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Using of Glass Wastes as a Fine Aggregate in Concrete Mixture

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Abstract:
In this study, the waste glass (WG) is considered as a fine aggregate in the concrete mixture. WG is used after grinding to size according to Iraqi sand specifications No.45. The waste glass has been used instead of sand in different proportions which are 0%, 33%, 66% and 100%. The effects of WG on compressive strength of the concrete and unit weight are analysed. As results of this study, WG is determined to have a significant effect upon the reduction of its compressive strength and there is a significant decreasing of its unit weight. As for cost analysis, it was determined to lower the cost of concrete production. This study was an environmental one in consideration of the fact that WG could be used in the concrete as fine aggreagates without the need for a high cost or rigorous energy.

Key words: Glass powder, Alkali Silica reactive, GLP, Waste Glass.

استعمال المخلفات الزجاجية كبديل عن الركام الناعم في المزجات الخرسانية

الخلاصة:
في هذه الدراسة تم اعتبار المخلفات الزجاجية كركام ناعم في الخلطات الخرسانية، حيث تم طحن وتنعيم المخلفات الزجاجيةحسب المواصفات العراقية رقم(45) وتم استخدامها بدل الرمل بنسب مختلفة 0% و33% و66% و100%. تبين حصول انخفاض واضح في مقاومة الانضغاط يقابله قلة في وحدة الوزن كلما زادت نسب المخلفات الزجاجية في الخلطات، ومن تحليل الكلف تبين أن هنالك انخفاض في كلفة إنتاج المتر المكعب الخرساني عند استخدام المخلفات الزجاجية كبديل عن الركام الناعم.

الكلمات الدالة:
المسحوق الزجاجي ،تفاعل السليكا القوية، المسحوق الزجاجي الناعم،المخلفات الزجاجية

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Introduction:

Glass has been indispensable to man life due to such properties to pliability to take any shape with ease, bright surface resistance to abrasion, safety and durability. Large quantities of waste glass (WS) are disposed as solid waste. United Nations estimated the volume of yearly disposed to be 200 million tons. Unlike other waste products glass is imperishable and thus detrimental to the environment. Glass is unstable in the environment of concrete and could cause deterious alkali-silica reaction (ASR) problems .This property has been used to advantage by grinding it into a fine glass powder (GLP) for incorporation in to concrete as a-pozzolanic material**.**

Topcu and Canbaz.(2003) used WG as coarse aggregates in the concrete. In this study the WG was reduced to (4-16) mm in the proportions of (0-60)% of concrete. They concluded that WG has not a significant effect upon the workability of the concrete and only slightly in the reduction of it's strength also the WG decreased the concrete slump, air content and fresh unit weight. This study showed a decrease of (49)% of compressive strength with a(60)% of WG addition .They also added that drying shrinkage of the concrete containing GLP was acceptable.

Meyer, Egosi and Andela (2001) used WG as aggregate in concrete, They founded that commercial production of specialty glass concrete products will have a major impact on the economics of glass recycling throughout the united states. They recommended a number of measures to avoid ASR. Some of that recommendations including of grinding the glass to pass at least U.S standard mesh size No.50, adding mineral admixtures that can effectively suppress the reaction and using a low-alkali cement.

Corinaldsi, et.al (2005) studied the reuse of ground glass as aggregate for mortars. They reported that if the waste glass is finely ground under (75) mm, the effect of ASR did not occur and the mortar durability is guaranteed. Also they showed that there is no reaction has been detected with particle size up to (100) um and thus indicating the feasibility of the waste glass reuse as fine aggregate in mortars and concrete.

Terro. M. (2006) used fine waste glass FWG, coarse waste glass CWG and fine and coarse waste glass FCWG in the concrete mixes. Samples were cured under (95)% relative humidity at room temperature (20-22)°C heated in the oven to the desired temperature, allowed to cool to ambient temperature, and then tested for their residual compressive strength. The compressive strength of the concrete samples made with WG was measured at temperature up to(700)°C. They concluded that compressive strength of concrete made with WG decreased up to (20)% of it's original value with increasing temperature up to(700)°C. Their tests showed that concrete with (10)% aggregates replacement with FWG,CWG, and FCWG had better properties in the fresh and hardened states at ambient and high temperature than those with larger replacement. Concrete made with FWG aggregates had higher compressive strengths than those made with CWG and FCWG at ambient elevated temperature.

Shayan. Ahmad. Aimin (2003) showed that there is great potential for the utilization of WG in concrete in several forms including fine aggregate, coarse

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aggregate and fine glass powder GLP for incorporation in to concrete as a pozzolanic material. Their results showed beneficial pozzolanic reactions in the concrete and could replace up to (30)% of cement in some concrete mixes with satisfactory strength development. The drying shrinkage of the concrete containing GLP was acceptable. They concluded that the release of alkali from GLP did not appear to be sufficient to cause deleterious ASR expansion.

Halstead (1992) used WG in highway construction; he showed that WG can be used in a number of highway constrictions applications with satisfactory performance; also he concluded that the preferred use of WG in highway construction was in imbackment and fills.

