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POTENTIAL UTILIZATION OF GRANITE WASTE WITH METAKAOLIN IN SUSTAINABLE CONCRETE

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Cement production is a crucial factor responsible for climate change and recognized as major environmental challenge for humankind. It causes around 5% of global CO_2 emissions resulting in lowering of air quality and human health. Production of cement is highly energy intensive process requiring consumption of depleting limited natural resources. Granite stone is famous for strength, elegance and durability. Enormous quantity of granite slurry waste is generated during processing of granite stone blocks, which adversely affect the fertility of land, environment and society. Metakaolin is an ultrafine pozzolonic and economical alternative to silica fume. It has positive influence on concrete properties because of filling effect and additional pozzolanic reaction. In this experimental investigation replacement level of both granite slurry waste and metakaolin are taken up to 10% as partial replacement of cement. Mechanical and durability properties of modified concrete have been evaluated. It has been shown that optimum replacement level of both materials enhances the compressive and flexural strength. Also, improvement in water permeability and resistance to acid attack has been observed. This study demonstrates that utilization of granite slurry waste and metakaolin as partial replacement of cement will reduce the consumption of cement, which will conserve the natural resource, reduces CO_2 emission, energy demand and waste accumulation. Hence, the production of new composite concrete will be sustainable and advantageous to the environment and society.

Keywords: Cement replacement, Granite slurry waste, Mechanical, Durability, Sustainability.

1 INTRODUCTION

Cement production is highly energy intensive process, which involves intensive fuel consumption for the clinker making and other production process. In cement production green house gases emitted is the root cause of the global warming. Furthermore, cement production requires extraction of natural resources, which results in depletion of these limited natural resources. Hence, there is a vital need of eco-efficient sustainable material, which can overcome the adverse issues related with cement production by reducing its consumption.

The granite industry produces about 15% to 20% of total waste during the cutting process of granite blocks. Granite slurry waste produced in powder form after drying is a fine material, which can be easily airborne and has detrimental effect on fertility of land, open source water, environment and society (Mashaly *et al.* 2018). Further, accumulation of this waste reduces the porosity of land, prevents ground water recharge and also decreases the quality of underground water. Metakaolin is an ultrafine pozzolonic and economical alternative to silica fume. It has positive influence on concrete properties because of filling effect and additional pozzolanic reaction.

Elmoaty (2013) assessed the impact of replacement of granite dust as cement alternative in concrete. The outcome of the result shows that granite dust can be used up to 5% as cement without compromising the compressive strength property of the concrete. Sharma *et al.* (2016) conducted an experimental investigation to determine strength properties of concrete by replacing cement with granite slurry waste. Test results shows increase in compressive and flexural strength of concrete as compared to reference concrete depending upon replacement level and w/c ratio. Dinakar *et al.* (2013) reported that incorporating 10% metakaolin as substitution of cement enhances the mechanical and durability properties of concrete.

It is evident from the available literature review that granite slurry waste and metakaolin modifies the properties of concrete depending upon various parameters. In the present experimental study granite slurry waste and metakaolin are used at w/c ratio 0.40. In this study the replacement level of granite slurry waste is taken up to 10% and metakaolin also up to 10% as partial replacement of cement. Various concrete properties such as workability, compressive strength, flexural strength, water permeability and loss of compressive strength in acid attack have been evaluated.

2 MATERIALS AND PROPORTION

2.1 Materials

In this research work Ordinary Portland cement confirming IS 8112 (2013) was used. The locally available Kharka river sand passing 4.75 mm sieve as per IS 383 (2016) was used and coarse aggregates were procured from the local supplier confirming the gradation as per IS 383 (2016). The granite slurry waste was collected from the dump yard of Udaipur, Rajasthan, India and Metakaolin procured from the local supplier. Physical properties and chemical composition of various materials are shown in Table 1 and Table 2 respectively.

Table 1. Physical properties of materials used in this research work.

Material	**Physical Property**
Cement	Consistency-32%, Initial setting time-130minutes, Final setting time-213 minutes, specific gravity-3.12
Fine aggregate	Specific gravity-2.71
Coarse aggregate	Specific gravity-2.80
Granite slurry waste	Form-fine powder, colour-red, water absorption-7.6%, consistency-37%, specific gravity-2.17
Metakaolin	Form-fine powder, colour-off white, consistency-45%, specific gravity- 2.42

Table 2. Chemical composition of materials (%).

