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STUDY THE EFFECT OF RECYCLED AGGREGATE ON SOME CEMENT MORTAR PROPERTIES

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Abstract: Increase the amount of gases emission and construction materials waste was lead to increased interest to used recycled materials in building projects. In this research the effect and interaction of used recycle cement mortar as aggregate to replaced natural aggregate (sand) on cement mortar properties with variable curing time and constant water to cement ratio (W/C = 0.5) used is studied. Four group of cement mortar were produced (M0, M25, M50, M100) with different recycled aggregate weight percentage (0, 25, 50, and 100) . The compressive strength, density, water absorption and porosity percentage were tested. The results shows the compressive strength and density were decreased with recycle aggregate percentage increment in cement mortar composition, while, the water absorption and porosity percentage increased with recycle aggregate percentage increment in cement mortar ,. The lower compressive strength and density obtained in M100 samples were 26.08 MPa, 1.83 g/cm^3, while; the higher compressive strength and density obtained in M0 samples were 32.95 MPa, 2.28 g/cm^3, respectively. the higher water absorption and porosity percentage obtained in M100 samples were 12.05, 18.08, while; the lower water absorption and porosity percentage obtained in M0 samples were 7.86, 15.25, respectively.

Keywords: *Cement, mortar, recycle aggregate.*

دراسة تأثير تدوير الركام على بعض الخواص لمونة الإسمنت

الخلاصة: الزيادة في كمية انبعاث الغازات ونفايات مواد البناء أدى إلى زيادة الاهتمام باستخدام المواد المعاد تدويرها في مشاريع البناء. في هذه البحث تأثير و تفاعل الناتج من استعمال مونة الاسمنت المعاد تدويرها كركام لاستبدال الركام الطبيعي (الرمل) على خواص مونة الاسمنت مع استعمال زمن معالجة متغير و نسبة ثابتة من الماء إلى الاسمنت (W/C=0.5) تم دراسته. تم إنتاج أربع مجموعات من مونة الاسمنت (M100, M50, M25, M0) بنسب وزنية مختلفة من الركام المعاد تدويره (0، 25، 50، و 100). مقاومة الانضغاط ،الكثافة ، نسبة امتصاص الماء ونسبة المسامية تم اختبارها. النتائج بينت إن كل من مقاومة الانضغاط وكثافتها انخفضت مع زيادة النسبة الركام المعاد في تركيبة مونة الأسمنت، بينما نسبة امتصاص للماء و مسامية ازدادت مع زيادة النسبة الركام المعاد في مونة الأسمنت . اقل مقاومة انضغاط وكثافة تم الحصول عليها في عينات M100 كانت 26.08 ميكاباسكال، 1.83 غم/سم^3 ، بينما أعلى مقاومة انضغاط وكثافة وجدت في عينات M0 كانت 32.95 ميكاباسكال ، 2.28 غم/سم^3 ، على التوالي. أعلى نسبة امتصاص للماء و مسامية تم الحصول عليها في عينات M100 كانت 12.05 ، 18.08 ، بينما اقل نسبة امتصاص للماء و مسامية وجدت في عينات M0 كانت 7.86 ، 15.25 ،على التوالي .

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1. Introduction

Sustainable development was defined as product development should be programmed with no harm, neither for present nor future generations. These harms are studied and classified into social, environmental impacts, and economic. [1]

Cemented materials was the first building material in the world, and the most broadly one was used in every civil engineering works type, and their production was increasing yearly.[2, 3] the increased volume of debris were produced from demolish of buildings, roads, and bridges either because ancientness of these construction projects or war . this waste materials became problem in direction of sustainable development because environmental effect by increasing the depletion of natural resources, a big disposal landfill was needed for debris of concrete , and gas emissions associated with cemented materials prepared when natural aggregates were used and from cement manufacture. [4, 5, 6]. The carbon dioxide (CO_2) quantity emitted, when cement production approximately (2.46 billion tons/year), was about (5%) of all (CO_2) emissions in the worldwide, and approximately (160 million tons/year) from natural aggregate production.[7, 8]

Recycling has the possible to reduce the amount of waste disposed of in landfills, protect natural resources, and afford energy and cost savings while limiting environmental trouble[9].

The recycled of cement mortar and concrete as aggregate were most important towards more sustainable construction, and because the cement, natural aggregates, and water use rate is very accelerating, the cement production and demand are rising; yearly world cement manufacture is expected to raise from about (2,540 million tons) in 2006 to about (3,680 million tons), and (4,380 million tons) in 2050 at low and high estimate [7].

Recycling of building materials has grown along with needed for aggregates. Recycled aggregates compete favorably with natural aggregates as road base material. possible sources for recycled material grow as maintenance or replacement of the infrastructure continues. Because of the finite life of such infrastructure, this “urban deposit” may be considered a renewable resource[9].

