Combined Effects of Sawdust and Building Rubbles as Aggregate on the Concrete

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Abstract

Most of building rubbles or wastes contain some damaged materials such as cement, brick, steel, ceramic, plastic and other substances. Among these materials, ceramic and brick when using both of them as a partial replacement by the weight of conventional coarse aggregate in mixture concrete with presence of variety ratios (10% to 30%) for sawdust as replacement of fine aggregate, the resulting concrete properties will affected. So, this paper was based on the study some properties of concrete that produced of 50% replacement for those rubbles plus to presence 10%, 20% and 30% sawdust for both of them. The results revealed that present of sawdust with each of type of those rubbles provides database which are potential to be used in the production of lighter and economical new concrete material. Furthermore, the higher ratios of sawdust (more than 10 %) lead to obvious affected on the strength as well as other properties. While, those negative effects will perceptible improved when added 10% sawdust in ceramic aggregate concrete compared to brick aggregate concrete.

Keywords: Building rubbles , Ceramic, Brick, Sawdust, Wastes.

Introduction

Concrete is the most important substitute in building material. Strength, cost and durability of building is highly depended upon it (ICJ,2013). So, the transformation from a conventional consumption based society to a sustainable society is important for several reasons such as lowering pollution of natural environment, prevention of exhaustion of natural resources and slowing down filling of final waste disposal facilities (Eguchi, K., 2007). In this regard, one of the greatest challenges facing the concrete industry is to focus its objectives towards the achievement of sustainable development (Duran, A., 2011). Since concrete is one of the principal materials for structures and it is widely used for many applications all over the world (Gencel, O., 2011). Thus, it is compelling to use life cycle and sustainable engineering approaches to concrete technology.

Concrete is the most widely used construction material in the world. Concrete requires basic ingredients like aggregates (coarse and fine), cement and water. At present there is no desperate concrete aggregate shortage in the world. But this will not be the case always. It has been noted that the demand of coarse aggregates is on an increasing trend worldwide (ICJ, 2013). Besides that, very large amounts of waste are being produced around the world. The most common method of managing wastes is through their disposal in landfills – creating in that way huge deposits of wastes. In this situation, waste recycling alternatives are gaining increasing importance (Correia, L., 2009).

Recycling has the potential to reduce the amount of wastes disposed of in landfills and to preserve natural resources. Recycling, one of the strategies in minimizing waste, offers three benefits; reduces the demand for new resources; cuts down on transport and production energy costs; and utilizes waste which would otherwise be gone into landfill sites. Concrete containing wastes can support construction sustainability and contribute to the development of the civil engineering area by using industrial waste, minimizing the consumption of natural resources and producing more efficient materials (Pelisser,F., 2011). Among these wastes, crushed ceramic and brick. Although the reutilization of ceramic wastes and has been practiced, the amount of wastes reused in that way is still negligible. Hence, the need for its application in other industries is becoming absolutely vital. Construction industry can be the end user of all ceramic wastes and in this way can contribute to solve this environmental problem. The nature of construction industry, especially the concrete industry, is such that ceramic wastes can be used safely with no need for dramatic change in production and application process (Mehta, K., 2001).

Since the last few decades, there has been an increasing tendency worldwide to look out for materials that can be used as alternative for conventional materials. Therefore, researches have been carried out to study the use of crushed brick beneficially which must conform to the applicable engineering properties as the raw materials. Crushed brick may be used as a sub-base material for driveway, sidewalk, or roadway construction, base or fill in drainage projects, and for utilization as aggregate in new concrete manufacture which can be used for specific purposes such as: foundation concrete for light buildings, flooring, walkway and foundation beneath light traffic roads (Swamy, N., 1983).

On the other hand, wood sawdust wastes are accumulated from the countries all over the world and cause certain serious environmental problems and health hazards (Turgut, P.,2007). Sawdust has been used in concrete for at least 40 years, but not widely (Taoukil, A., 2011). Sawdust can be defined as loose particles or wood chippings obtained as by-products from sawing of timber into standard useable sizes (Chemani, H.,2013). Clean Sawdust with reasonable amount of bark has proved to be satisfactory, since it does not introduce high content of organic material that may upset the reactions of hydration (Neville, M., 2000). Although seriously limited by its low compressive strength, sawdust concrete can be made to perform well in certain floor and wall applications (Taoukil,A.,2011).

Experimental investigations to evaluate the possibility of using sawdust as a construction material have been reported by various researchers. (Al-Numan, B.,2004) studied the effect of adding sawdust on the compressive strength, flexural strength and splitting tensile strength for concrete mixes with mix proportions cement: sand: sawdust (1:1:1) , (1:1.5:1.5) , (1:2:1) and (1:1:0) by volume. (Al-Jelawe, N.,2010) prepared several concrete mixes with proportions cement /aggregate ranging (1:4 to 1:7) by volume using siporex and porcelinite with sawdust to obtain lightweight concrete of two densities ranging from (350-880kg/m^3). In addition to the use various ratios of water/cement (0.45,0.50 and 0.55) with different cement contents (300, 400 and 500) Kg/m^3. (Bdeir, L., 2012) investigated compressive strength and hardness of mortar at sawdust replacement levels (5, 10, 15, 25, 50 and 75) % by volume of sand. However, many previous researches undertaken obtained valuable results to use the industrial wastes in various forms of concrete production. So, the concrete mixes having both wood sawdust wastes and some building materials wastes combination hitherto has not been investigated. These wastes utilized in this research are currently disposed in sanitary landfills or open-dumped into uncontrolled waste pits and open areas.

In this study an attempt has been made to find the suitability of the building rubbles and sawdust as a possible replacement on conventional coarse and fine aggregate respectively. So, the pilot project was based on the 50% replacement for both of ceramic and brick with presence of 10%, 20% and 30% sawdust.

