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Use of Waste Glass as Partial Replacement of Fine Aggregates in Concrete and Mortar: A Review

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Abstract: ***Now-a-days concrete is widely used as construction material. Cement, sand (Fine), and coarse aggregates are the main constituents in concrete. Due to some limitation of production of cement, and availability of sand from river, it is mandatory to address these environmental affects extensive research on partial Cement and sand replacement in concrete. In our surrounding there are many solid wastes (like broken or crushed glass waste, plastic, fly ash, rubber, rice husk etc) are available. Among which glass waste is a non-biodegradable material. So we can use this glass waste as partial replacement of fine aggregate or partial replacement of cement in concrete as a construction material. By texture of broken glass waste it is possible to add as replacement of sand in crushed and cement in powder form. We can use some admixture of plasticizer to enhance strength of concrete. In this study, review about different aspects of use of waste glass in concrete, mortar, as partial replacement of fine aggregates in concrete .***

Keywords: Recycled waste Materials, Glass waste, Concrete, Workability, Compressive and Split tensile strength.

I. INTRODUCTION

Glass is man-made materials. This glass always produced in many forms, including packaging or container glass, bulb glass, flat glass and cathode ray tube glass and many have a limited life in the forms in which they are produced and need to be reused/recycled in order to avoid environmental problems that would be created if they were to be stockpiled or sent to landfills. Theoretically, glass is a 100% recyclable material (Zainab Z. Ismail et.al ,2008).

In construction industries concrete is widely used as construction material. Cement, sand (Fine), and coarse aggregates are the main constituents in concrete. Glass waste is a non-biodegradable material. So we can use this glass waste as partial replacement of fine aggregate or partial replacement of cement in concrete as a construction material.

A plenty of waste glass material is being generated yearly all over the world. It will dispose as landfills, which does not decompose in the soil and again a challenge to the environment. So to avoid these disposable issues waste glass is use as partial replacement of fine aggregate in concrete and mortar. Use of waste glass in concrete results the structure denser; this outcome in decrease of water absorption and improves durability property of concrete. By adding waste glass in concrete glass powder in concrete, compressive strength, flexural and tensile strength will improve. Glass generally made with melting of silica, soda ash and calcium-carbonate at high temperature [Ilker Bekir Topc¸u et al. ,2003].

Glass powder has high silica content (70%), high surface area and amorphous character. These all such factors are shows glass powder will use as supplementary cementing material in concrete. Fortunately many studies have focused on the use of waste glasses as partial replacement of natural coarse aggregate in concrete and mortar.

Fig. 1 Waste glass mixed in concrete

II. LITERATURE REVIEW

There are lot of papers related utilization of waste glass as construction material in concrete are publish and available in many journal and conferences all over the world. In this section, some research paper has explained for easy understanding about utilization of waste glass as construction material. Accordingly the present study has been planned under following topics and subheadings –.

A. Properties of Concrete Containing waste Glass

1) *Ilker Bekir Topcu et al. (2003)*: In this study, experimental investigation had done using waste glass (WG) as coarse aggregates in the concrete, Waste glass was used reduced to 4-16 mm in proportion of 0-60% in the production of cement. The workability and strength of the cement with fresh and hardened concrete tests were conducted on waste glass concrete. As a result of this experimental study, using waste glass as aggregate did not have a marked effect on the workability of concrete. When hardened concrete sample properties were analysed, compressive, flexural and indirect tensile strengths values were determined to reduce in proportion to an increase in waste glass proportion. In particular, the compressive Strength reduced much as 49% with a 60% of waste glass addition. After words they conclude that by using waste glass preference to fine aggregate would make improved results assuming that its geometry be more proper and almost spherical. Beside this, provided that waste glass finely due to fact that it have high amount of silica (SiO2) and amorphous, it will show pozzolanic activity, in which case silica reactivity should be taken in consideration. Waste glass cannot be used as aggregate without taking into account its alkali – silica – reaction (i.e. ASR) Properties. P. Turgut, E. S. Yahlizade (2009) – did their research on a parametric experimental study for producing paving blocks using fine and coarse waste glass. In this study researchers are investigated some of the physical properties of paving and mechanical properties of paving block having various levels of fine glass and coarse glass replacement with fine aggregate. Finally the test results are shows that, the replacement of fine glass by fine aggregate at level of 20% by weight has a major effect on the compressive strength, flexural strength, splitting tensile strength and abrasion resistance of the paving blocks as compared to with control sample of pozzolonic nature of fine glass. The results like compressive strength, flexural strength, splitting tensile strength and abrasion resistance of the paving block in the fine glass replacement at level of 20% are 69%, 90%, 47% and 15% higher as compared with control sample respectively. i.e. from test result showed that the fine glass at level of 20 % had a possible to be used in the manufacture of paving blocks.

