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BENEFICIAL ROLE OF GLASS WASTES IN CONCRETE – A REVIEW

Dr. Sheelan Mahmoud Hama[1], Mohammed Tarrad Nawar[2], Dr. Abdulkader Ismail Al-Hadithi[3]

1) Lecturer Civil Engineering Department, University of Anbar, Anbar, Iraq.
2) Assist Lecturer. Dam and Water Resources Engineering Department,University of Anbar,Anbar, Iraq.
3) Prof., Dam and Water Resources Engineering Department, University of Anbar, Anbar, Iraq.

Abstract: Environmental problems have been taking into consideration as serious situation in the modern construction. Reusing and recycling the wastes consider as the only methods to reduce waste generated. However, the applications still have much opportunity for enhancement. This scientific paper review the researches in field of glass waste material reusing in construction application. The influence of the size and content of particles and the percentage of wastes replacement on fresh and hardened properties of concrete are also been discussed.

Keywords: *Fresh properties, Hardened properties, Portland cement, glass waste.*

الدور المفيد للنفايات الزجاجيةِ في الخرسانةِ ـ مراجعة

الخلاصة: المشاكل البيئية يجب ان تَؤْخذُ بنظر الإعتبار بجدية في البناء الحديث. اعادة الاستخدام و تدوير النفاياتَ تَعتبرُ الطريقة الوحيدة لتقليل النفايات وتاثيراتها السلبية على البيئة. على أية حال، هذه التطبيقات ما زالَتْ لَها فرص كثيرةُ للتحسنِ. في هذا الورقة العلمية تم استعراض اهم البحوث المنشورة في حقل اعادة استخدام مخلفات الزجاج في التطبيقات الانشائية. اضافة الى مناقشة تأثيرَ حجمِ حبيبات الزجاج و نسب التعويض على خواص الخرسانة.

1. Introduction

There is a rising enthusiasm for utilizing glass-waste in concrete. These interests have been exasperated by the large amount of glass-wastes existing from empty bottles, broken windows and glass containers. On the off chance that such glass could be consumed in concrete, it would impressively diminish the transfer of glass and take care of some of environmental issues. Utilizing glass as a development material is among the most entirely pick in light of the conceivably decreasing the cost of glass transfer and concrete production. This inclusive decreased bond strength between the aggregate and the cem ent paste. [1]

*Corresponding Author drsheelan@yahoo.com

Glass can be found molded in numerous shapes, like packaging of containers (bottles, jars), flat glass(windows,windscreens), lamp glass (light globes), cathode ray tube glass (TV screens, monitors, etc),
all of which have a partial life in the shap they are produced and require to be reuse/second hand in order to prevents environmental issues[2]. Orderly, the utilization of waste in place of natural one is one of the most magnificent approach to make concrete sustainable . A large enormous quantity of glass materials in shape of waste are generated in the world [3].

If fine aggregate(sand) is replaced by glass aggregate by exact percentages with exact size range, it will decrease the amount of fine aggregate content. The quantity of waste-glass produced has slowly increased due to the increasing of utilizing glass products. The land filling of waste glass is unwanted since waste-glass is non-biodegradable that makes these waste environmentally less friendly[4].
The reusing of waste glasses in concrete as fine aggregate may cause a problem of Alkali Silica Reaction(ASR). The reaction between alkalis in cement and silica in glass aggregate results in formulation of silica gel which absorbs water and cause volume increasing. The swelling and expansions of ASR gel made a hydrostatic pressure inside concrete and with continues of this reaction the inner pressure exceeds the tensile strength of the concrete matrix. Cracks will began to form around glass aggregate particles[5]. Earth waste glass was utilized as fine aggregate but no reaction was noticed. In this way showing the viability of the waste glass reuse in concrete as fine aggregate with an improvement in the mechanical performance and properties[6].
The largest coarse particles size of waste glass aggregate have a more large possibility of suffering from ASR occurrence. The attention of the construction community in utilizing waste or reused materials in concrete is expanding a result of the pressure put on sustainable construction. Glass is not moving material that could be reused and utilized many times without changing its chemical characteristics [7] ,[8].

Because of the increasing in concrete demand the using of river sand fine aggregate causes consumption of natural resources, bridge piers sinking, lowering of water table, etc. therefore the utilizing of crushed glass as fine aggregate will solve the problem[9].

2. Utilizing of Waste Glass In Concrete

Waste glass can be used in concrete in many way as partial substitutions of one or more of its components. So may researcher investigated in using waste glass as partial replacement of fine or coarse aggregate, other used glassed powder as partial substitutions of cement because of its pozzalanic actions. Following a literature review about the different usages of waste glass in concrete.

2.1Waste Glass as Coarse Aggregate

Christopercheese incorporated waste glass partial replacement of coarse aggregate in production of concrete. He found decreasing in the workability and dropping in

compressive strength[10]. Other researchers did not find significant influence of coarse glass aggregate on the workability of concrete but only a slight reduction in strength[11] . Topçu et al. [12] and Palmquist [13] used glass cullet as coarse aggregate in concrete. They found that glass aggregate was causing expansions in concrete or mortar and internal stresses because of ASR which result in an lossing in durability and crack formation and an increasing in permeability. also used glass in cullet form, as aggregate in concrete.

