and at the same proportion of W / C where this behavior is dominant for all ratios of W / C used. After reviewing all the results, the selected ratio W / C, was (0.55) for use in all concrete mixes because they make almost all the slump required (80 - 120) mm . **Table (3)** and **Figure (3)** illustrate the relationship between the values of slump and the ratios of replacement at W / C = 0.55.

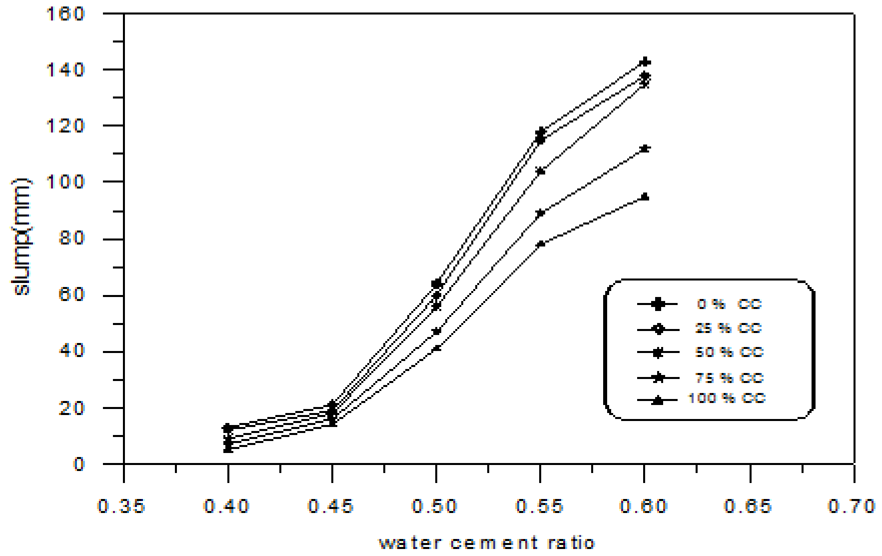

Fig .(2) Relationship between the values of slump for mix (A) and the w/c ratio and all replacement ratios

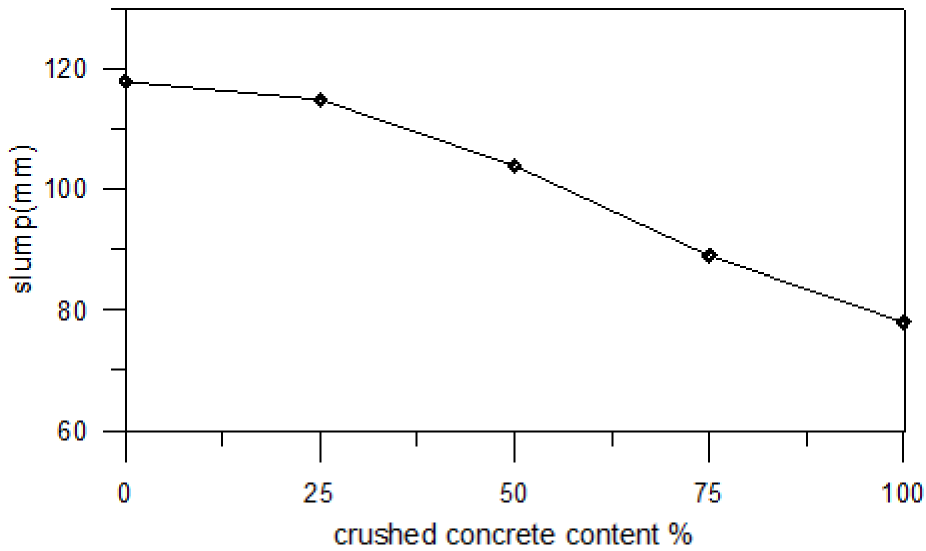

Fig .(3) Slump for mix (A) with different replacement ratios at W/C=0.55

Table .(3) Values of slump for mix (A) with different replacement ratios

Replacement Ratio %	w/c Ratio %	Slump (mm)
0	0.55	118
25	0.55	115
50	0.55	104
75	0.55	89
100	0.55	78