B. Utilization of waste glass a fine Aggregate

1) *Zainab Z. Ismail *, Enas A. AL-Hashmi (2009):* In this study the properties of concrete having waste glass as fine aggregate were examined. The strength properties and alkali – silica reaction (ASR) expansion were analyzed in terms of waste glass. For this study 80 kg crushed waste glass was used as a partial replacement for sand at 10%, 15%, and 200% with 900 kg of concrete mixes. Finally researches are concluded that, the slumps of waste glass concrete samples decreased with increase in waste glass quantity. In spite of this refuse in the slump of these mixtures they have good quality workability. The 20% sample gives optimum effect of waste glass that gives the maximum values of compressive and flexural strength. Results showed that partial replacement of sand with waste glass powder decreased the ASR expansion.
2) *M. Iqbal Malik et al. (2013):* Carried out thus study to find permissibility of using waste glass powder as partial replacement of fine aggregate. In this study, the issues like environmental and economic status are addressed by the use of waste glass as partial replacement of fine aggregate in concrete. In this study, fine aggregate were replaced by waste glass as 10%, 20%, 30% and 40% by weight for M25 grade of concrete mix. All specimen were tested for compressive strength, water absorption (i.e. for durability), Splitting tensile strength and density at 28 days of age and all results were compared with those of control concrete i.e. normal concrete sample. Finally researchers concluded that, 20% replacement of fine aggregate showed 15% increase in compressive strength at 7 days and 25% increase at 28 days. Fine aggregate can be replaced by waste glass up to 30% by weight showed that 9.8% increase in compressive strength at 28 days. With increase in waste glass content, % of water absorption also decrease. Workability of concrete mix increases with increase in waste glass content. Splitting tensile strength decreases with increase in waste glass content. Use of waste can prove to be economical and it will eradicate the disposal problem.
3) *Nur Liza Rahim et al. (2015):* In this study, the properties of concrete containing waste glass as fine aggregate were investigated. Glass dust was used in 10%, 20% and 50% partial replacement concrete mix samples were casted and tested with those concrete made with natural fine aggregates. Compressive testing done for every 7, 14 and 28 days and results compared with control mix. The result from this experimental investigation confirms that the use of glass waste as fine aggregate replacement

material in concrete is effective. The compressive strength of the waste glass samples at 7, 14 and 28 days are shown on fig. 2 from test result compressive strength value of 32.9 Mpa was obtained from the concrete mix made up of 10% glass dust fine aggregate, at 28 days, which represent an increase in the compressive strength of up to 13.6% as compared to control concrete.

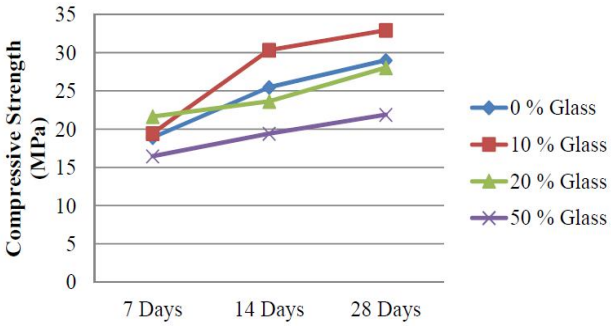

Fig. 2 Compressive strength results (Nur Liza Rahim et al.,2015)

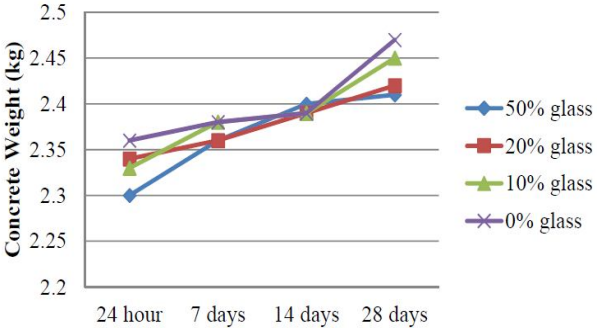

Fig. 3 Concrete density results (Nur Liza Rahim et al.,2015)

4) *W. Otunyo and B. N. Okechukwu (2017):* In these experimental study total 36 cubes were casted and tested. Among which 6 cubes were cast without waste glass means control concrete cubes and remaining 30 cubes containing waste glass as partial replacement for fine aggregates at 15%, 25%, 35%, 45% and 50%. For concrete mix water cement ratio of 0.6 was used. Compressive strength were found to increase by 3% and 7% at 7 days and 28 days respectively as waste glass content was increased up to 15% replacement, after which the compressive strength started to decrease. As waste glass content increased, the water absorption of the concrete has decreased. Most favourable replacement of fine aggregate with waste glass occurred at 15% replacement level. As percentage of waste glass content increased, the flexural strength of concrete fluctuated. For this particular area further study will required. The initial and final setting times decreased as the percentage of waste glass increased up to 15% replacement.

