Innovative Approaches to Integrate Recycled Glass into Sustainable Concrete Design

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ABSTRACT

Reuse of glass waste in concrete industries in India is not broadly developed, while its application in concrete-based products can sustain that faces the solid waste management and the greening of the environment. To enhance sustainability of concrete manufacturing industry , recycle waste glass is replaced by fine aggregates .Replacement is in predetermined percentage and range. Sand consumes around 20 to 27% of concrete by volume, thus playing an important role in fresh and hardened properties of concrete (Neville, 1995). Concerning Economical vision and Sustainable Environmental perspectives incremental rise in interest in waste glass as fine aggregates . According to(Turgut and Yahlizade, 2009) UK produces over three million tons of waste glass annually. As per report of Central Pollution Control Board, 2000 India total urban waste contains 0.7% of glass . The purpose of this study is to evaluate properties of Concrete mixes containing waste glass as fine aggregate in varying percentages in Concrete mixes in both fresh and hardened states and find the optimum dosage of FWGA in which higher compressive strength, flexural strength and fatigue life of structures can be achieved

Keywords: Glass Aggregates, Concrete, Fine waste glass aggregates (FWGA) ,Compressive strength , Flexural strength.

I. INTRODUCTION

Influential property of taking tensile stresses makes concrete brittle. As compared to compressive strength tensile strength is approximately one tenth. The addition of waste glass as an aggregates caused a slight weight reduction and it is because of the lower specific gravity of glass aggregates as compare to fine aggregates (sand), also dry density of the concrete mixes having glass aggregates showed decreasing tendency and this again because of the lower density of glass aggregates, compared to sand. The unit weight of concrete is reduced by replacing natural fine aggregate with glass (Topcu and Canbaz, 2004). The dry density of concrete mix with 40% glass replacement level was 4,5% lighter than concrete with sand used and the dry density of the same mix was 2.4% lower than the control mix (Adaway and Wang ,2015).A clear reduction of the fresh density is observed with the incorporation of glass aggregates. This reducing trend is explained by the difference between natural aggregates and glass aggregates in terms of particles density (Castro and Brito, 2012).

Structural members are enable to sustain tensile loads , stresses. Concrete reinforced with steel to compensate tensile bearing capacity . It also enhances ductility of concrete. Fibre reinforced concrete enhances flexural strength as well tensile strength. Analysis of concrete with fibres is done so to arrest cracks. The randomly distributed short fibres are generally introduced into concrete to enhance its control crack system and mechanical properties such as toughness, impact resistance, ductility (post cracking), tensile strength etc. of basic matrix. Synthetic , Natural, Metallic fibres are available are used in normal concrete as shown in Fig 1. It contains short discrete fibres that are uniformly distributed and randomly oriented.

1.1. Importance of Waste Glass Recycling

Glass as a hard, brittle, and commonly transparent substance, white or colored, made by melding sand or silica together with lime, potash, soda or lead oxide. Glass is a completely recyclable material, it is assessed that glass recycling rate in the United States is about 40% and that of Brazil is around 50% of the total glass waste produced in their respective countries (Environment and Community Organizing, 2010).
Malik et al (2013), studied the issues of ***environmental and economic concern*** addressed by the use of waste glass powder as 10%, 20%, 30% and 40% by weight for M-25 mix. Comparative analysis was done. The results concluded the permissibility of using waste glass powder as partial replacement of fine aggregates up to 30% by weight for particle size of range 0-1.18mm. All tests like compressive strength, tensile strength done .

Salman et al (2013), investigated correlation between some physical properties of glasscrete and replaced both fine aggregate (sand) and coarse aggregates (gravel) with fine sheet glass size (2.36-4.75mm) and crushed waste glass size (9-12mm) respectively. For fine aggregate replacement crushed glass sheet used in following proportions (10%, 20%, 30%, 40%, 50%) . For site applications the natural aggregates can be replaced by clear glass waste. Construction activity leads to dumping of glass wastes which can be converted in to aggregates will save landfill space.