Abdullah[14] found that concrete unit weight was decreased with coarse aggregate glass exceeded0.4. Also the coarse glass did'nt affect the workability of the mix. He made an numerical analysis and concluded that the optimum content percentage of glass coarse aggregate as partial replacement of natural coarse aggregate to be used with w/c ratio of 0.4was about 0.265with 28days compressive strength about 385kg/cm^2. Also he concluded there was a negligible effect on pull-out strength, an improvement in the flexural-strength, and slight decreasing in the splitting strength of concrete.

2.2 Wastes Glass as Fine Aggregate

The using grounded waste glass as fine aggregate and study its effects on the fresh and hardened characteristics of concrete were investigated. One of studies results showed that the glass as fine aggregate decreased concrete strengths. This due to highly reactive of silica in glass with the alkalis in cement paste. This results in a an expansion and cracking in concrete [15]. The results showed that 80% of strength was given by adding glass after 28day age. [16]

Saccani and Bignozzi [17] invesitigated the Alkali-Silica reaction for several types of glass. The expansion of concrete mortar with different content of waste glass as fine aggregate has been made in different conditions. They evaluated: pozzolanic activity and fines inhibitor assessments. They concluded that there was no swelling was recorded due to ASR for glass grains diameter are less than 1mm.

Kou &Poon[18] investigatedthe effect of recycled glass-cullet(RCG) as fine aggregate on properties of SCC. RCG was used as partial replacement of river sand at 10.0%, 20.0% &30.0%. Fly ash was used in order to control the ASR. The results showed that the slump diameter, blocking ratio & air content of the RCG–SCC mixes increased with increasing glass content. The mechanical properties of the RCG–SCC mixes were decreased with increasing of glass aggregate content. The resistance to chloride ion penetration was increased but the drying shrinkage decreased with fine glass content increasing.

According Mageswari et.al.[19] the sheet glass powder(SGP) is suitable for using in concrete when substituted the fine aggregate in different sections and its gave strengths higher than the conventional concrete.

Table 1 indicates Types and percentage of replacement of natural aggregate by waste glass in several studies which reported both partial or full substitutions of natural aggregates with waste glass.

Table 1. Types and level of substitution of natural Aggregate by waste glass in concrete

References	Origin of waste glass	Type of composite	Amount and type of substitution
[16]	waste glass	concrete mixes	80kg of sand
[18]	recycled glass cullet	self-compacting concrete mixes	10%, 20%, 30% of river sand and 5%, 10%, 15%of granite .
[20]	waste glass	concrete mixes	20%of sand
[21]	liquid crystal display glass	concrete	0%, 20.0 %,40.0 %, 60.0 %&80.0 % LCD-glass sand substitutions.
[22]	recycled glass	concrete	100%of fine aggregates.
[23]	clear glass cullet		100%of sand
[24]	Waste glass powder	concrete	10%, 20%, 30% and 40%of fine aggregates

Table 2 presented the effect of waste glass on the slump and unit weight i.e. density of concrete from previous studies.

Table 2. Relation between waste glass ratio and its influence on slump and density of concrete

References	Waste glass ratio substitution	Influence on the concrete density	Influence on the slump
[14]	0.4of concrete	Decrease	
[18]	10%, 20%, 30% of river sand and 5%, 10%, 15%of granite in SCC.	Decrease	Decrease
[22]	100%of natural fine aggregates.	No effect	No effect

Tests which have been done by AL-Rubaie[20] to study the characteristics of concrete mixtures containing waste glass as partial substitutions up to 20.0%by volume of sand. She noticed slight decreasing in compressive and tensile strength compared to control one without glass.

Another research [22] study effecting of glass as 100.0% substitutions of natural fine aggregates. Seven mixes were prepared and tested, including three fine glass aggregate mix and four natural sand mix. The fresh and mechanical chracteristics of the two types of mixtures with same w/c and cement paste content were compared for 28days compressive strength.

Table 3 shows and summaries the influence of waste glass on the compressive & tensile strengths in concrete from previous researches.

Table 3. Relation between waste glass ratio and its influence on compressive strength and tensile strength in concrete

References	Waste glass ratio substitution	Influence on the compressive strength	Influence on the tensile strength
[16]	80kg of sand in 900 kg of concrete mix	Increase	Increase
[18]	10%, 20%, 30%of river sand and 5.0%, 10.0%, 15.0%of granite in SCC.	Decrease	Decrease
[20]	20% of sand in concrete mix	Decrease	Decrease
[21]	0%, 20.0%,40.0%,60.0% & 80.0%LCDglass sand substitution	Increase	Increase
[22]	100% replacement of natural fine aggregates.	Increase	Increase
[25]	(42.3,39.2,40.9,39.1)MPa respectively of fine aggregates	No significant change	

Oliveira et al.[26] used fine groundedwaste glass as partial of natural sand in concrete. The results indicated that an improvement in compressive strength was notice with the increasing of glass aggregate content.