Materials

Cement : The cement used in all concrete mixtures was ordinary Portland cement type1 complies with the requirement of IQS No.5/1984 as denoted in Tables 1 and 2.

Natural Aggregate : Natural sand and gravel of maximum size 4.75mm and 20 mm respectively were used as fine and coarse aggregates. Some properties for both of them are denoted in Table 3. All their met the requirements of ASTM C33-03 with respect to the sieve analysis as showed in Table 4.

Recycled Aggregate: In this research, recycled aggregate was included;

- **Sawdust:** locally available sawdust from special carpentry factories was used as recycled fine aggregate. It was cleaned and screened to pass through 4.75 mm.
- **Building Rubbles :** In building construction, ceramic wastes are generated due to transportation to the building site and during the execution of construction elements. So, it was the major source to supply two types of recycled coarse aggregate. The first type includes a mixture of wall and floor tiles and called ceramic aggregate. While, the second type includes a mixture of brick, blocks and roof tiles and called brick aggregate. Both types of aggregate were cleaned, crushed, sieved within (20– 4.75)mm. and then used in saturated surface dry conditions.

Table 5 and 6 illustrated some properties and sieve analysis respectively for recycled aggregate.

Water : Tap water was used for mixing and curing of concrete.

Research Methodology

The possibility of using sawdust and building wastes together need to be investigate for confident used of these materials. The review of literature however, could not find any comparative study addressed together the effect of these materials on the properties of produced concrete. Thus, in the present work a holistic approach was adopted to investigate the possibility of using sawdust and building wastes to produce low-cost and light construction material. The main parameter for this study was verification of the proportion of sawdust which then is going from normal concrete to lightweight concrete.

In this study, two types of recycled coarse aggregate were used as already mentioned (ceramic and brick) with one type of recycled fine aggregate (sawdust). To evaluate the combined effects of these variables, night mixes were prepared. The mix was designed for the target strength of 25 MPa at 28-day with slump (75-100) mm for control mix (M0) according to ACI 211.1-95 standard. The ratios of (cement : sand : gravel) and (w/c) were kept constant as (1:1.59:2.57) and 0.48 respectively. In mixes MC0, MC10, MC20 and MC30, the sand was partially replaced with 0%,10%, 20% and 30% sawdust with presence of 50% ceramic. In contrast, MB0, MB10, MB20 and MB30 mixes were prepared with existence of 50% brick as explained in Table 7. Because all other parameters were constant for all mixes, it was expected that the effect of type recycled coarse aggregate would be reflected in any difference in sawdust levels on the properties of concrete.

Experimental Investigations

To estimate the recycled aggregate concrete, the practical program was planned to investigate some properties such as slump, compressive strength, splitting tensile strength, flexural strength, hardened density and water absorption. Experiments were conducted on cube, cylindrical and prism specimens. The cube specimen of dimensions 100mm x 100mm x100mm was used for compressive strength, hardened density and water absorption tests while the cylindrical specimen of height 200mm and 100mm diameter was used for splitting tensile strength test and the prism specimen of dimensions 100mm x 100mm x500mm was used for flexural strength test.

A total of 135 specimens, 9 cubes, 3 cylinders and 3 prisms were prepared for each mix. Specimens were cast in steel moulds and placed in a room for 24 hours until demoulding. Thereafter, all specimens were placed in water tanks until the examination date (at age 28-day).

Results and Discussion

1. Slump test values for all mixes reveal that the inclusion of recycled aggregate regardless of whether it is fine or coarse aggregate in concrete mix design did not improve the workability as shown in Table 7 and Fig.1. On the contrary, as recycled aggregate content in concrete mixtures increases, their workability decreases. For example, the reduction in slump for MC0 and MB0 mixes reached 6.98% and 11.63% respectively compared to control mix. This behavior is substantially ascribed to the smooth surfaces and better bond effect in case of natural aggregate than that of the highly angular and rough surface for the recycled aggregate. Beside, the data results as represented in Table 7 and Fig.2 indicated to occurrence of an additional reduction in values of slump test with presence of sawdust regardless of recycled coarse aggregate used. This returned to the use of sawdust which has high absorption and increased substitution in mix. The proportions of increasing in slump reached 31.14% and 38.18% for MC10 and MB10 compared to MC0 and MB0 respectively. Also, it can be noted that all the sawdust mixes not satisfy the requirements of design.
2. Compressive strength values for the natural and recycled aggregate concretes made from same mix proportions and water/ cement ratios as represented in Table 8 and Fig.3 demonstrated that the recycled aggregate concretes exhibited reduction in compressive strength than that of natural aggregate concrete. The main reason is due to the particle shape of the recycled coarse aggregate was more edged and angular compared to the natural coarse aggregate, resulting in best interlocking effect and higher friction forces inside the concrete mix. The reduction in compressive strength reached 24.18 % and 31.71% for MC0 and MB0 respectively compared to M0 . Also, it can be seen that ceramic aggregate concretes appeared increasing in values of compressive strength then that of corresponding brick aggregate concretes. This is may be attributed to the higher bond strength between cement paste and aggregate in the case of using ceramic aggregate. The increasing in compressive strength reached 11.02%, 15,82%, 25.26% and 29.04% for MC0, MC10, MC20 and MC30 respectively relative to their corresponding brick aggregate concretes .
3. The compressive strength values showed that the corporation of various ratios for sawdust in the concrete mixture did not enhance its compressive strength regardless of type recycled coarse aggregate used as illustrated in Fig. 4. Conversely,as the percentage of sawdust content increased, the compressive strength decreased. The ratios of reduction in compressive strength for MC10 reached 21.39% obverse 24.65% for MB10 compared to their corresponding MC0 and MB0 respectively. This attributed to sawdust contains some substances which are injurious to the cement. These substances actually inhibit the hydration of cement and hence the development of strength (Oyekan, G., 2007).
4. The splitting tensile strength test results as summarized in Table 8 and Fig.5 denoted that the recycled aggregate concretes showed more reduction in splitting tensile strength than that of natural aggregate concrete. The reason dates back to the enhancement of bond between the aggregate and the paste when using natural aggregate, as a result to that, higher resistance to mechanical actions. The reduction in splitting tensile strength reached 8.74% and 12.94% for MC0 and MB0 respectively compared to control mix. Furthermore, the ceramic aggregate concretes appeared evident increasing in splitting tensile strength with compared to their corresponding brick aggregate concretes. The increasing in splitting tensile strength reached 4.83%, 9.96%, 17.88% and 21.88% for MC0, MC10, MC20 and MC30 respectively.
5. Fig.6 showed the influence of sawdust levels on splitting tensile strength for recycled aggregate concretes. It is clear that the splitting tensile strength significantly reduced and more obvious at higher sawdust ratios regardless of the type recycled coarse aggregate used. This is due to weakness of sawdust as an aggregate as a result to that weak interface between the aggregate and the paste. The reduction in splitting tensile strength reached 9.93% for MC10 opposite