The economic environment for recycling can be enhanced by increment tipping fees for waste disposal in landfills making it less attractive, rising markets for recycled materials, increasing research and development to improve recycled aggregates quality or show consumers where recycled products are competitive with natural materials, enlightening the public as to the recycling benefits ,changing specifications to accept more recycled material where it has demonstrated its ability to compete technically, and facilitating the flow of market information[9].

The aim of this study the cement mortar was used recycled fine aggregate to replacement natural aggregate (sand) for production new cement mortar and concrete, decrement concrete waste and production sustainability construction materials.

2. Experimental Work

2.1. Materials

There are many materials which are used to prepare specimens, these materials consist cement, fine aggregate, water and recycle cement materials.

2.1.1. Water

The water is used for all physical tests and mortars specimens' preparation from mixing and curing stages and it was used for all the mechanical tests that had been carried out.

2.1.2. Cement

The type of cement was used in all mixes in this research is the Ordinary Portland cement (type I).Ordinary Portland cement manufactured in Iraq by Tasloga Cement Factory . The chemical analysis of the cement composition used is listed in table 1. The cement concordance with the Iraqi specification (No.5/1984).

2.1.3. Fine aggregate

Fine aggregates generally consist of natural sand or crushed stone with most particles smaller than (5 mm). The most desirable fine-aggregate grading depends on the required of work. The sand grading analysis was conforms to the Iraqi Specification requirement of No.45/1984, as illustrated in table 2. AL-Ekadir in Karbala region sand was used as fine aggregate. It was tested to determine the grading and other physical properties. The sand used in this study is according to the standard specifications.

Table 1. The chemical composition of ordinary Portland cement (OPC).

Oxide	Weight (%)	Limits of Iraqi Specification No.5/1984[10]
SiO_2	17.85	-
CaO	63.17	-
Al_2O_3	5.31	-
SO_3	2.25	< 2.8
MgO	2.42	< 5.00
Fe_2O_3	4.37	-
Loss on Ignition	1.55	< 4.00
Insoluble residue	1.14	< 1.50
Lime saturation factor	0.88	0.66-1.02
Specific surface area (Blaine method), m^2/kg	331	-

Table 2. Sand Grading and requirements

Sieve Size (mm)	Accumulative Passing (%)	Accumulative Passing (%) According to Limits of I.O.S No.45/1984(Zone 3)[11]
4.75	100	90-100
2.36	100	85-100
1.18	87.22	75-100
0.60	67.85	60-79
0.30	28.53	12-40
0.15	8.91	0-10

2.2. Recycle mortar mixing

The cement mortar block having (1:2.75) cement/sand ratio by weight, the water/cement ratio was (0.35), and cured for (28)days was recycled to manufacture a fine aggregate to replacement natural fine aggregate (sand). The aggregate bulk density was estimated according to (ASTM C29),[12] as shown in table 3.

Table 3. Aggregate bulk density.

Aggregate type	Loose bulk density (kg/m^3)	Compact bulk density (kg/m^3)
Fine aggregate (Sand)	1.489	1.583
Recycled fine aggregate	1.334	1.475

3. Mixture Proportioning

In this study, four recycled percentage (0, 25, 50, 100) wt.% were used to replaced natural aggregate in cement mortar composition, i.e. (four cement mortar mixture were prepared (M0, M25, M50, M100)), three samples were molding for each replacement percentage cement mortar. For preparing samples, first Cement and fine aggregate (natural or recycled) were mixed for approximately two minute by hand, cement/standard sand weight ratio (C/S) of 1:3 was used, then the water addition gradually with mixing for about two minute, 0.5% of water /cement ratio was used. The molding process of the samples was performed by pouring mortars in the Cube mold of 50 mm edge. The samples were kept in the mold for 24 hours under constant ambient temperature to be cured. Then all samples were stored in the water tank, until the day of the test.

4. Result and Discussion

4.1. Physical properties

The physical properties one of the most important tests for specimen such as (apparent density, water Absorption%, and porosity %) for cement mortar samples were

prepared can be concluded by using the procedure specified in accordance to ASTM C642 [13]. Three samples in 28 day curing age were considered from each mixture and then the average obtained rate of water absorption for each sample was taken. The sample was dried in oven at a temperature of (105±5) during (24) hour and then weighed. The obtained result was considered as dried mass (WS).After that, To determine the saturated mass (WD), samples were put in the water for (72) hours and then surface dried with a cloth and finally weighed again, and to obtained apparent mass of sample in water after immersion (WA) the sample was immersed in water for (72) hours, and then the submerged weight of the sample was obtained. This test was conducted at age of (28) days. The apparent density, water absorption%, and porosity % can be calculated from following equations, respectively:

$$\text{Apparent density } (g/cm^3) = (WS/ (WS-WA)) * \rho w \quad (1)$$

$$\text{Water absorption } (\%) = ((WD-WS)/WS) *100 \quad (2)$$

$$\text{Porosity } (\%) = ((WD-WS)/ (WD-WA)) *100 \quad (3)$$

Where,

ρ_w: the density of water which is equivalent to 1 (g/cm^3).

