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Glass Powder Utilisation in Concrete Production

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Abstract: This paper investigates the performance of concrete containing glass powderas partial substitution of cement. Portland cement (PC) was partially replaced with 0-40% glass powder. Testing included ultrasonic pulse velocity, compressive strength and absorption. Specimens were cured in water at 20°C. The results indicate that the maximum strength of concrete occurs at around 10% glass powder. Beyond 10% glass powder the strength of concrete reduces and is lower than that of the control.

Key words: Concrete · Glass Powder · Pozzolanic Materials · Strength · Ultrasonic Pulse Velocity · Waste

INTRODUCTION

Due to global warming the need to cut down energy consumption has increased. The effect of global warming has impacted everyone on the planet and is a well-recognised concept. High levels of energy are needed to produce cement, which releases large amounts of carbon dioxide (CO_2) and also contributes to the green house gases. Atmospheric levels of carbon dioxide have risen by about 30 percent over the past 200 years [1]. Each year approximately 111 million tonnes of controlled waste from household, commercial and industrial waste are disposed of in landfill sites in the UK causing a rise in landfill costs and environmental problems [2]. Recycling of construction waste helps saving the limited landfill space and save waste disposal costs. The energy required to reuse the recyclable material is less than that of virgin materials.Use of recycled materials in construction is the most attractive option because of the large quantity due to widespread sites of construction. Recycled aggregates can be used in as replacement in asphalt concrete, unbound base course, pipe bedding, landfill gas venting systems and gravel backfill for drains [3].

The use of recycled waste glass in Portland cement and concrete has attracted a lot of interest worldwide due to the increased disposal costs and environmental concerns. Glass used for containers, jars and bottles is soda lime silica counts for 80% of the recycled glass [4].

The glass being mainly a silica-based material in amorphous formcan be used in cement-based applications. The main concerns for the use of crushed glasses as aggregates for Portland cement concrete are the expansion and cracking caused by the glass aggregates due to alkali silica reaction [5]. Due its silica content, ground glass is considered a pozzolanic materials and as such can exhibit properties similar to other pozzolanic materials such as fly ash, metakaolin, slag and wheat husk ash [6-17]. This paper reports the preliminary results of an experimental investigation on the use of glass powder to partially replace cement in concrete applications.

Although there is strength reaction in the presence of glass powder, however, glass powder can be used to replace 30% of the cement in a concrete mix with satisfactory strength development due to its pozzolanicreaction [18]. Authors found that using glass in mortar applications caused more expansion compared with mortars without glass particles. This expansion can in some cases cause deterioration to the material [19, 20].

MATERIALS AND METHODS

The control mix (C1) has a proportion (by weight) of 1 (cement): 2 (sand): 4 (coarse aggregate) and the water to cement ratio (W/C) is 0.5. In Mixes C2 to C5, the cement is partially replaced with 10%, 20%, 30% and 40% glass powder.

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For each mix, 15 cubes of 100mm in size were prepared. Before casting, the slump test was conducted to assess the workability. Specimens were cast in steel moulds and placed in a room at 20°C for 24 hours until demoulding. Thereafter, all specimens were placed in water at 20°C. The cubes were used to determine the compressive strength and ultrasonic pulse velocity (UPV). Testing for UPV was determined at 1 day, 7, 14, 21 and 28 days whereas the compressive strength was determined at 28 days only.

RESULTS AND DISCUSSION

Figure 1 shows the slump value for concretes with varying amounts of glass powder as partial replacement of cement. There is a systematic increase in slump as the glass powder in the mix increases. The slump ranged from around 40mm for the reference mix (i.e. 0% glass powder) to 160mm at 40% glass powder.

The density values for the various mixes with and without glass powder is presented in Figure 2. The densities ranged from 2180 to 230 kg/m^3. All densities seem to be similar except the mix with 40% glass powder where a slight drop is observed. The average density for all mixes is about 2280 kg/m^3.

The compressive strength values at 28 days of curing are shown in Figure 3. There is an increase in compressive strength at 10% glass powder compared to the control. All other concrete mixes containing glass powder (above 20%) show a systematic reduction in strength with the increase in glass powder content. This is shown more clearly in Figure 4 where the relative strength to the control is plotted against glass powder content. Glass powder more than 20% shows a relative strength less than one and at 40% glass powder content the reduction in strength is about 60%.