14.13% for MB10 compared with their corresponding mixes without sawdust.

6. Table 9 and Fig 7 illustrated the test results of the flexural strength of specimens with different replacement percentage of natural aggregate by recycled aggregate. From these results, it can be seen that recycled aggregate concretes exhibited decrease in values of flexural strength compared with natural aggregate concrete. This can be explained as a result of substituting natural aggregate for a less stiff aggregate. The reduction in flexural strength reached 18.45% and 23.23 % for MC0 and MB0 respectively compared to M0. Moreover, ceramic aggregate concretes showed increasing in flexural strength compared to their corresponding brick aggregate concretes. This may be return to the more angular shape of ceramic aggregate than brick aggregate that is beneficial to a good bond between the aggregate and the cement paste. The ratios of increasing in flexural strength reached 6.23%, 7.14%, 18.09% and 22.22 % for MC0, MC10, MC20 and MC30 respectively.
7. The flexural strength for all the concrete mixes that contain variable percentage of sawdust explained in Fig 8. The results showed reduction in the flexural strength with increasing of sawdust content in concrete mix. This is due to high sawdust absorption which cause increase in the amount of the voids in the concrete structure as a result weak bond strength. The reduction in flexural strength reached 12.01 % for MC10 obverse 12.76 % for MB10 compared to their corresponding MC0 and MB0 respectively.
8. The data of the hardened density test for natural and recycled aggregate concretes explained in Table 9 and Fig. 9. The results revealed that recycled aggregate concretes demonstrated high decrease in hardened density when compared it with reference concrete. This is strongly linked with the higher amount of voids, smaller specific gravity and unit weight for recycled aggregate than that of natural aggregate. The reduction in hardened density reached 29.21% and 30.98% for MC0 and MB0 respectively compared to M0. On the other hand, it is obvious that ceramic aggregate concretes showed higher hardened density compared to their corresponding brick aggregate concretes. The increasing in hardened density reached 2.56%, 1.68%, 4.79% and 12.16% for MC0, MC10, MC20 and MC30 respectively.
9. The effect of sawdust ratios on hardened density for all concretes are represented in Fig.10. It can be seen that the relationship between the sawdust content and hardened density were inversely proportional. This mean that the hardened density of concrete specimens decrease with increasing the sawdust ratio, due to the lower density for sawdust than that of sand. The reduction in hardened density reached 5.33% for MC10 versus 4.51%, for MB10 compared to MC0 and MB0 respectively. Beside that, it can be noted that hardened density at high sawdust levels (20% and 30%) was less than 2200Kg/m^3. This means the beginning of the transition to the lightweight concrete at these ratios of sawdust.
10. From Table 9 and Fig.11, the results revealed that the water absorption for recycled aggregate concretes were higher than that of natural aggregate concrete. This is returned to a number of causes; firstly, the total porosity of recycled aggregate concrete is more than that of natural aggregate concrete due to the higher porosity for recycled aggregate, secondly, recycled aggregate contain higher micro-cracks which are incurred during crushing of its from which recycled aggregate are derived. The increasing in water absorption reached 15.67% and 25.37%% for MC0 and MB0 respectively compared to M0. However, it is clear that ceramic aggregate concretes have lower tendency toward absorption than that corresponding brick aggregate concretes. The reduction in water absorption reached 7.74%, 6.67%, 30.65% and 10.19% for MC0, MC10, MC20 and MC30 respectively.
11. It is seem from the values of water absorption test as indicated in Fig.12 that water absorption increase with the inclusion of sawdust. When increases of sawdust content in the mix concrete, the water absorption also increases. The increasing in water absorption reached 89.68% for MC10 versus 87.50% for MB10 compared to their corresponding MC0 and MB0 respectively. This is associated with the high absorption nature for the sawdust.