The European's glass recycling (Lets recycle, 2010) reported that since 1996, most of the European countries recycled more than 50% of their glass wastes. Total urban wastes comprises 0.7% glass in India (Pappu et al, 2011).

1.2. Behaviour of Glass Aggregates in Concrete
Alkali Silica Reaction with Glass Aggregate (ASR)
It is generally believed that glass is unstable in the alkaline environment of the concrete. The alkalis in the concrete pore react with reactive siliceous minerals and form an alkali-silica gel product which swells and gives additional internal pressures in the presence of water; thereby resulting to failure of concrete (Rear et

Fig.1: Fine Waste Glass

al.1994).Use of up to 30% glass aggregate in concrete might not cause any deleterious effects, particularly if the alkali content of the concrete is below 3 kg/m3 (Shayan and Xu , 2004).
Aggregates Used in the Study

Effect of Waste Glass on Unit Weight and Density of Concrete
The addition of waste glass as an aggregates caused a slight weight reduction and it is because of the lower specific gravity of glass aggregates as compare to fine aggregates (sand), also dry density of the concrete mixes having glass aggregates showed decreasing tendency and this again because of the lower density of glass aggregates, compared to sand. The unit weight of concrete is reduced by replacing natural fine aggregate with

glass (Topcu and Canbaz, 2004). The dry density of concrete mix with 40% glass replacement level was 4,5% lighter than concrete with sand used and the dry density of the same mix was 2.4% lower than the control mix (Adaway and Wang ,2015)

Waste Glass Aggregates reactions with concrete
Pozzolanicity of glass powder (GP) was first studied in 1973 (Reindl, 2003), but a major progress has been achieved in the last 10 years. Published research work has shown that glass powder could react in a pozzolanic manner in the cementitious systems and contribute to the strength development of concrete (Reindl, 2003, Shi and Zheng, 2007).

1.3. Properties of Glass Aggregates in Concrete
Workability of FWGAC
Addition of glass shows a decreasing trend in slump (Adaway and Wang, 2015). Severe segregation and bleeding was observed in higher mixes with addition of glass effecting it negatively (Taha and Nounu, 2009). Decrease in slump value as much 20% due to poor geometry of glass aggregates (Ismail and Hashmi, 2009). The concrete mix by addition of waste glass has decrease concrete slump . yet workability was still deemed sufficient adequate without, need for any admixtures at for replacement levels up to 50% (Taha and Nounu, 2008).

Compressive Strength of FWGAC
Compressive strength is one of the properties of concrete which gives the idea about the characteristics of compressive stress under the gradually applied load which a given concrete specimen can sustain the load without fracture. It was observed that the percentage increases in compressive strength with age, overall increased with the optimum increment of glass aggregate replacements. This may be the cause of the Pozzolanic reaction that appears to offset this trend at a later stage of hardening and such contributes to an improvement in the compressive strength at 28 days(Abdallah & Fan, 2014). A similar remarks was stated by (Metwally, 2007). Use of high dosage glass aggregate will decrease compressive strength and it is due to the high brittleness of

glass leading to cracks which result in imperfect adhesion between the waste glass aggregates and cement paste, while the poor geometry and reduced specific gravity of glass leads to assorted distribution of aggregates (Topcu and Canbaz 2004).

Replacement of fine glass aggregates by waste glass showed an increasing trend and with 20% replacement the compressive strength obtained at 7 and 28 days was 15% and 25% increased while with 30 % this increment was 9.8%, (Malik et al, 2013).With 20% optimum waste glass content compressive strength of specimens were 10.99% higher than control mix at 28 days (Ismail and Hashmi, 2008).