Compressive strengths for the reference mix (A) and the replacement mixes (A1, A2, A3, A4) at ages 7, and 28 days are shown in **Table (4) and Figure (4).** In general, the compressive strength of concrete containing crushed concrete as fine aggregate decreased. The compressive strength of all mixes containing crushed concrete decreased at the first 7 days regardless of the percentage of the crushed concrete, which reached 25% of the compressive strength of the reference mix at replacement ratio 100%. Also, the compressive strength decreased at replacement ratios 25%- to- 75%, reached 24% of the compressive strength of the reference mix at replacement ratio 75%, while the largest decrease in the compressive strength was at replacement ratio 100%, which reached 32% of the compressive strength of the reference mix. **Figure (5)** shows the relationship between the replacement ratios and the compressive strength as a percentage of the reference mix at 7, and 28 days.

Table .(4) Compressive Strength at different replacement ratios at ages 7 and, 28 days

Mix No.	Replacement Ratio %	Compressive Strength (MPa)	
		7 days	28 days
A	0	25.92	33.86
A1	25	20.32	26.30
A2	50	20.13	26.23
A3	75	19.72	25.96
A4	100	19.48	23.11

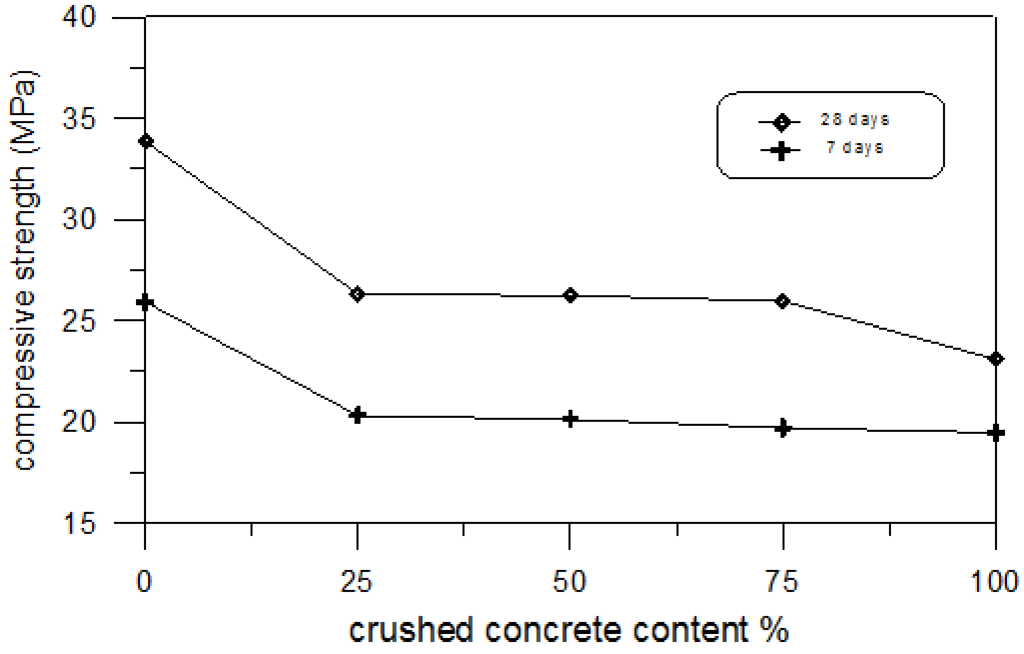

Fig .(4) Relationship between the Compressive Strength for mix (A) and Ratios of Replacement at Ages 7 and, 28 days