Conclusion

The high difference in consistency was not obvious between both of ceramic and brick aggregate mixes. While, another properties changed depending on the type of recycled coarse aggregate used. Results showed that concretes made with ceramic aggregate behave in a better manner than of concrete made with brick aggregate. This mean that of ceramic particles have effective impact upon these properties more than brick particles. This can be ascribed to the higher bond strength between cement paste and aggregate in the case of using ceramic particles than of brick particles. Furthermore, the using of sawdust with those types of building rubbles provides database which are potential to be used in the production of lighter and economical new concrete material. Also, It can be concluded that using ceramic and brick particles as recycled coarse aggregate were acceptable in recycled concrete production when the content both of them is 50%.The observations during the tests show that the high ratios of sawdust (more than 10 %) with 50% recycled coarse aggregate lead to low strength in compressive, tensile and flexural beyond high absorption capacity and low hardened density compared with natural aggregate concrete. This reveal that using sawdust in concrete will affect on its properties with increasing its percentage. To achieve a better result in the use of sawdust for production, the percentage replacement of sand should not be exceeded 10%. Furthermore, attempt made at using more than 30% replacement of sand with sawdust was not successful as there the bonding was very poor.

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Table 1: Chemical composition of cement used

Compound	Weight%	IQS No.5/1984	ASTM C150-15
CaO	64.10	–	_
SiO_2	20.88	–	_
Al_2O_3	3.74	–	_
Fe_2O_3	4.50	–	_
SO_3	2.10	≤ 2.8%	≤ 3.5%
MgO	1.00	≤ 5.0%	≤ 5.0%
I.R.	0.82	≤ 1.5%	≤ 0.75%
L.O.I.	1.98	≤ 4.0%	≤ 3.0%
L.S.F	0.95	0.66-1.02	_
C_3S	21.30	–	_
C_2S	52.30	–	_
C_3A	6.20	≥ 5.0%	_
C_4AF	9.30	–	_

***The tests were conducted in national center for laboratories and construction researches.

Table 2: Physical properties of cement used

Property	Value	IQS No.5/1984	ASTM C150-15
Fineness, m^2/Kg	338	≥ 230	≥ 260
Setting time, hrs:min			
Initial set.	2:35	≥ 00:45	≥ 00:45
Final set.	4:30	≤ 10:00	≤ 6:15
Compressive strength, MPa			
3-day	20.35	≥ 15.0	≥ 12.0
7- day	26.26	≥ 23.0	≥ 19.0
Autoclave expansion,%	0.14	≤ 0.80	≤ 0.80

***** The tests were conducted in national center for laboratories and construction researches.

Table 3: Properties of natural aggregate used

Property	Gravel	Sand
Specific gravity	2.70	2.61
Absorption capacity (%)	0.97	1.04
Unit weight (kg/m^3)	1680	1734
Sulfate content (%)	0.01	0.05

*****The tests were conducted in college of science, university of Baghdad..

Table 4: Gradations of natural aggregate used

Aggregate code	Sieve size						
	10 mm	4.75 mm	2.36 mm	1.18 mm	600 μm	300 μm	150 μm
ASTM C33-03	100	95-100	80-100	50-85	25-60	10-30	2-10
IQS No.45/1984 Zone1	100	90-100	60-95	30-70	15-34	5-20	0-10
Sand	100	98.02	96.24	54.11	31.57	12.10	3.66

	Sieve size				
	25 mm	20 mm	10 mm	4.75 mm	2.36 mm
ASTM C33-03	100	90-100	20-55	0-10	0-5
IQS No.45/984	100	95-100	30-60	0-10	0
Gravel	100	92.99	25.30	2.72	1.80

Table 5: Properties of recycled aggregate used

Properties	Ceramic	Brick	Sawdust
Specific gravity	2.03	1.88	0.65
Absorption capacity (%)	9.70	11.30	190.50
Unit weight (kg/m^3)	1200	1158	189
Sulfate content (%)	0.05	0.06	0.58
Los Angeles Abrasion (%)	42.10	37.2	−
Impact index (%)	13.57	19.89	−

*****The tests were conducted in college of science, university of Baghdad.

Table 6: Gradations of recycled aggregate used

Aggregate code	Sieve size						
	10 mm	4.75 mm	2.36 mm	1.18 mm	600 μm	300 μm	150 μm
Sawdust	100	78.02	36.24	10.11	6.57	4.10	2.66
	Sieve size						
	25 mm	20 mm	10 mm	4.75 mm	2.36 mm		
ASTM C33-03	100	90-100	20-55	0-10	0-5		
Ceramic	100	90.08	21.44	2.63	0.75		
Brick	100	92.99	25.30	2.72	1.0		

Table 7 : Replacement proportions and slump test results

Mix code	Sawdust %	Ceramic %	Brick %	Slump mm
M0	-	-	-	86
MC0	-	50	-	80
MC10	10	50	-	61
MC20	20	50	-	45
MC30	30	50	-	38
MB0	-	-	50	76
MB10	10	-	50	55
MB20	20	-	50	36
MB30	30	-	50	28

Table 8 : Compressive and splitting tensile strength test results

Mix code	Compressive strength (MPa)	Reduction (%)	Splitting tensile strength (MPa)	Reduction (%)
M0	29.11	-	3.09	-
MC0	22.07	24.18	2.82	8.73
MC10	17.35	40.39	2.54	17.79
MC20	12.05	58.60	2.11	31.71
MC30	11.42	60.76	1.95	36.89
MB0	19.88	31.70	2.69	12.94
MB10	14.98	48.54	2.31	25.24
MB20	9.62	66.95	1.79	42.07
MB30	8.85	69.59	1.60	48.22

Table 9 : Flexural strength, hardened density and water absorption test results

Mix code	Flexural strength (MPa)	Hardened density (Kg/m^3)	Water absorption (%)
M0	4.39	3341	1.34
MC0	3.58	2365	1.55
MC10	3.15	2239	2.94
MC20	2.61	1859	4.14
MC30	2.42	1697	7.23
MB0	3.37	2306	1.68
MB10	2.94	2202	3.15
MB20	2.21	1774	5.97
MB30	1.98	1513	8.05