C. Utilization of Waste Glass as Partial Replacement of Fine Aggregate for HPC

1) *PAVLŮ Tereza et.al (2018):* This experimental investigation were carried out in order to analyze the possibility of waste glasses as partial replacement of silica powder for HPC. Chemical composition of waste glass is very important for utilization of glass in concrete. Chemical of cement, sand and glass are cited in table-1. Researchers were developed HPC mixture that has been designed using locally available raw materials. The mixture of HPC that was used in this investigation was without any fibers. The water cement ration taken was 0.25 and water binder ratio was about 0.20 for this developed mixture. There were three sample are studied such as HPC A, HPC B and HPC C having cement, Technical Silica sand, Silica flour, waste glass powder (grinding), waste glass powder (milling), silica flume, super plasticizers and water (12^0C) are 680 Kg/m3, 960 Kg/m^3, 325 Kg/m^3 (Silica flour- for only HPC A), 325 Kg/m^3 (waste glass powder (grinding)- for only HPC B), 325 Kg/m^3 (waste glass powder (milling) - for only HPC C), 175 Kg/m^3, 29 Kg/m^3 and 171 Kg/m^3 respectively designed. Total quantity of HPC mix design of each sample has 2340 Kg/m^3

TABLE I
CHEMICAL COMPOSITION OF CEMENT, SAND AND GLASS (Pavlů Tereza et.Al (2018)

Chemical Composition	Cement	Pure Glass	Grinding Glass	Glass powder	Sand
SiO_2(%)	20,2	72,42	72,61	72,2	78,6
Al_2O_3 (%)	4,7	1,44	1,38	1,54	2,55
CaO (%)	61,9	11,5	11,7	11,42	7,11
Fe_2O_3 (%)	3,0	0,07	0,48	0,48	2,47
MgO (%)	2,6	0,32	0,56	0,79	0,46
Na_2O (%)	0,19	13,64	13,12	12,85	0,42
SO_3 (%)	3,9	0,21	0,09	0,09	-

2) *Recycled glass Powder:* In this experimental investigation, the silica flour (Type A) is replaced by glass powder from in two different sources. The first type of recycled glass powder originated from grinding of glass (Type B) and second one from milling of the municipal waste of glass (Type C)
3) *Result and Discussion:* The workability was tested for all samples of HPC mixtures by mortar flow test. By experimentally it was proved that, workability of fine aggregate concrete is not affected by using waste glass powder as replacement of silica flour. The results of density of hardened concrete – the results showed that HPCA with silica flour had the highest density.

D. Utilization Of Waste Glass As Sand Replacement In Cement Mortar

1) *V. Corinaldesi et. al (2004):* the aim of this study the possibility of reusing waste glass from crushed containers and waste from building demolition as aggregate for preparing concrete and mortar. From literature show that if the waste glass is finely ground, less than 75 micron, this effect does not occur and mortar durability is guaranteed. Therefore in this research the possibility reactivity of waste glass with cement paste in mortar was experimentally verified by varying the particle size of finely ground glass waste. From results indicating that the feasibility of the waste glass reuse as fine aggregate in concrete and mortar because no reaction has been found with particle size up to 100 micron.
2) *Nurhayat Degirmenci et.al (2011):* This study was carried out on waste glass as sand replacement in cement mortar and also for ASR expansion and strength characteristics of mortar containing waste glass are examined in terms of content of waste glass and color of glass. In this study three different colors of waste glasses (white, green and brown) were taken and are replaced with sand of ratio 10%, 30% and 100% by weight. The mixture used in this study did not show significant alkali- silica – reaction (ASR) expansion. All batches had expansion less than 10% is indicative if non- toxic expansion. However, the samples continued to expand beyond 14 days which makes the test period doubtful for glass containing samples. The lower value of compressive strength had determined in 100% replacement sample. It can be concluded that up to 30% replacement of waste glass containing mortar can achieve better strength performance compared to 100 % lime stone mortar.