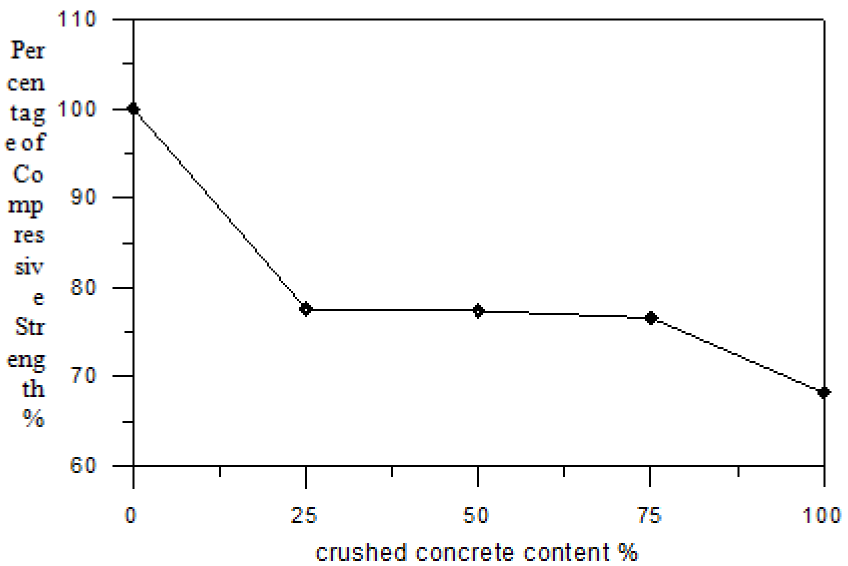

Fig .(5) Relationship between the Replacement Ratios and Compressive Strength for mix (A) as a Percentage of the Strength of the Reference Mix at 28 days

Splitting tensile strengths of the reference mix (A) and all mixes' replacement at age 28 days are shown in **Table (5)** and **Figure (6)** In general, the splitting tensile strength expressed behavior somewhat different from the behavior of compressive strength at the same age where the greatest rate of decrease in splitting strength was 24% of the strength of the reference mix when the replacement ratio was 100% crushed concrete while the greatest decrease of compression strength was 32% of the strength of the reference mix for the same rate of replacement and the same age. On the other hand, the proportion of low splitting tensile strength gradually increased with increasing rates (13%, 15%, 18%) of strength of reference mix at replacement ratios (25%, 50%, 75%), respectively, unlike the compressive strength where the compression strength ratio was almost constant at the same ratios of replacement above. **Figure (7)** illustrates the relationship between the rates of replacement and splitting tensile strength as a percentage of the reference strength.

Table .(5) Tensile Splitting Strength for mix (A) verse Replacement Rates at age 28 days

Mix No.	Replacement Rate %	Tensile Splitting Strength (MPa)
A	0	3.41
A1	25	2.97
A2	50	2.89
A3	75	2.80
A4	100	2.58