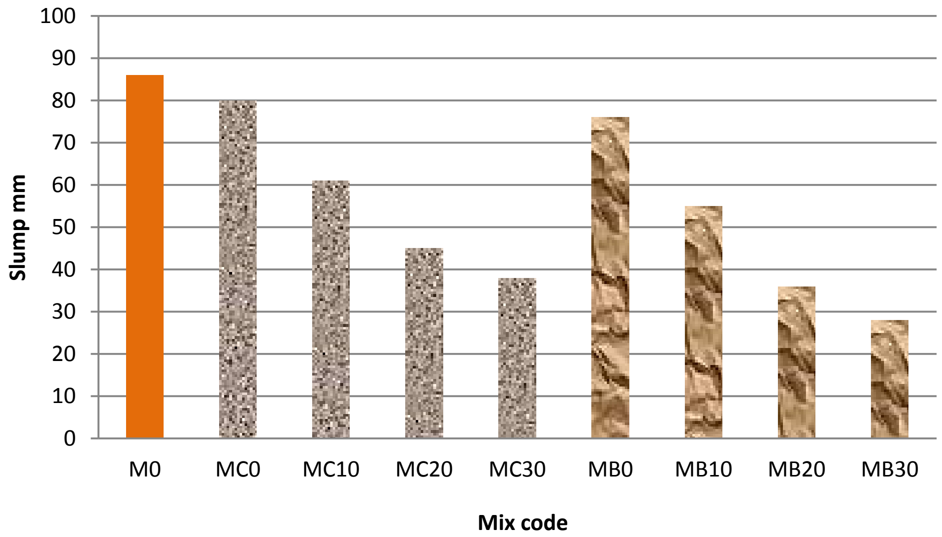

Figure 1: Variation of slump with recycled aggregate content

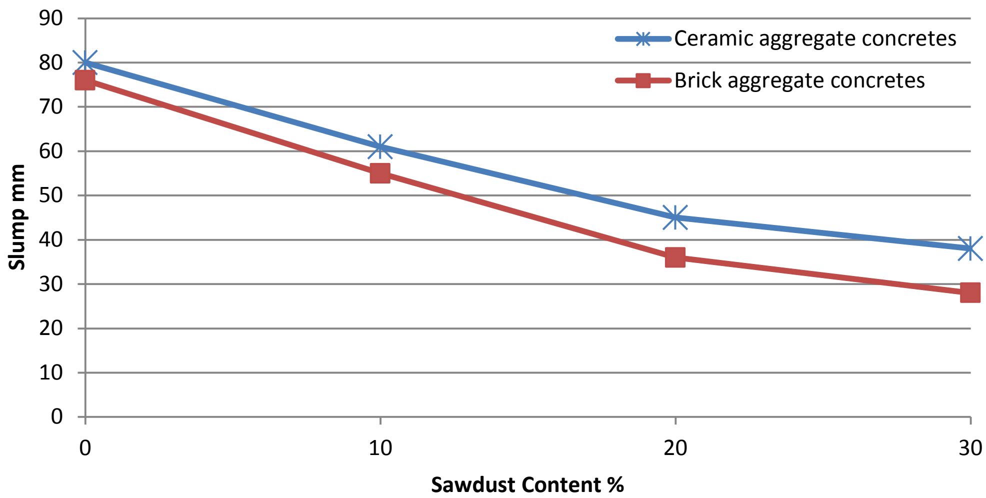

Figure 2: Variation of slump with sawdust content

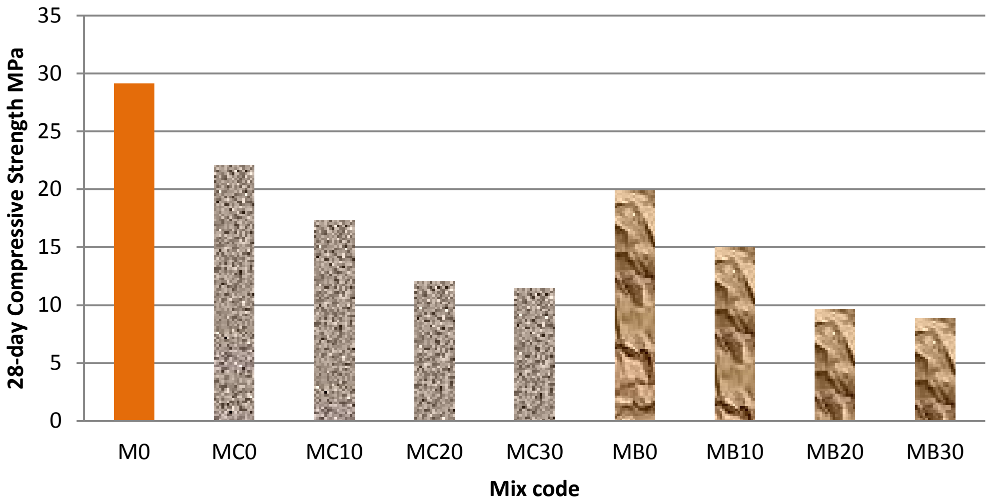

Figure 3: Variation of compressive strength with recycled aggregate content

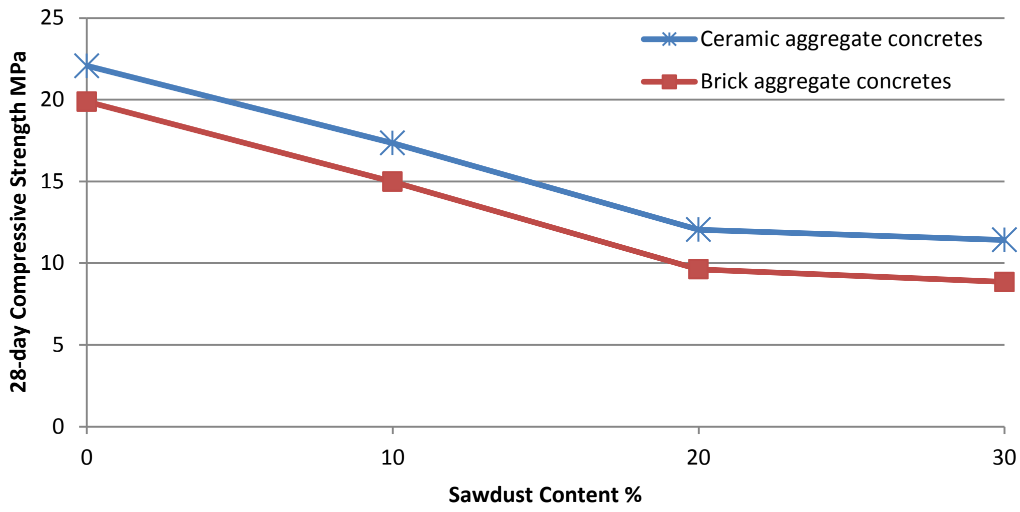

Figure 4: Variation of compressive strength with sawdust content

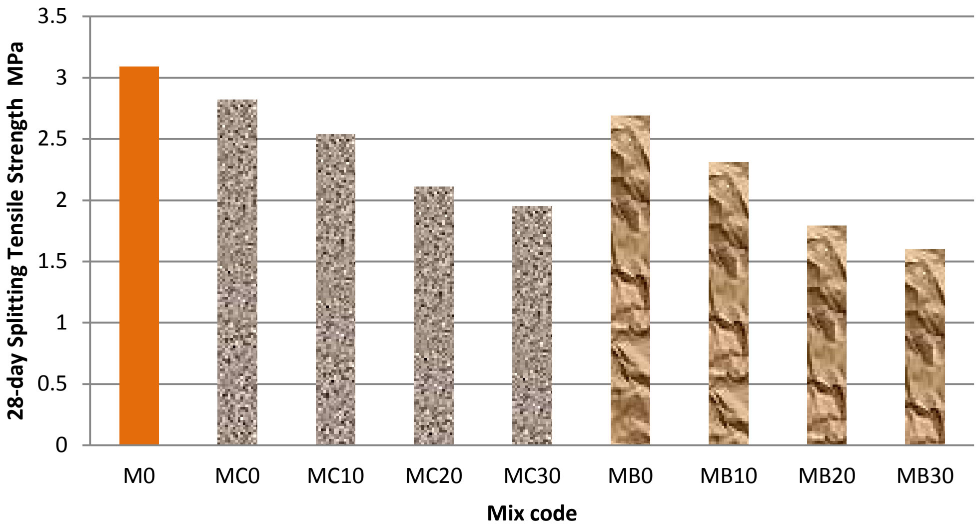

Figure 5: Variation of splitting tensile strength with recycled aggregate content