Material	**SiO_2**	**Fe_2O_3**	**Al_2O_3**	**TiO_2**	**CaO**	**MgO**	**LOI**	**Na_2O**	**K_2O**
Cement	18.70	3.55	8.31	-	61.60	0.80	3.34	-	-
Granite slurry waste	71.22	0.56	12.48	0.16	1.40	0.81	1.20	6.16	4.56
Metakaolin	57.08	1.42	32.72	0.16	0.56	0.20	5.60	1.45	0.37

2.2 Mix Proportions

The concrete mix design of M25 grade was made as per IS 10262 (2009) and IS 456 (2000). Concrete specimens for w/c ratio 0.40 with granite slurry waste and metakaolin as a partial replacement of cement were cast and cured for 28 days standard curing. Mix proportions of various ingredients used in the study are presented in Table 3.

Table 3. Mix proportion of concrete containing granite slurry waste and metakaolin.

Sample	Cement kg/m^3	% of cement replacement by GSW	GSW as partial replacement of cement Kg/m^3	% of cement replacement by MK	MK as partial replacement of cement Kg/m^3	FA Kg/m^3	CA Kg/m^3
CC	372.0	0	0.0	0	0.0	586	1279
G5M0	353.4	5	18.6	0	0.0	586	1279
G10M0	334.4	10	37.2	0	0.0	586	1279
G0M5	353.4	0	0.0	5	18.6	586	1279
G5M5	334.4	5	18.6	5	18.6	586	1279
G10M5	316.2	10	37.2	5	18.6	586	1279
G0M10	334.4	0	0.0	10	37.2	586	1279
G5M10	316.2	5	18.6	10	18.6	586	1279
G10M10	297.6	10	37.2	10	37.2	586	1279

GSW: Granite slurry waste, MK: Metakaolin, FA: Fine aggregates, CA: Coarse aggregates

3 RESULTS AND DISCUSSION

3.1 Workability

Slump test is used to determine the workablity of concrete and has been performed as per Indian standard IS 1199 (1959). Variation of slump of control concrete and other concrete mixes has been presented in Figure 1. It can be seen from the figure 1 that slump value decreases with an increase in replacement level of cement by granite slurry waste and metakaolin. Slump value of control concrete mix is highest (60mm) whereas minimum slump value (30mm) is observed at 10% replacement of both granite slurry waste and metakaolin. Both granite slurry waste and metakaolin consist of very fine particle, which increases the surface hydration of the modified concrete produced, leading to the greater water absorption which intern decreases the workability of mix.

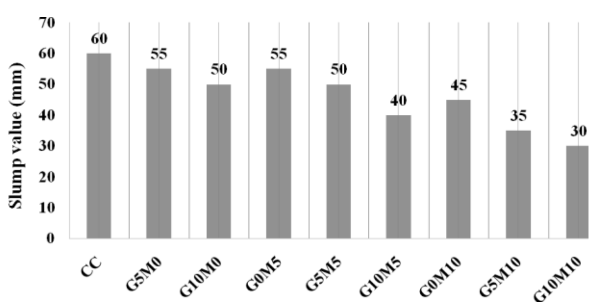

Figure 1. Slump value for granite slurry waste concrete with and without metakaolin.

3.2 Compressive Strength

Compressive strength test has been conducted according to IS 516 (1959) on cube specimen of size 150mm. It can be observed from the Figure 2 that the 28 days compressive strength of concrete increases with increase in the replacement level up to 10% of granite slurry waste without use of metakaolin G10M0 (35.82 N/mm^2). However, inclusion of metakaolin leads to increases the compressive strength of the granite slurry concrete. This behavior is due to the chemical reaction between $Ca(OH)_2$ and metakaolin, which results in the formation of additional CSH gel. It is observed that the maximum compressive strength was found for the mix containing maximum utilization of metakaolin without granite slurry waste (G0M10). It can be also seen that the compressive strength for the mix G10M10 was observed as 34.62 N/mm^2, which was more than the control concrete mix 29.82 N/mm^2. Hence, to accomplish maximum replacement of cement and also at the same time maximum utilization of granite slurry waste, optimum replacement combination is G10M10.

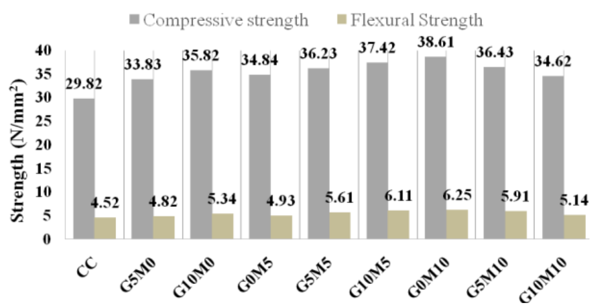

Figure 2. Compressive and Flexural strength for granite slurry waste concrete with and without metakaolin**.**

3.3 Flexural Strength

The flexural strength of concrete beam samples (100mmx100mmx500mm) was evaluated by two point loading test as per IS 516 (1959). Figure 2 illustrates the results of flexural strength test. It can be observed from the test results that variation of flexural strength of concrete samples was similar to that of compressive strength. In optimum replacement combination G10M10, the value of flexural strength is higher (5.14 N/mm^2) than that of control concrete mix (4.52 N/mm^2).