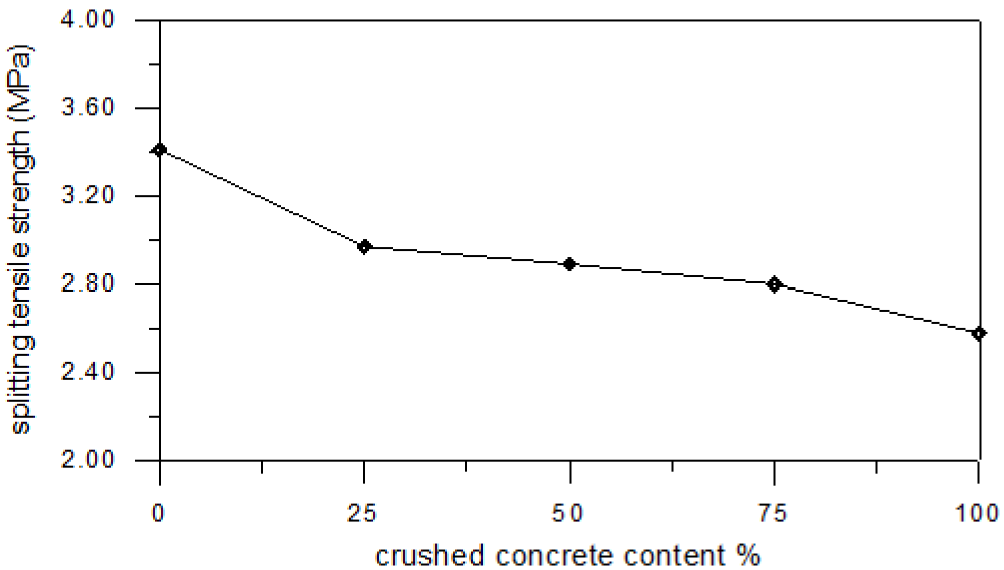

Fig .(6): Relationship between the Tensile Splitting Strength for mix (A) and Ratios of Replacement at 28 days

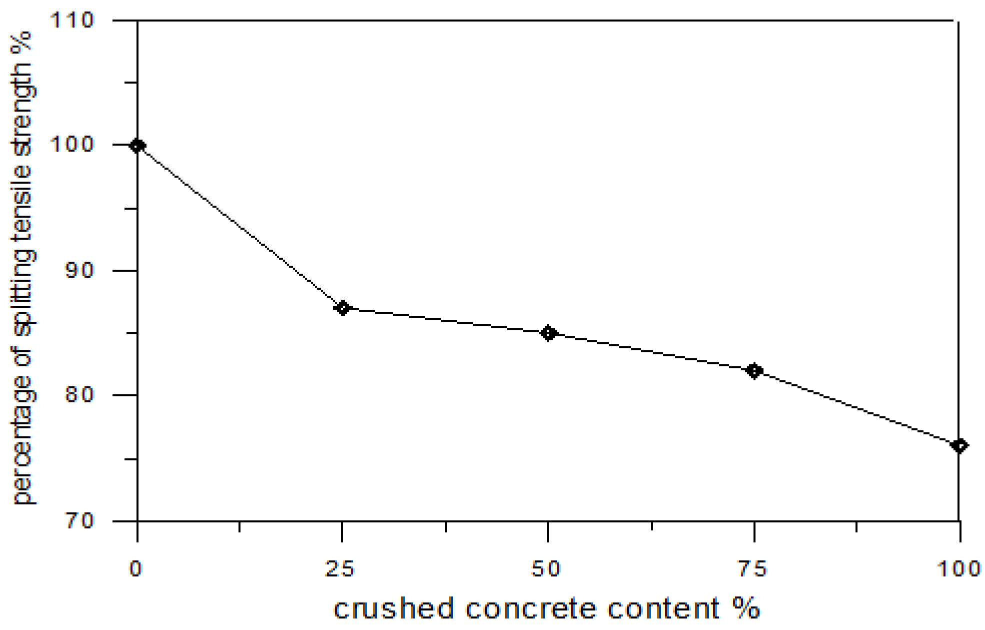

Fig .(7) Relationship between the Replacement Ratios and Tensile Splitting Strength as a Percentage of the Strength of the Reference Mix (A) at 28 days

Densities of the reference concrete mix (A) and all mixes replacement at age 28 days are shown in **Table (6) and Figure (8).** Note from **Table (6)** that the density of concrete resulting from the replacement of crushed concrete instead of fine aggregate is less than the density of the reference mix. The decreasing rate is 4.5% of the density of the reference mix at 100% replacement ratio of crushed concrete. It is also noted that the decrease in density is directly proportional to the percentage of replacement.