Flexural Strength of FWGAC

Flexural strength is one of the properties of concrete and it is a measure of unreinforced beam or slab which can resist in failure in bending. In highway pavement due to varying traffic conditions the formation of micro cracks in the pavement quality layer under the wheel loads take place due to formation of these types of cracks and flexural strength decreases, the PQC layer deteriorated rapidly. The concrete without any fibres may develop cracks due to plastic shrinkage, drying shrinkage and other reasons of changes in volume of concrete. With addition of glass aggregates flexural strength values increased and this may be attributed to pozzolanic reactions which seems to accelerate with age, and help to improve hardening process and increase the flexural strength (Shehata et al,2005). It must be noted that adding higher amount of waste glass may have an adverse effect on the flexural strength at early stage (Abdallah and Fan, 2014). It was determined that, the flexural strength of concrete mixes containing fine waste glass aggregates generally followed the compressive strength trend, (Park et al, 2004, Taha and Nounu, 2008). The flexural strength up to the optimum dosage 20% showed increasing trend, beyond the optimum dosage flexural strength value is decreasing and this decrease in flexural strength may be due to the decrease in adhesion between the smooth WG surface and the cement paste (Taha and Nounu 2008, Park et al. 2004).

II. EXPERIMENTAL PROGRAMME

2.1 Materials

The concrete mix design for Concrete was proposed by using IS 10262:2009 with the water to cement ratio of 0.43 for the design compressive strength of 48.25 N/mm^2 and design flexural strength 4.86N/mm^2, cubes and beams were casted for FWGAC containing 10%,15%,20%,25% and 30% fine waste glass aggregate as partial replacement for fine aggregate (natural sand) The design of FWGAC mixes is done as per guidelines given in is 10262:2009, Ultratech Ordinary Portland Cement (OPC) of 43 grade was used during the entire experimental work, natural locally available crushed stone aggregates with maximum size of 20 mm and 10 mm graded aggregates, natural clean sand sized 4.75mm maximum and minimum 150 micron conforming to zone-II was used.

To find the suitability of aggregates for the FWGA mix design the sieve analysis, specific gravity test, water absorption test, aggregate impact test and loss angles abrasion test are carried out. During the entire experimental work Ordinary Portland Pozzolana Cement (OPC) make Ultra tech cement is used. To find the suitability of OPC cement various test were conducted like fineness test, consistency test, initial setting and final setting time test and compressive strength test are carried as per Indian specifications.

2.2 Experimental Results of FWGAC Mixes

Workability of FWGAC Mixes

The slump demonstrates a decreasing trend in response to the addition of waste glass (Adaway and Wang, 2015). In higher mix proportions, the addition of waste glass as aggregates was found to negatively affect the properties of fresh concrete, resulting in severe segregation and bleeding of the mix (Taha and Nounu, 2009).Using a high proportion of waste glass aggregates was observed to decrease slump value as much as 20% due to the fact that waste glass aggregates has a poor geometry (Ismail and Hashmi, 2009). The addition of waste glass to the concrete mix has been found to decrease concrete slump, yet workability was still deemed sufficient adequate without, need for any admixtures at for replacement levels up to 50% (Taha and Nounu, 2008).

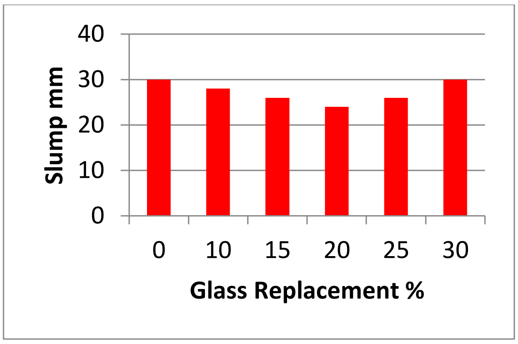

Fig. 2: Slump Value of FWGAC Mixes

It can be seen that slump demonstrates a decreasing trend with addition of fine waste glass aggregates. The slump value of unmodified Concrete mix was obtained as 30 mm. On 10% and 15% replacement, a gradual decrease of slump value is seen, while the optimum value for slump was found corresponding to 20% fine aggregates replacement in conventional concrete mix, in which the slump value reduced to 20%. The slump value increased with further replacement, such that with 25% replacement it was 8% more than mix with optimum content of FWGA and with 30% replacement slump was 25% higher than the mix with optimum content of FWGA but this value of slump was equal to that of conventional Concrete mix.