3.4 Water Permeability Test

The water permeability of cube specimens of size 150mm was determined as per guidelines of DIN 1048 (1981). It can be observed from the Figure 3 that the depth of water penetration increases with increase in replacement of granite slurry waste. However, addition of metakaolin in the granite slurry concrete reduces the water penetration depth. Dinakar *et. al.* (2013) also reported similar behavior of metakaolin. In optimum replacement level combination G10M10, the value of water penetration depth is lower (23 mm) as compared to that of control concrete mix (24 mm).

3.5 Loss of Compressive Strength in Acid Attack

Acid resistance of concrete samples was tested after immersing the samples in 5% H_2SO_4 acid solution for 28 days. It can be observed from the Figure 4 that loss in compressive strength increases with an increase in the percentage of granite slurry waste. Increase in loss of compressive strength was due to increase in the permeability of water through the grains of granite slurry waste. However, inclusion of the metakaolin in the granite slurry concrete further decreases the loss of compressive strength. In optimum replacement level combination G10M10, loss of compressive strength shows lesser value (23.56%) as compared to the value (24.46%) for control concrete mix.

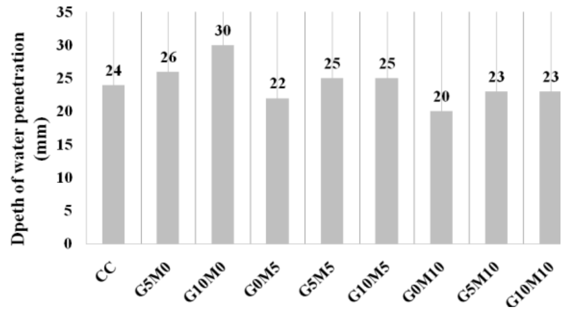

Figure 3. Depth of water penetration for granite slurry waste concrete with and without metakaolin**.**

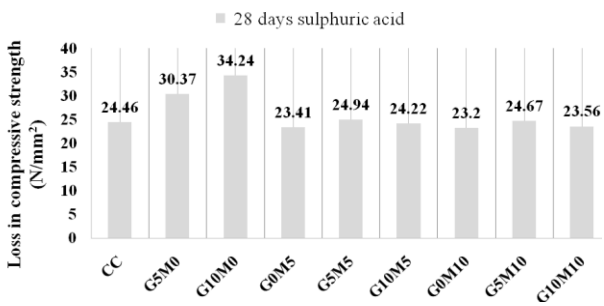

Figure 4. Loss of compressive strength in acid attack for granite slurry waste concrete with and without metakaolin.

4 CONCLUSIONS

Suitability of granite slurry waste and metakaolin for the production of concrete has been evaluated in this research work. Cement is partially replaced by granite slurry waste and metakaolin at varied replacement level ranging (0%, 5%, and 10%). The behavior of granite slurry waste concrete was evaluated first, followed by the addition of metakaolin at varied replacement level in the concrete. The following conclusions can be drawn based on the experimental results:

- The slump value of concrete decreases with the increasing replacement level of granite slurry waste. Further, decrease in the slump value was also observed with increasing percentage of metakaolin.
- The compressive and flexural strength of concrete increases with increasing replacement level of granite slurry waste. Further, addition of metakaolin improves the compressive and flexural strength of the concrete.
- Depth of water penetration increases with the increasing replacement level of granite slurry waste. Conversely, inclusion of metakaolin in granite slurry concrete decreases the depth of water penetration.

- The acid attack test demonstrated that loss in compressive strength increase with the increasing replacement level of granite slurry waste. However, inclusion of metakaolin shows better resistance to acid attack.

Based on the various test results, it was found that the optimum replacement combination level is G10M10. This combination is eco-friendly and sustainable because of the maximum replacement of cement and also maximum utilization of granite slurry waste in the concrete.

The development of modified concrete will lower down the consumption of cement significantly which intern will conserve the natural resources and reduces the emission of green house gases. Furthermore, it will also solve the disposal and accumulation problem associated with the granite slurry waste. Hence, the production of new composite concrete will be sustainable and advantageous to the environment and society.

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