Table .(6) Density of Concrete for mix (A) versus Replacement Rates at age 28 days

Mix No.	Replacement Rate %	Density (kg/m^3)
A	0	2396.3
A1	25	3386.7
A2	50	2352.8
A3	75	2327.1
A4	100	2290.6

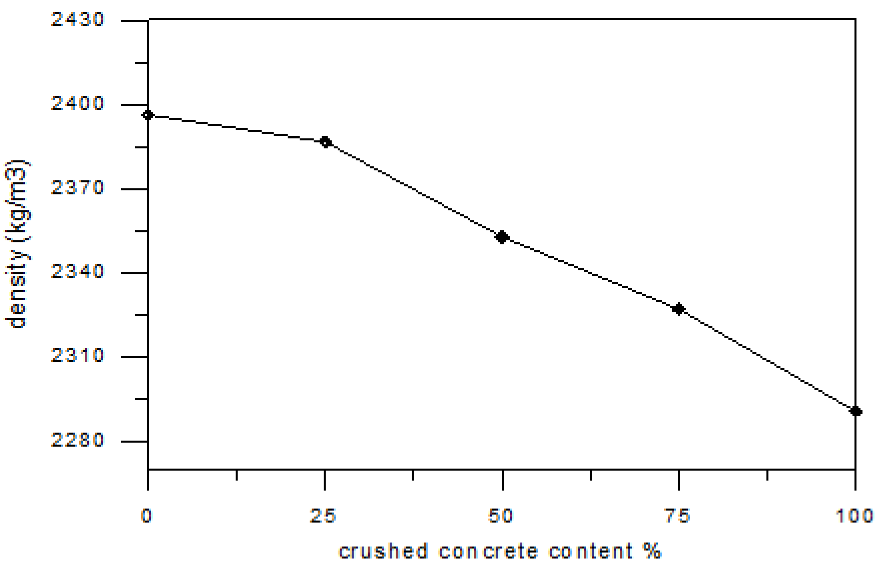

Fig .(8) Relationship between the Density for mix (A) and Ratios of Replacement at 28 days

The compressive strength for the reference mix (B) and replacement mixes (B1, B2, B3, B4) at ages (7, 28) days are shown in **Table (7)** and **Figure (9).** The compressive strength of the reference mix formed a significant decrease as a result of the presence of sulphate salts in fine aggregate (sand) by ratio beyond the borders of the Iraq Standard these salts lead to an increase in the size of the concrete and thus break the ties that bind its components. But when replacing the sand containing salt with crushed concrete, the strength returned and rose significantly during the first seven days of the treatment there was a gradual increase in strength directly proportional with the proportions of replacement, especially with replacement ratios (25%, 50%, 75%), reaching increased rates (20%, 28%, 42%) of the strength of the reference mix respectively. The largest increase in percentage was at 100% replacement ratio of crushed concrete and accounted for 94% of the strength of the reference mix. **Figure (10)** shows the relationship between the increase in the compressive strength and replacement rates at 28 days. The reason for the rise in strength came as a result of lower salt content in the concrete mix when the fine aggregate in the concrete was replaced, which in turn led to decrease the effect of salts on the concrete mix and increasing strength.

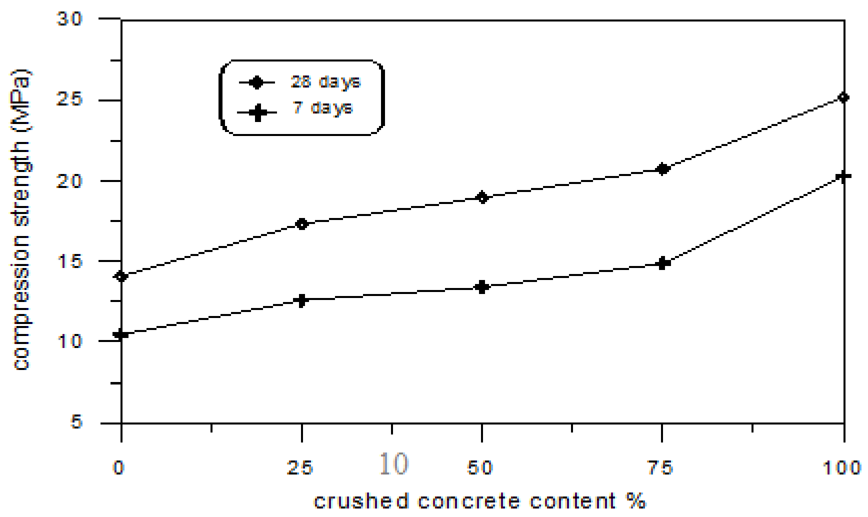

Fig .(9) Relationship between the Compressive Strength for mix (B) and Ratios of Replacement at 7 and, 28 days