Despite the reduction in slump values, all concrete mixes were considerably workable and were within tolerance level of 20±5 mm. During preparation , molding and compaction of FWGAC mixes no excessive bleeding or segregation of concrete specimens was noticed .

Compressive Strength of FWGAC Specimens

Compression test was conducted on different Concrete mixes with varied dosage of fine waste glass aggregates. This section presents the result of compression test of different FWGAC mixes. Figure 3 presents 7 & Figure 4 presents 28 day compressive strength results of various FWGAC.

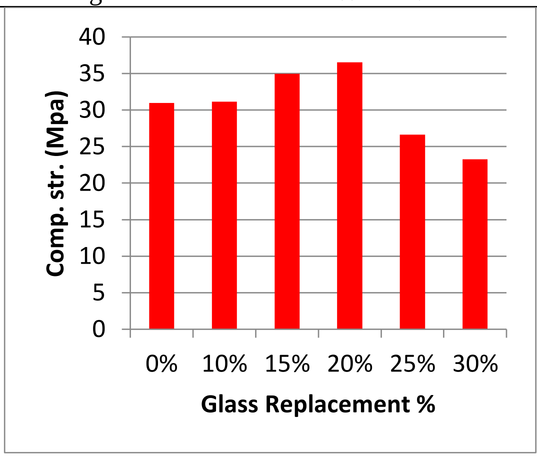

Fig. 3: Comp Str of FWGAC 7 days

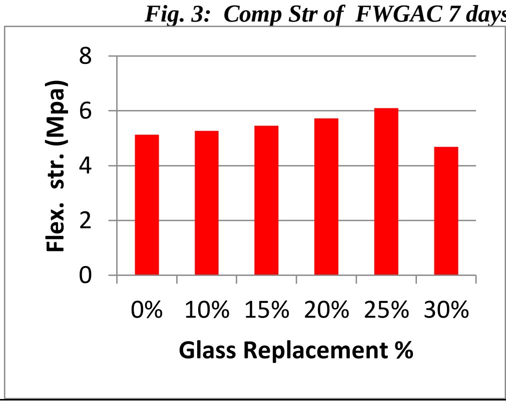

Fig. 4: Comp Str of FWGAC 28 days

An increasing trend in compressive strength can be seen along with the addition of glass aggregate. The optimum value for compressive strength of FWGAC mixes was found corresponding to 20% FWGA replacement. The maximum compressive strength at 7 days obtained was 36.54 MPa with optimum FWGA replacement while it was 57.33 MPa at 28 days, which is 18% higher than the Conventional Concrete mix. While with 25% replacement the 7-days compressive strength was 26.96 N/mm2 and it reduced to 23.26 N/mm2 on 30% FWGA replacement. The compressive strength at 28 days with 25% FWGA was 41.04 N/mm2, while this value reduced to 33.19 N/mm2 on 30% FWGA replacement which is 30% lower than the conventional Concrete Mix and 40% lower than maximum compressive strength of FWGAC mix..

2.3.1 Flexural Strength of FWGAC Specimens

This section deals with the results flexure strength tests of FWGAC mixes with various fine glass aggregates contents after 7 and 28 days curing. The 7 and 28 days Results obtained from flexure strength tests of FWGAC mixes are shown in Figure 5 & 6. All Concrete mixes show a gradual increase in flexural strength with increase in fine waste glass percentage. The optimum value for flexural strength of FWGAC mixes was found corresponding to 25% FWGA replacement. A steady increase in flexural strength was seen with 10%, 15% and 20% FWGA replacement. When the waste glass content was increased by 25%, 7 days flexural strength result was 5.54 N/mm2 while 28 days flexural strength obtained was 6.1 N/mm2 which are 7% and 18.9% higher as compared to modified Concrete mix. When the glass content is further increased by 30% the flexural strength obtained in 7 and 28 days were 4.5 N/mm2 and 4.68 N/mm2 and are 6.5% and 9.5% lower than the conventional Concrete mix and are 19.5% and 21% lower than the maximum values of flexural strength.