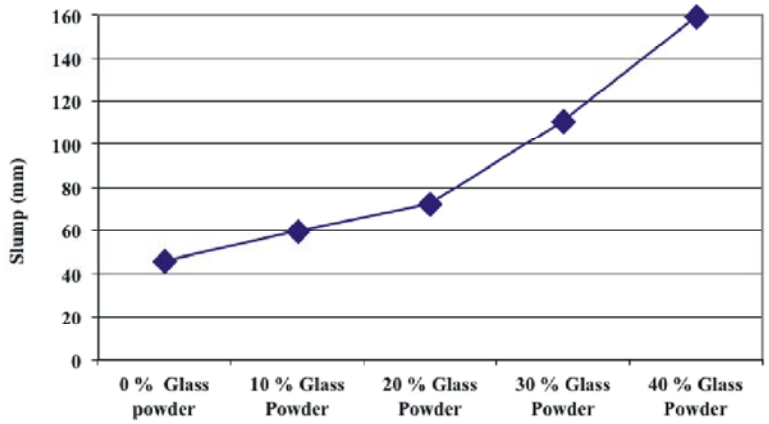


Fig. 1: Slump values of concretes with varying amounts of glass powder

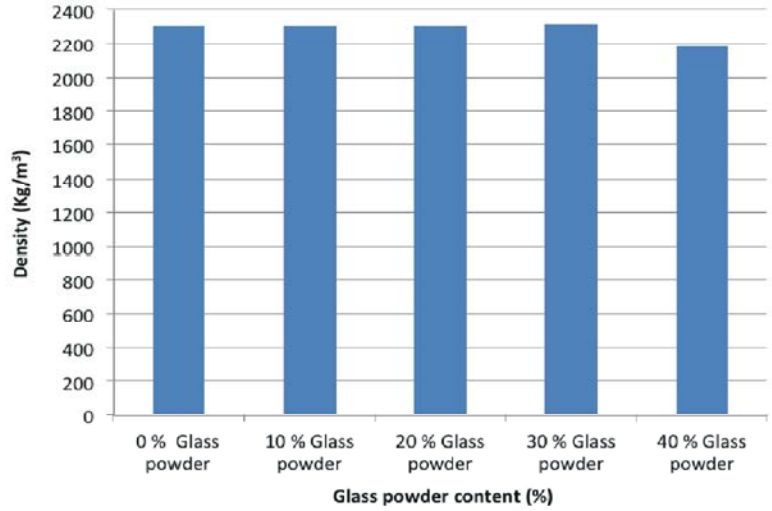


Fig. 2: Density of concretes with varying amounts of glass powder

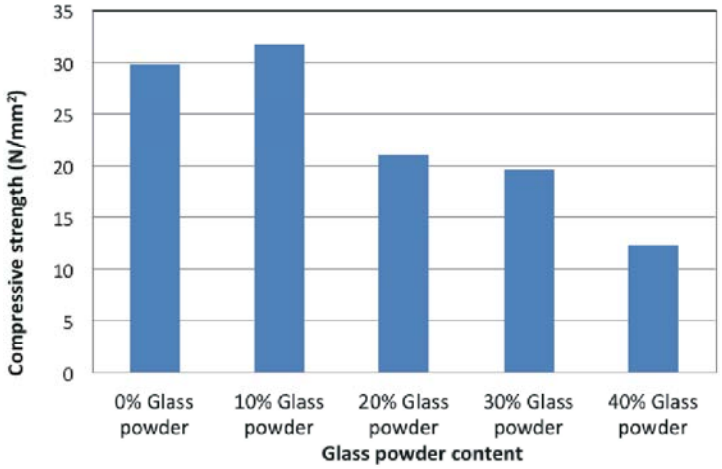


Fig. 3: Compressive strength of concretes with varying amounts of ground glass at 28 days of curing

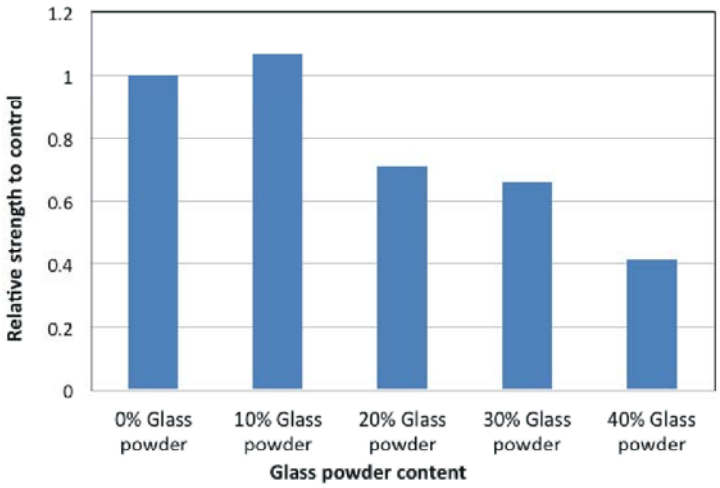
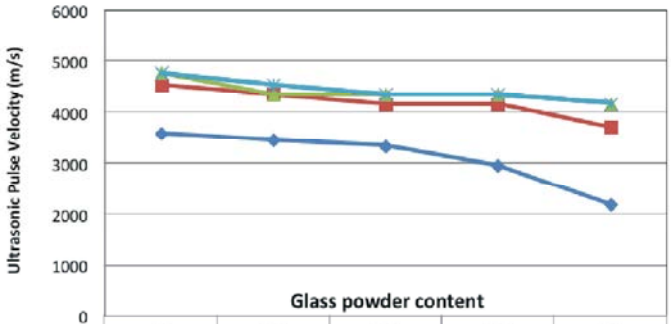


Fig. 4: Relative compressive strength to the control at 28 days of curing of concrete with varying amounts of glass powder.



	0%	10%	20%	30%	40%
Day 1 Velocity m/s	3571	3448	3333	2941	2173
Day 7 Velocity m/s	4535	4348	4167	4167	3704
Day 14 Velocity m/s	4762	4348	4348	4348	4167
Day 21 Velocity m/s	4762	4535	4348	4348	4167
Day 28 Velocity m/s	4762	4535	4348	4348	4167

Fig. 5: Ultrasonic pulse velocity for concretes containing varying amount of ground glass at different ages of curing.

The ultrasonic pulse velocity (UPV) for the various concrete mixes with and without glass powder is shown in Figure 5. The trend is not quite similar to the compressive strength, in that the ultrasonic pulse velocity reduces systematically with the increase in glass powder with maximum reduction occurs at 40% glass powder content. Even at 10% glass powder the UPV reduces compared with the control. However, the strength at 10% was the highest compared with all other mixes including the control.

CONCLUSIONS

Using ground glass powder can reduce the use of cement and the associated energy demand and impact on air pollution and CO_2 emission. The slump of concrete seems to increase with the increase in glass powder in the concrete mix. At 10% glass powder content the compressive strength of concrete is higher than that of the control. Above 20% glass powder the strength substantially decreases.

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