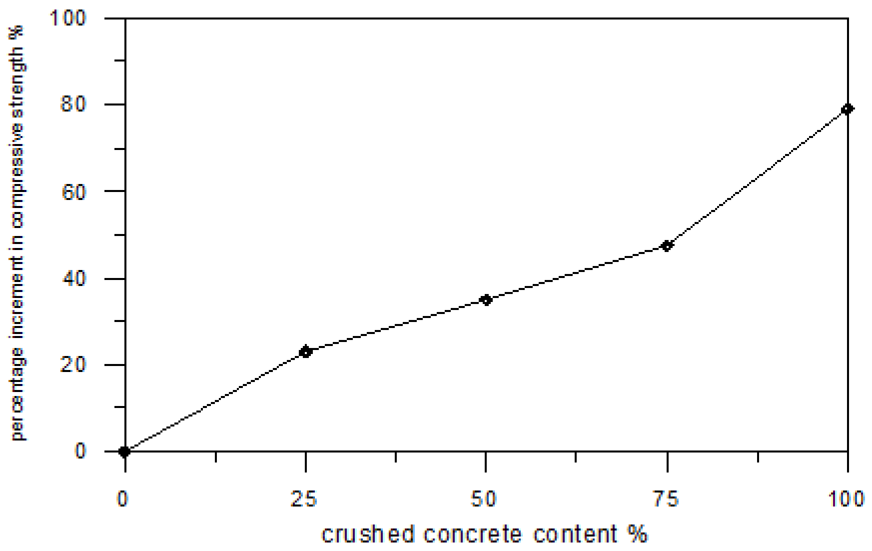

Fig .(10) Relationship between the Replacement Ratios and Compressive Strength as a Percentage of the Strength of the Reference Mix (B) at 28 days

Table .(7) Compressive Strength at different replacement ratios at ages 7 and, 28 days

Mix No.	Replacement Ratio %	Compressive Strength (MPa)	
		7 days	28 days
B	0	10.45	14.07
B1	25	12.58	17.33
B2	50	13.4	18.96
B3	75	14.87	20.74
B4	100	20.29	25.16

Tensile splitting strength of the reference mix and replacement mixes are shown in **Table (8)** and **Figure (11).** Generally, the tensile splitting strength has shown a similar behaviour to the compressive strength, which decreased largely because of sulphur salts in the sand and that leads to an increase in the size of concrete and thus breaks the ties that bind the components of concrete as mentioned earlier. Note in **Table (8)** that when low and medium (25%, 50%) rates of replacement were increased in the tensile splitting strength this led to small convergence with the increase in the compressive strength not exceeding 21% of the tensile strength of the reference mix at 50% replacement ratio, which reached a 28% increase in the strength of the reference mix at the same ratio as above. But at high replacement ratios (75%, 100%), expressed tensile splitting strength significantly increased reaching 78% of the strength of the reference mix when the replacement ratio was 100%, which is higher than the increased percentage in the compressive strength, which amounted to 79% of the strength of the reference mix at the same replacement rate for the same age. **Figure (12)** shows the relationship between the increase in the tensile splitting strength and the percentage of replacement at age 28 days. The reason for the rise in the splitting tensile strength came as a result of lower salt content in the concrete mix when replaced with the fine aggregate concrete, which in turn led to reduced effect of the salt on the concrete mix and increased strength.