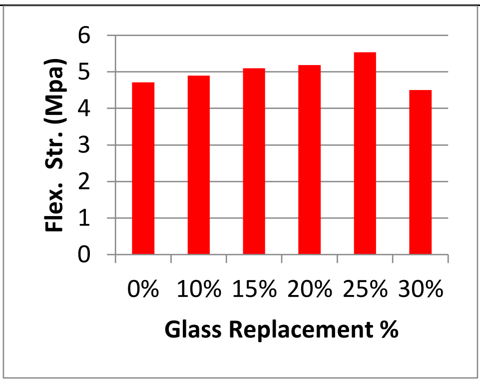

Fig. 5: Flex Str of FWGAC 7 days

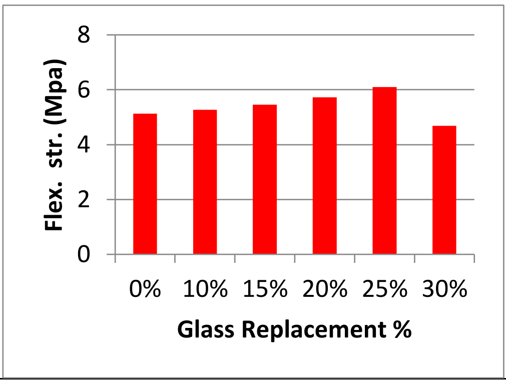

Fig. 6: Flex Str of FWGAC 28 days

III. RESULTS AND DISCUSSION

- FWGAC mixes slump decrease by addition of waste glass. Glass particles has angular geometry which reduces the fluidity of the mix as less availability of cement paste.
- The optimum percentage of FWGA for maximum compressive strength of FWGAC mixes was 20%. Addition of FWGA to Concrete mixes up to the optimum value has shown an increasing trend in compressive strength. The maximum compressive strength 57.33 MPa, at 28 days was obtained at optimum FWGA content. With further increase of FWGA content, compressive strength has shown decreasing trend. Glass bears physical properties intends to be brittle so it leads to decrease in compressive strength . Adhesion between FWGA and cement paste is governed by poor geometry of glass. No uniform distribution of aggregates because of heterogeneous mix.
- The optimum percentage of FWGA for maximum flexural strength was 25%. Flexural strength of FWGAC mixes has shown an increasing trend up to the optimum content of FWGA and the

maximum value obtained after 28 days was 6.1 MPa. As per experimental evaluations there is decreasing trend in flexural strength because of improper adhesion between the smooth surface FWGA and the cement paste.

- The increase of compressive strength of FWGAC mixes might be possibly because of two reasons, first, the pozzolanic reaction of cement with the fine glass particles which are pozzolanic in nature. It possess angular geometry of fine glass aggregates having greater surface area which leads to increase in compressive strength at 28 days. A strong concrete matrix is formed due to increased surface area with strong bonding with cement paste.

IV. CONCLUSION

A large part of the development budget is spent for the maintenance and improvement of roads and this indicates the importance and role of roads in the national economy. If a road is designed and maintained properly, then after 16 years of pavement life, its quality will be reduced to only about 40%. However, pavement degradation is accelerated after 16 years, so that after another four years, the pavement will completely collapse (Hicks et al, 1997). The life of the pavement can be increased by improving the properties of the Concrete Mix itself.

The present study is concerned with improvement of Concrete Mix for the construction of pavements, slabs, deck slabs, wall panels by using waste and innovative materials such as fine waste glass aggregates which could increase the compressive and flexural strength characteristics of Concrete Mix, reduce the thickness of slab, reduce cost, enhance durability and reduces the requirement of maintenance

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