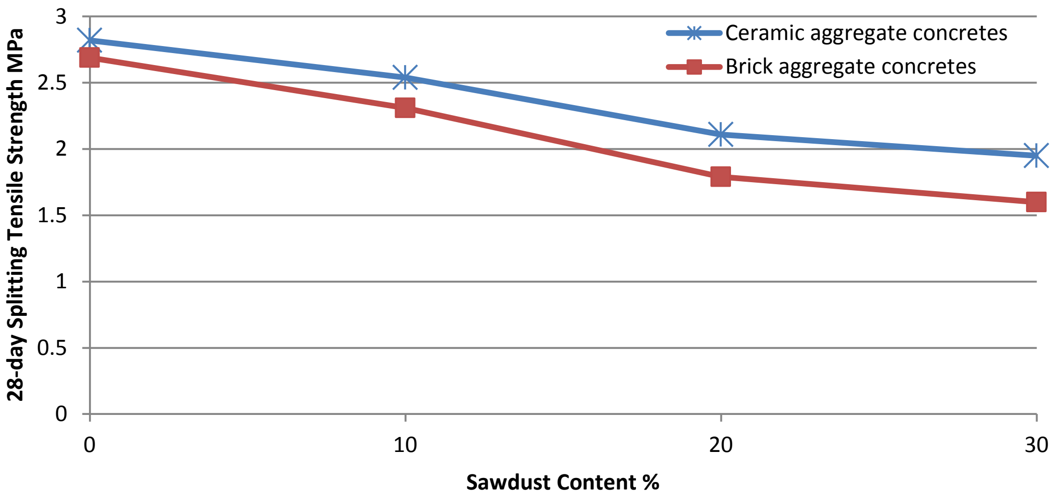

Figure 6: Variation of splitting tensile strength with sawdust content

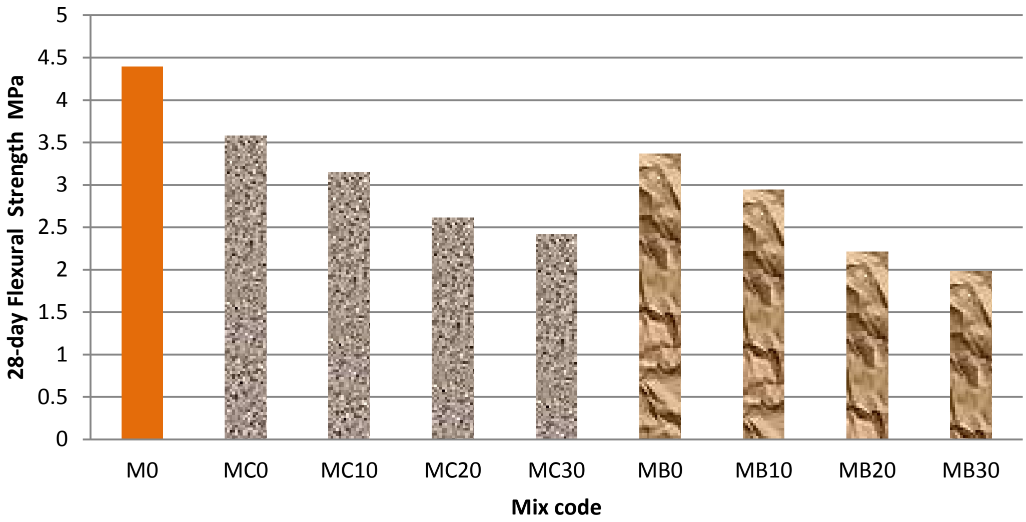

Figure 7: Variation of splitting tensile strength with recycled aggregate content