Table .(8) Tensile Splitting Strength for mix (B) verse Replacement Rates at age 28 days

Mix No.	Replacement Rate %	Tensile Splitting Strength (MPa)
B	0	1.43
B1	25	1.56
B2	50	1.73
B3	75	2.35
B4	100	2.67

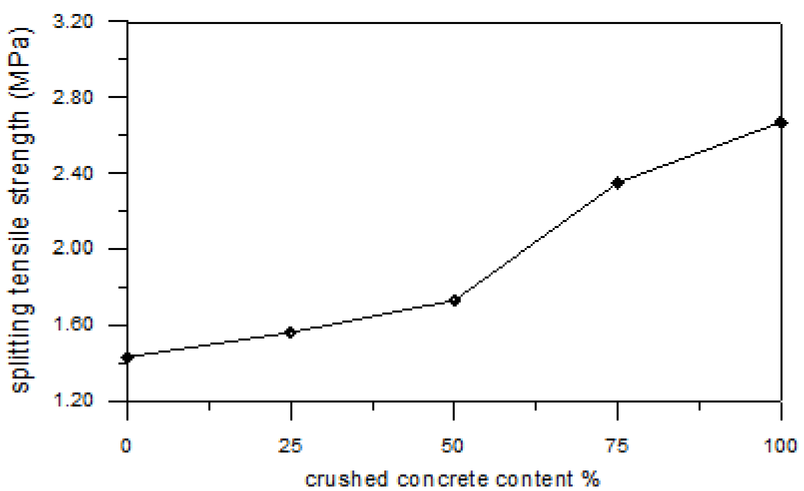

Fig .(11) Relationship between the Tensile Splitting Strength for mix (B) and Ratios of Replacement at 28 days

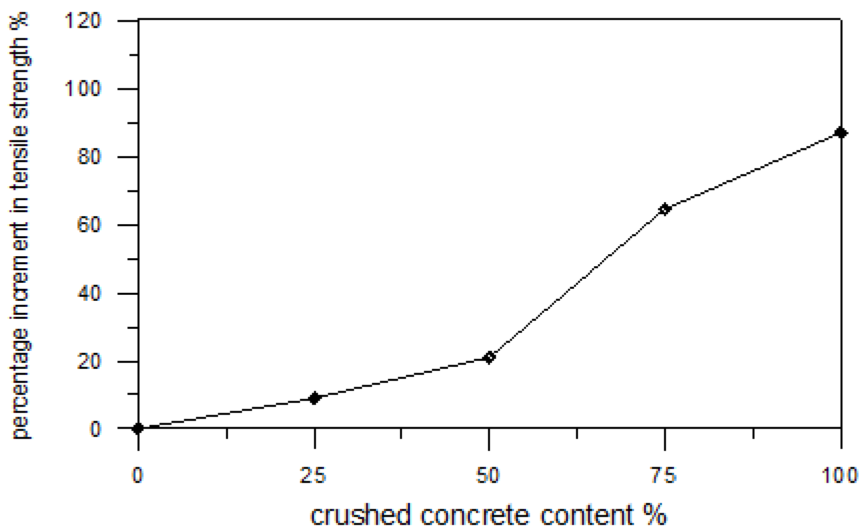

Fig .(12) Relationship between the increase in Tensile Splitting Strength for mix (B) and Replacement Ratios

The densities of the reference concrete mix and all mixes replacement at age 28 days are shown in table (9) and figure (13).Note from **Table (9)** that the density of concrete resulting from the replacement of fine aggregate by crushed concrete is less than the density of the reference mix, as the decline amounted to 4.8% of the density of the reference mix at 100% replacement ratio. It is also observed that the decrease in density is directly proportional to the ratio of replacement.

Table .(9) Density of Concrete for mix (B) verse Replacement Rates at age 28 days

Mix No.	Replacement Rate %	Density (kg/m^3)
B	0	2396.3
B1	25	3386.7
B2	50	2352.8
B3	75	2327.1
B4	100	2290.6