The density of cement mortar is a function of the densities of the initial ingredients, mix proportions, initial and final water contented, air contented, degree of consolidation, degree of hydration, volume change, and consequent gain or loss of water, along with other factors.

The results discovered that replaced natural by recycled aggregate the density of cement mortar samples were decreased with increased recycled aggregate as shown in Fig. 1. That may be due to the recycled aggregate having lower bulk density than natural aggregate as illustrated in table (3).

In fact, the water absorption has increased continuously in samples containing recycled aggregate additives. i.e. the water absorption percentage was increased with increased recycled aggregate replacement percentage, as shown in Fig. 2 that may be because the recycled aggregate having high volume of voids that fill with water lead to increased water absorption, that agreement with the porosity % values were estimated for prepared cement mortar samples, as shown in Fig. 3.

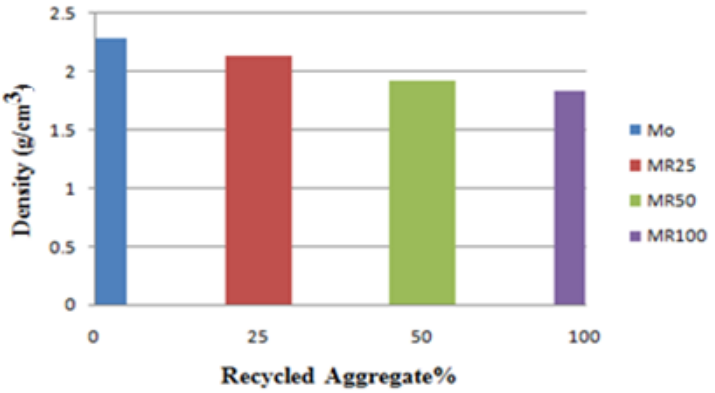

Figure 1. Apparent density of recycled cement mortar

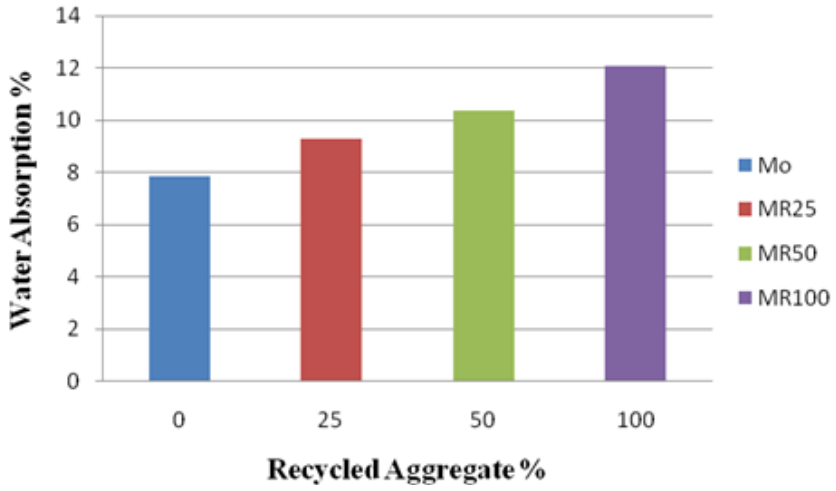

Figure 2. Percentage of water absorption of recycled cement mortar samples.

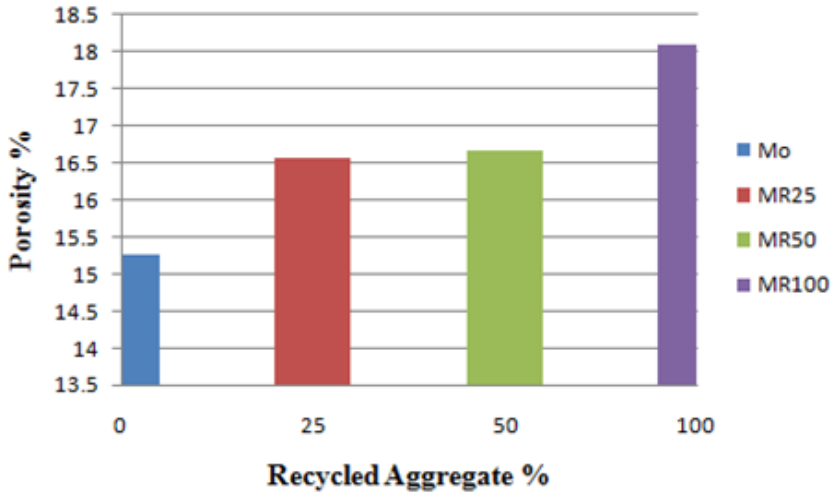

Figure 3. Percentage of porosity of recycled cement mortar samples.