Yunping et.al (1995) used WG as aggregate in concrete. The research showed that there are several approaches that can effectively control the expansion of ASR due to class aggregate, when WG was ground to mesh size no. (50) or finer, no expansion of the glascrete mortar was observed .This means that the ASR expansion increases with the increasing fines of glass particles up to certain point and then decreases afterward. The practical implication of this finding is that WG, ground at least meshes no. (100) is not likely to cause an acceptable expansion due to ASR.

Chen, et.al.(2006) studied the use of E-glass particles in cementations mixtures ,They showed that the compressive strength of specimen with 40% wt E-glass content was 17%,27%,and 43% higher than that of control specimen at age (28),(91),(365) day respectively. They concluded that E-glass can be used in concrete as cementations material as well as inert filler which depending upon the particle size and dividing size appears to be (75) um. They showed that the workability decreased as the glass content increase due to reduction of fines modulus and the addition of high-range water reducers was needed to obtain a uniform mixture.

Experimental Works

A- The used Materials:

1- Glass: it is used in this research replaced by several percentage of sand in the concrete mixture, using waste glass after grinding and screening of sizes corresponding to the sizes of the sand shown in table1
2- Sand and Gravel: are used according to Iraqi Specification No.45
3- Cement: Ordinary Portland Cement (OPC) is used in this research.
4- Water: tap water is used.

B- The mixtures:

Four mixtures has been prepared, the glass have been used instead of sand in different proportions (0)%, (33)%, (66)% and (100)%.

Cost Analysis:

For the purpose of concrete cost analysis produced in based on unit weight cost compare with local prices in Iraq (2009). The costs of materials are calculated as follows:

1 - Compose (OPC) = 133 \$/ton.
2- Sand =13.5 $\$/m^3$.
3- Gravel =8 $\$/m^3$.
4- Water =2.5 $\$/m^3$.
5- Cement =40 $\$/m^3$.
6- (W.G) =2 $\$/m^3$. (Topcu et.al.2004)

Cost of m^3 plain concrete = 64 $\$/m^3$.
Cost of m^3 with 100%W.G= (52.5) $\$/m^3$.
Reduction in cost = (18) %.

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Results and Discussion

The Results

- The result of the sieve analysis for WG were explained in table (1) and shown in photographic picture (1).
- The results of the compressive strength for the four mixtures were explained in table (2) and figure (1).
- Table (3) and Figure (2) are explaining the relationship between the density and the proportions of the used glasses.
- Table (4) and Fig.(3) showed the relationship between (compressive strength/WG/sand ratio) and (WG/sand ratio).

The Discussion

- The results in table (2) and Fig.(1) show the decreasing in compressive strength with increasing the proportion of the glass shown in photographic picture (3), Where the percentage of decrease in the compressive strength reaches to 40%, 48%, and 54% according to used ratios 33%, 66%, and 100% of the glass respectively. These results are identical with the results of Terro and Chen (2006) and Canbaz (2003).

  The reason of the decline in the compressive strength is due to the lack of coherence between the components of the concrete mixture with broken glass because of the soft surfaces of glass particles and there is not the porosity among them.
- There is a decrease in unit weight of concrete which contain glass, with increasing the ratio of glass compared with normal concrete. The percentages of decreasing are (5.9)%, (6.6)%,(7.1)% according to ratio of glass 33%, 66%, 100% respectively. These results are compatible with Chen et.al. 2003 and Shayan et.al.(2006). This is attributed to the fact that the density of glass is less than sand.
- The ratio of (unit weight /compressive strength) is observed that it increases with increasing of glass content. The ratios were : (123.69), (140.1) and (157.24) according to the ratios of glass (33%, 66%, and 100%) respectively, while the ratio of plain concrete is (79.01)%.This clearly showed that in spite of decreasing compressive strength due to addition of WG ,the weight was decreasing, thus it can keep the ratio of unit-weigh/compressive strength approximately constant as showed above.
- As shown in table (4), there is slight difference among ratios (compressive/unit weight), in spite of decreasing of the compressive strength due to adding waste glasses, this is attribute to decrease in concrete density.
- According to cost analysis shown there is decrease in the cost of 1m^3 of concrete contains the glass by 18% from the plain concrete. This result is compatible with Topcu's studies (Topcu et.al. 2004).

Recommendations:

1) Studying the role of additives in the increasing compressive strength of the concrete mixture that contains glass.