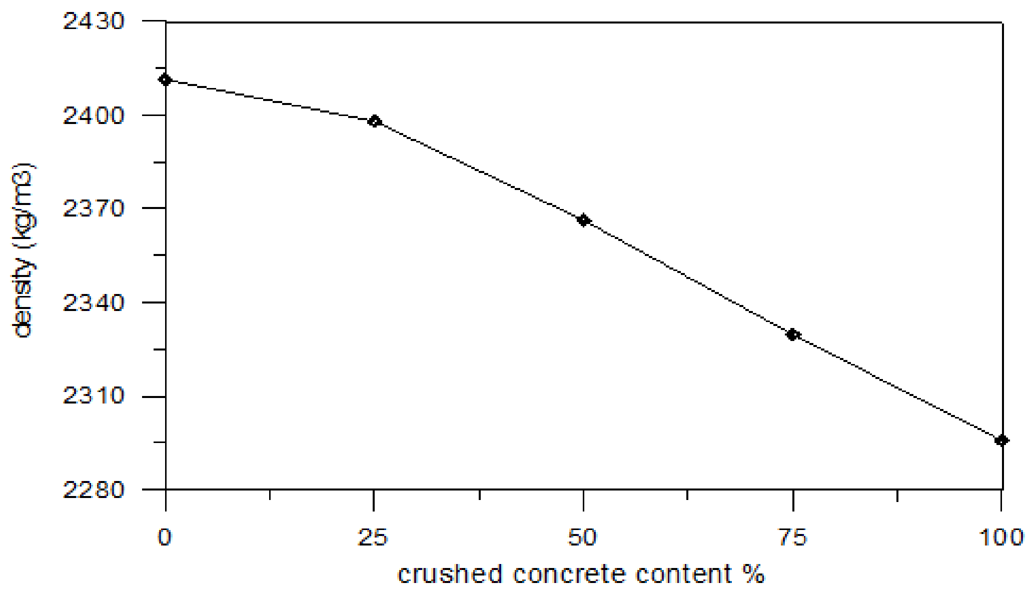

Fig .(13) Relationship between the Density for mix (B) and Ratios of Replacement at 28 days

4. Conclusions

This research addressed the study of the replacement of fine aggregate by crushed concrete and included multiple experiments which have identified the changes in the properties of the resulting concrete. Through follow-up laboratory results and examination of the relationships resulting from them the following conclusions can be reached:-

1) The use of crushed concrete in the production of concrete mix leads to a gradual decrease in workability, which can be increased the decreasing by increasing the content of the crushed concrete.
2) The use of crushed concrete instead of fine aggregate containing the proportion of salts in conformity with the Iraqi Standard Specifications led to a similar decrease in compressive strength regardless of the content of crushed concrete during the first seven days, and at 28 days the same behavior can be noted except at replacement ratio 100%, which suffered a higher drop than the other replacement ratios. As for splitting tensile strengths, in turn, these also have fallen, but gradually, depending on the content of the crushed concrete where the percentage of decrease in tensile strength is less than the percentage of decrease in compressive strength at each replacement ratio.
3) When use crushed concrete instead of fine aggregate containing salts with a ratio identical to the Iraqi Standard Specifications, this has led to a gradual increase in compressive strength, depending on the content of the crushed concrete used.
4) Splitting tensile strength expressed almost similar behavior to the behavior of compressive strength, where it gradually increased depending on the content of the crushed concrete.

5. Recommendations

1) The use of plasticizer for strength and workability suitable for concrete, in this article (crushed concrete).
2) Use different mixing ratios such as (1:2:4) and (1:1:2) and (1:3:6) and note the change that occurs in the behaviour of the resulting concrete.
3) Study other mechanical properties of concrete, such as flexural strength, modulus of elasticity and durability.
4) Study the effect of different ages on the mechanical properties of concrete and especially ages after 28 days.
5) The state departments need to focus on producing instructions on how to use these residues and especially look at project using waste.
6) Need to conduct a detailed study of the economic feasibility of the use of these wastes in projects and comparison between the cost of a project that contains the primary materials and the cost when using the crushed concrete.
7) It is recommended that 25% of crushed concrete is used.

Acknowledgment

Thanks to Mohammad Dhahir Karem and Humam Nazar Kadhem for their help in the preparation of this research.

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