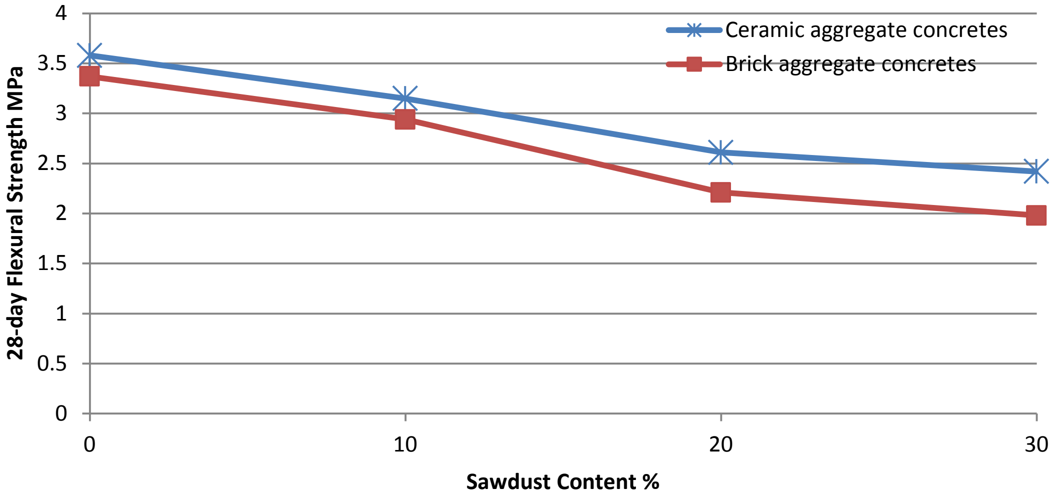

Figure 8: Variation of splitting tensile strength with sawdust content

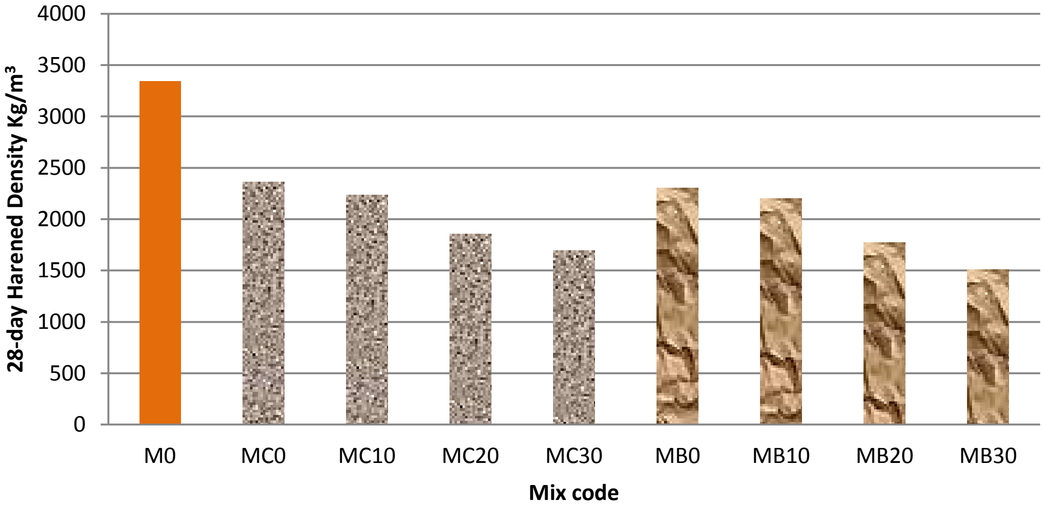

Figure 9: Variation of hardened density with recycled aggregate content

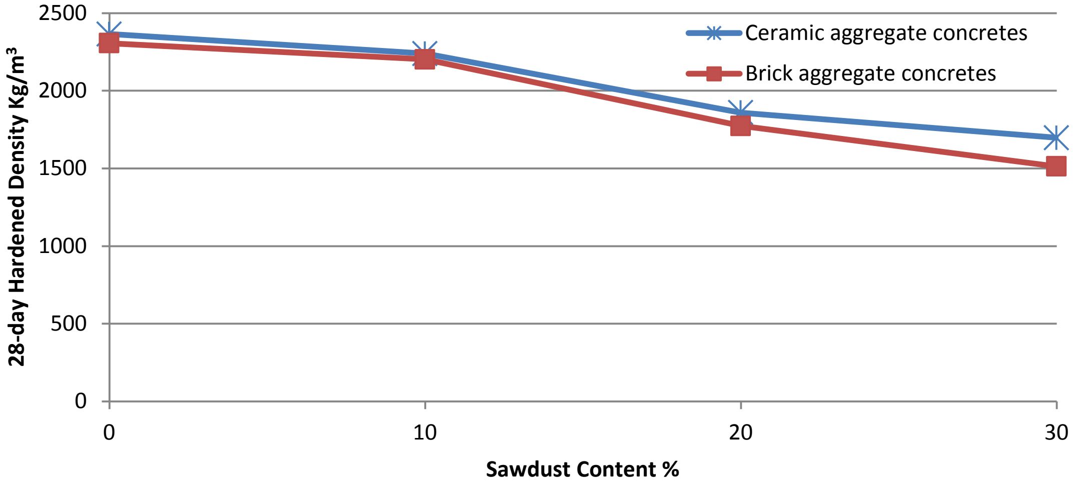

Figure 10: Variation of hardened density with sawdust content

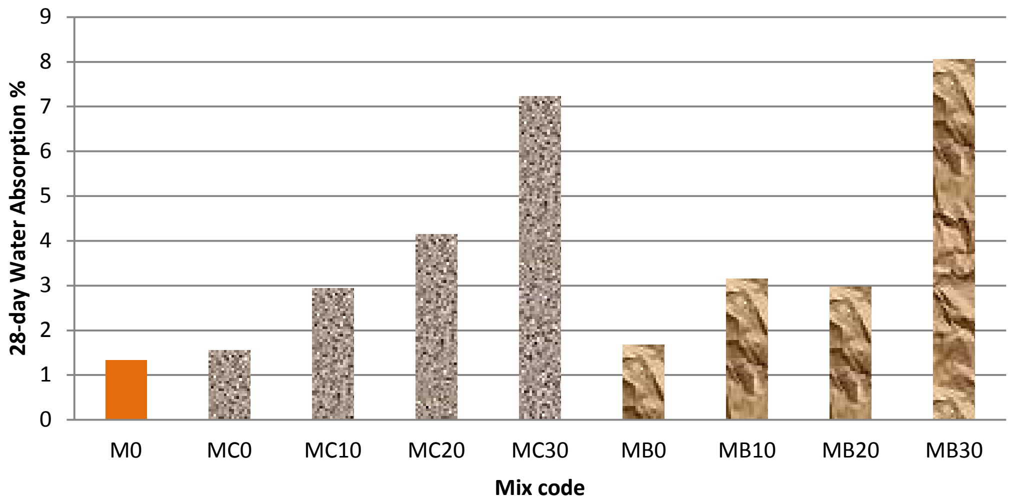

Figure 11 : Variation of water absorption with recycled aggregate content

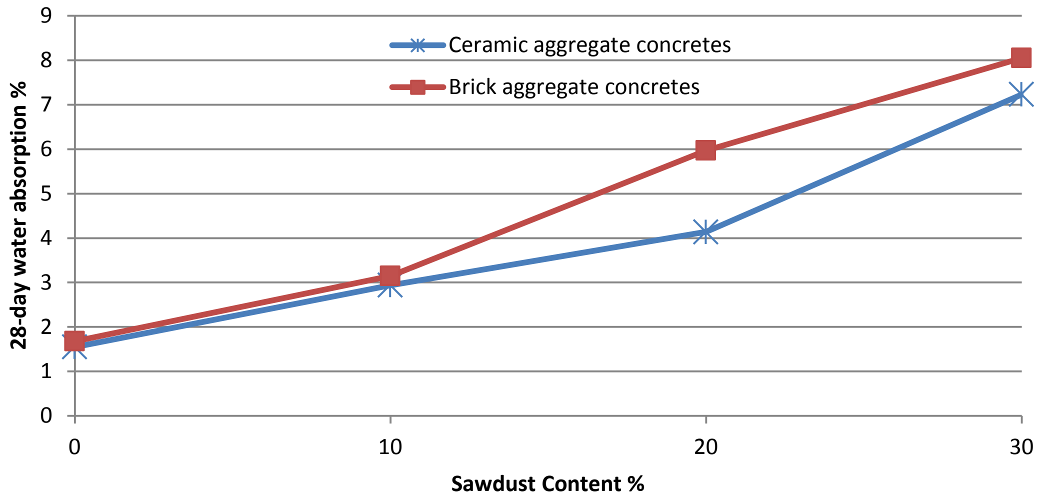

Figure 12 : Variation of water absorption with sawdust content

التأثيرات المشتركة لنشارة الخشب و أنقاض البناء كركام على الخرسانة

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الخلاصة :