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2) Studying the use of concrete mixture contains the glass in the precast portions because it has architect view for the surface without plastering**.**

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Table (1)
Sieve Analysis of Waste Glass

Open size(mm)	% finer
20.0	100
4.75	90
2.36	68
1.18	37
0.6	16
0.3	5.5
0.15	0
0.075	0

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Table (2)
The Relationship between Compression Strength and WG/Sand

Comp. Strength(MPa) (WG/Sand) ratio	Sample 1	Sample 2	Sample 3	Average (MPa)
0 % plain concrete (1:2:4)	32.88	31.78	33.00	32.55
33%	19.55	20.21	18.98	19.58
66%	17.33	17.25	16.82	17.13
100%	14.66	15.00	15.90	15.18

Table (3)
The Relationship between Unit weight and WG/Sand

Unit weight(kg/m^3) (WG/Sand) ratio	Sample 1	Sample 2	Sample 3	Average	Reduced ratio
0% Plain (1:2:4)	2570	2575	2572	2572	0 %
33%	2420	2430	2415	2422	5.1%
66%	2400	2390	2410	2400	6.6%
100%	2378	2400	2385	2387	7.1%

Table (4)
The Relationship between Strength and WG/Sand

Strength (WG/Sand) ratio	Sample 1	Sample 2	Sample 3	Average
0% Plain (1:2:4)	78.16	80.93	77.94	79.01
33%	123.78	120.23	127.23	123.69
66%	138.48	138.55	143.28	140.10
100%	162.21	160.00	150.00	157.24

Picture (1) - shows sample of WG after grinding, sieving, and washing

Picture (2) - shows (100% WG) instead of sand in concert mixture

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Picture (3) - shows harden cubes of (100% WG) instead of sand

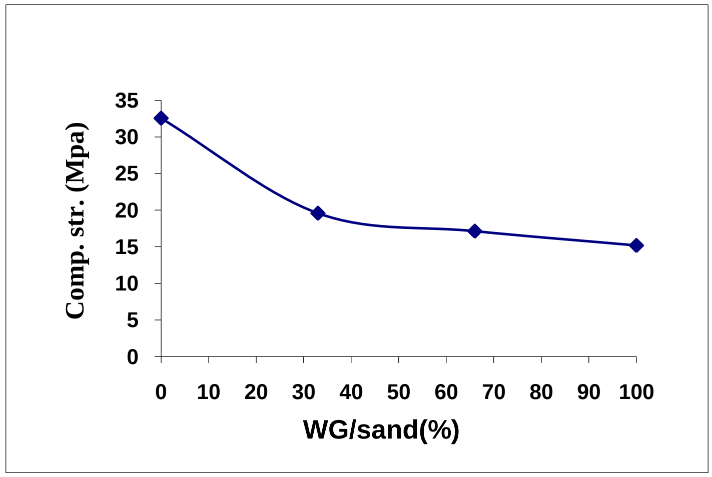

Figure (1) - the relationship between compressive strength and (WG/sand (%))

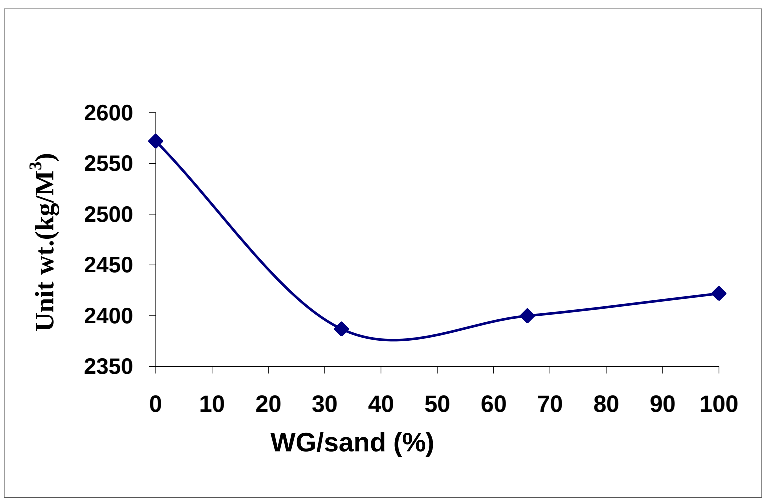

Figure (2) – the relationship between unit weights of concert and (WG/sand (%))

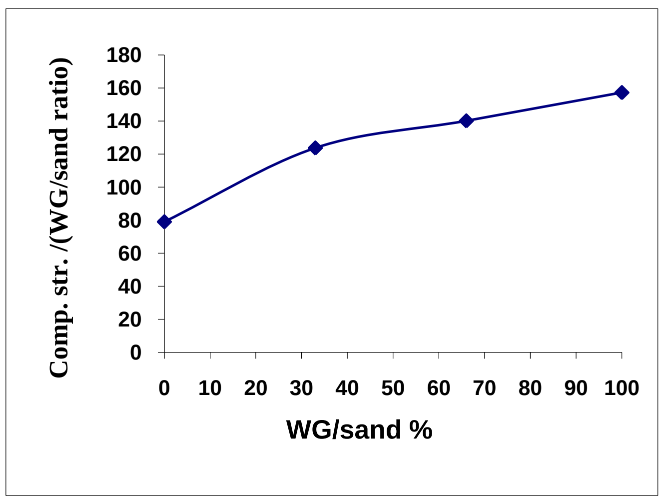

Figure (3) – the relationship between (compressive Strength /(WG/sand ratio)) and (WG/sand (%))