III.CONCLUSIONS

In order to make concrete industry sustainable, the make use of of solid wastes (like broken glass waste, plastic, fly ash, rubber, rice husk etc) in place of natural resources is one of the most excellent approach. A huge amount of wastes glass is generated all around the world. In India, 0.7% of the total urban waste generated comparison of glass. From the study of work presented in the various important papers, it was observed that waste glass in crushed and powder form can be successfully utilized in the partial replacement of fine aggregate in the concrete and mortar. The results from various papers are proved that utilization of waste glass might increase the compressive strength, flexural strength, workability and tensile strength of concrete at in between 20% to 30% replacement of fine aggregates with waste glass (powder). As percentage of waste glass content increased, the flexural strength of concrete fluctuated. For this particular area further study will required. Use of glass waste will prove economical and environment friendly as compared to conventional concrete.

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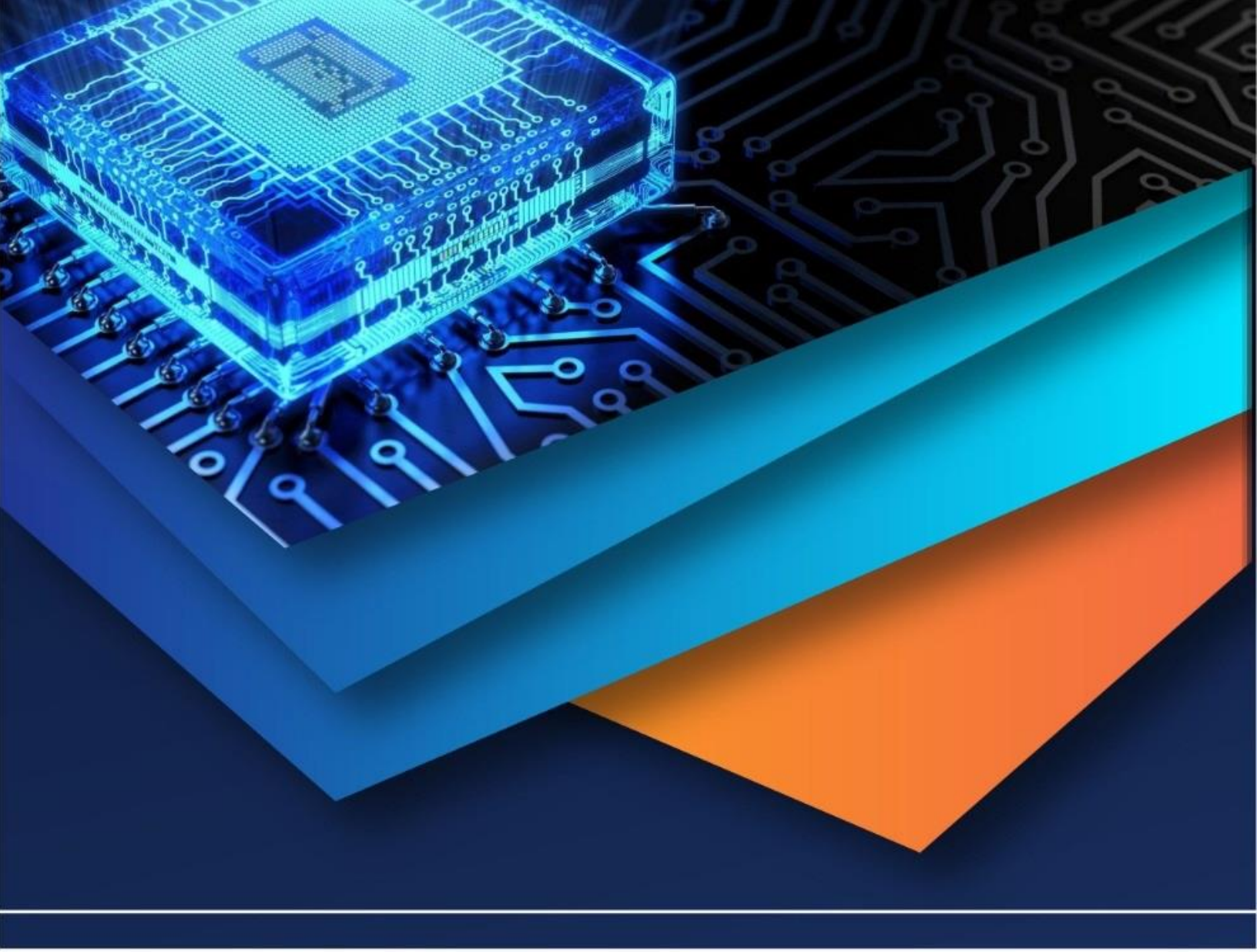

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