تتضمن معظم أنقاض أو مخلفات البناء على بعض المواد التالفة كالسمنت، الطابوق، حديد التسليح، السيراميك، البلاستك ومواد اخرى. ومن بين هذه المواد السيراميك والطابوق عند استخدام كلا منهم في الخرسانة كتعويض جزئي عن الركام الخشن التقليدي مع وجود نسب مختلفة من نشارة الخشب كتعويض عن الركام الناعم فأن خصائص الخرسانة الناتجة سوف تتأثر لذلك تم دراسة بعض الخصائص للخرسانة الناتجة من تعويض 50% من تلك المخلفات أضافة الى وجود 10% ،20% و 30% من نشارة الخشب لكل منهم. أظهرت النتائج بأن وجود نشارة الخشب مع كل نوع من تلك الانقاض سيوفر قاعدة بيانات بالامكان استخدامها في انتاج مادة خرسانية جديدة اقتصادية وخفيفة. بالاضافة لذلك، فأن النسب العالية من نشارة الخشب (اكثر من 10%) ستؤثر بشكل ملحوظ على مقاومة الخرسانة فضلا عن غيرها من الخواص. بينما تتحسن تلك التأثيرات السلبية بشكل مقبول عند اضافة 10% من نشارة الخشب في خرسانة ركام السيراميك مقارنة بخرسانة ركام الطابوق.