4.2. Mechanical Properties

ASTM C109-93 was used to assess the compressive strength behavior of samples [14]. Fig. 4 expresses the compressive strength results of mortar mixtures containing different recycled aggregated. According to the results, compressive strength of samples decreased with increasing the content of recycled aggregated to the extent that the strength reached the lowest amount in samples containing 100% recycled aggregated with 17.392,and 26.088 MPa for 7,and 28 day curing, respectively ,compared with 24.408, and 32.96 MPa which was obtained by control samples for 7,and 28 day curing, respectively. That may be due to the lower properties of recycled aggregate compared with natural aggregate, as shown in Fig. 1 and table 3.

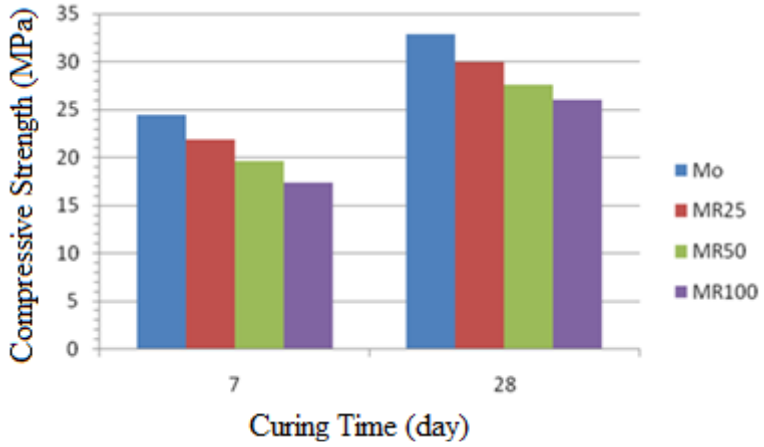

Figure 4. Compressive strength for cement mortar samples at 7 and 28 day

The results revealed that replaced natural by recycled aggregate up to 50% having approximated compressive with lower density than control samples, i.e. the recycled cement mortar have approximately control specimen(cement mortar with natural aggregate) specific compressive strength, as illustrated in Fig. 5.

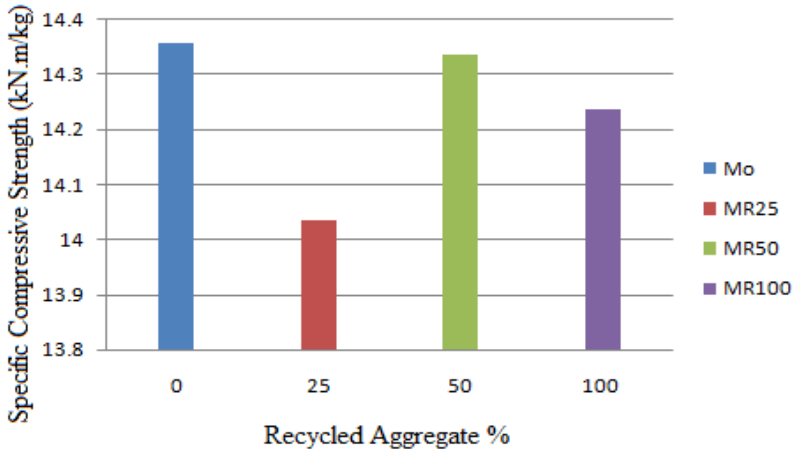

Figure 5. Specific Compressive Strength for prepared cement mortar samples at 28 day.

5. Conclusions

According to the results from the experimental tests, the following points can be concluded:

1. The recycled aggregate have lower bulk density than natural aggregate.
2. The apparent density for cement mortar samples were decreased by 6.64%, 15.73%, 19.9% with replacement percentage of recycled aggregate increased (25, 50, 100)wt.%, respectively, compared with control samples (M0).
3. The recycled cement mortar samples (M25, M50, M100) had higher water absorption and porosity percentage than control sample (M0). The percentage of absorption increment with recycled aggregate increased by 18.11%, 31.74%, 53.19%, respectively, while , porosity increment with recycled aggregate increased by 8.56%, 9.17, 18.56 ,respectively, compared with M0.

4. The compressive strength was decreased by with recycled aggregate percentage increased in cement mortar samples. The lower compressive strength obtained in M100 samples were 26.08 MPa, while; the higher compressive strength and density obtained in M0 samples were 32.95 MPa
5. the recycled cement mortar sample have just about specific compressive strength of control sample.

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