2.3 Mixed fine and coarse glass aggregate

Other investigators [26] study experimentally the possibility of producing paving blocks by using fine and coarse waste glass aggregates. The results indicated that the replaced of natural sand fine aggregate by mixed glass aggregate at substitution level of 20% has a significant effect on abrasion resistance and mechanical chracteristics of the paving blocks with compared to the control one. This due to pozzolanic nature of glass aggregate. The compressive,flexural and splitting strengths besides of abrasion resistance of the paving block at FG substitution level of 20.0% were 69.0%,90.0%, 47.0% &15.0% respectively. They were higher with compared to the control one. It reported in the previous works the replacement of FG by FA at level of20% suppress ASR in the concrete. The test outcome shows that the FG at level of 20% has a potential to be used in the production of paving blocks. The useful effect on these properties of CG substitute with FA islittle as compared with FG.

Meena and Singh[27] utilize mixed glass coarse aggregate in concrete. Its performance has been investigated. The results showed expansion in the samples due to alkali-silica reaction and also found a strength loss due to fine aggregate replacement.

3. The Utilize of Glass Powder as Partial Substitution of Cement

Vasudevan and Pillay [28] investigate the effect of utilizing glass powder in concrete,the results showed that glass powder was increasing the workabilityof concrete and also increasing the compressive strength. But the density is reduced compare to conventional concrete.

Hama (2017) study utilizing companion of waste glass powder and plastic fiber to improve properties of lightweight concrete. The utilizing of glass powder as partial

replacement of cement at different level of replacements with1%plastic fiber was improved the mechanical properties of lightweight concrete. The 20% glass powder gave higher compressive strength. [29]
Other researchers found that the optimum dosage of glass powder should be chosen based on cement paste content[30,31].

Shayan and Xu [32] showed that incorporating of glass powder into concrete up to 30% will reduced ASR. In this research, fine aggregates were also partially replaced by waste glass as 10.0%, 20.0%, 30.0% and 40.0% by weight. It was found that max.increasing in compression was at 20% waste glass as fine aggregate and 30% as a powder. Increasing glass powder content result in decreasing of water absorption & density of concrete making concrete lighter .

Omoniyinet et. al.[33] study the teffect of waste glass powder in sawdust composite brick . glass powder was used to partially replace cement at 0%, 5%, 10%, 15%, 20%, 25%, and 30% in the production of test samples of100x100x100mm. Compressive strength,porosity,water-absorption,and capillary-water absorption were testd. The results indicated that glass powder can be used as cement replacement material up to30%for particle size≤100μm to prevent ASR. The study further revealed thatwaste glass, if ground finer than 100μm shows a pozzolanic behavior. They found an increasing in durability of composite brick which result of low porosity, water absorption andcapillary absorption of the samples.

Meena and Singh [30]showed that 30%of glass powder of size ≤100μm could be utilized as cement substitutions without any harmful influence.
Patricija Kara [34] study effect of glass slurry applied as a cement substitusions on the concrete properties. The test programmers results showed that glass slurries have pozzolanic characteristics and can be using them as a cement substitutions. The glass powder improved work ability and also improved the hardened chracteristics of concrete at early ages. TheASR tests results show that the glass powder has a relatively small effect ASR expansion in awet environment.

Alyet et.al[35] determined the influnce of partial substitutions of cement by finely glass powder and nano clay particles on the mechanical performance and durability of flaxfiber cement composites. Results show that utilization of glass powder has a positive influence on the hardened characteristics and durability of fiber reinforced cement especially when nano clay is presented.
The XRD & DTA-test analysis showed a reduction in the calcium hydroxide level in mortars with both glass powder and a hybrid combination of glass-powder &nano clay. This explain the improvement of mechanical properties at 28day age.

5. Conclusions

Based on the previous researchers works, the following conclusions are made:

1. Concretes mixes with glass-wastes as partial substitutions of aggregate (either fine or coarse) have a lower compressive strength than conventional concrete at the samew/c.

2. Concretes mixes with glass-wastes as partial substitutions of aggregate (either fine or coarse) have a same slump as conventional concrete.
3. Concretes mixes with glass wastes as partial substitutions of aggregate (either fine or coarse) caused an expansions due to ASR
4. Glass powder with particle size smaller than75μmshows a pozzolanic behavior, and can be used as partial replacement of cement
5. Concretes mixes with glass wastes as partial substitutions of cement have a better low permeability and better resistance against penetration of moisture. And the using glass powder will improveASR.
6. The results of presented studies in this paper showed that utilizing of glass as poweder has a positive influnce on the mechanical characteristics and durability of concrete.

Abbreviations

A list of symbols should be inserted before the references if such a list is needed

ASR	Alkali Silica Reaction
FRC	Fiber Reinforced Concrete
R_f	failure ratio
NC	Normal Concrete
OPC	Ordinary Portland Cement
XRD	X-Ray Differaction
w/c	Water/cement ratio
WGP	Waste Glass Powder

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