FRESH AND HARDENED PROPERTIES OF GRANITE SLURRY CONCRETE INCORPORATING METAKAOLIN

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ABSTRACT. Climate change is recognized as a major environmental challenge for the humankind nowadays and cement production is one of the key reasons for this change. These emissions are not only declining air quality but also adding up in human health degradation. Granite stone is renowned in the worldwide market for its elegance, aesthetic quality and its durability. Large quantity of granite waste is generated during processing of granite stone and this waste has detrimental effect on fertility of land, environment and society. Metakaolin is an innovative and economical alternative to silica fume and can be used as a substitute for cement in concrete production. It can be seen from available studies that the combination of metakaolin with other cementitious material modifies the various concrete properties. In this investigation effect of metakaolin on fresh and hardened properties (workability, compressive strength and flexural strength) of granite slurry concrete has been studied. Granite slurry and metakaolin are utilized up to 20% as partial replacement of cement. It has been found that metakaolin has positive influence on hardened properties of granite slurry concrete and utilization of waste material (granite slurry) as cement at optimum replacement level. This study demonstrates that incorporation of metakaolin maximize the utilization of waste material (granite slurry) as partial replacement of cement. This will trim down the consumption of cement which will conserve the natural resource, reduce CO_2 emission, energy demand and also waste accumulation. Hence, the production of new modified concrete will be sustainable and advantageous to the environment and society.

Keywords: Cement replacement, granite slurry, metakaolin, sustainability

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INTRODUCTION

Around the world, concrete and other cement-based materials effectively accomplish the rise in demand of infrastructure development. Cement is a main binding material in concrete and other cement based products. Its production is highly energy intensive process, which involves intensive fuel consumption for the clinker making and other production process. Cement production contributes green house gases (CO_2, NO_2, NO_x etc.) which are the prime cause of the global warming. Moreover, cement production necessitate extraction of natural resources which results in exhaustion of these limited natural resources. Each ton of cement requires approximately 1.5 tons of raw material and 1700 kWh in terms of energy [1]. Hence, there is a vital need of utilizing the supplementary cementitious materials (SCMs) which can overcome the adverse issues related with cement production by reducing its consumption.

The stone industry produces enormous amount of wastes in form of solids (generated during the extraction stage in quarries) and fine powder or sludge (produced during the manufacturing processes).The granite industry is one of the dominating stone industry which produces about 15% to 20% of total waste during the cutting process of granite blocks[2]. Granite slurry waste produced in sludge form and become fine material after drying, which can be easily airborne and has detrimental effect on fertility of soil and open source water, environment and civilization [3].Moreover, accumulation of this granite waste reduces the porosity of soil, prevents ground water recharge. 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.

Mashaly *et al.* [2] found out the feasibility of granite sludge as cement replacement in concrete by assessing physical, mechanical and durability performance. In this study cement was substituted by granite sludge up to 40% with increment of 10% replacement level. The results stated that 20% cement replacement exhibited a negligible decline in physical and mechanical properties and enhancement in resistance to abrasion, freeze and thaw and sulfate attack. Sharma *et al.*[4] reported an increase in compressive and flexural strength of concrete containing granite slurry as cement replacement as compared to reference concrete depending upon replacement level and w/c ratio. Abd Elmoaty [5] studied the concrete properties modified with granite dust waste as cement replacement and addition. The outcome of the result showed that granite dust can be used up to 5% as cement without compromising the compressive strength property of the concrete. Al-Humaiedeh and Khushefati [6] conducted an experimental investigation to determine the compressive strength of concrete modified with granite powder. Test results showed that utilizing 10% of granite powder as cement replacement has no effect on the compressive strength of concrete. Furthermore, effect of nano metakaolin as partial replacement (5% and 10%) of cement on concrete properties was investigated by the Supit *et al.* [7]. Results of the study revealed that at 10% replacement, there was an enhancement in properties of concrete. Similarly, Dinakar *et al.* [8] reported that incorporating 10% metakaolin as substitution of cement enhances the mechanical and durability properties of concrete.

From the experimental studies discussed above, it can be observed that granite waste and metakaolin modifies the properties of concrete depending upon various parameters. The present study aims at evaluating the performance of concrete incorporating granite slurry waste and metakaolin at water cementitious material ratio (w/cm) ratio 0.50. In this study the replacement level of granite slurry waste is up to 10% and metakaolin is also up to 10% as partial replacement of cement by weight. Various concrete properties; workability, compressive strength and flexural strength have been evaluated.

MATERIALS AND CONCRETE MIXTURES

Materials

Cement

Portland cement confirming IS 8112-1989 [9] was used. Physical and chemical attributes of cement has been conducted and results are presented in Table 1 and Table 2 respectively.

Fine aggregates

The locally available Kharka river sand confirming the requirement as per IS 383-2016 [10] was used. Physical properties such as specific gravity and fineness modulus have been found and results are shown in Table 1.

Coarse aggregates

Coarse aggregate of size 20mm and 10mm was used in this study and were procured from the local supplier confirming the requirement and gradation as per IS 383-2016 [10]. Physical properties such as specific gravity and fineness modulus have been measured and results are provided in Table 1.

Granite slurry waste

The granite slurry waste was obtained from the dump yard of Udaipur, Rajasthan, India. It was collected in the slurry form and dried at room temperature for sufficient duration prior to testing. Physical attributes (consistency, water absorption and specific gravity) and chemical attributes of granite slurry waste have been shown in Table 1 and Table 2 respectively.

Metakaolin

Metakaolin used in this study was procured from the local supplier. Physical and chemical attributes of metakaolin has been determine and summarized in Table 1 and Table 2 respectively.

Table 1 Physical attributes of materials

MATERIAL	PHYSICAL PROPERTIES
Cement	Consistency-32%, Initial setting time-130minutes, Final setting time-213 minutes, specific gravity-3.12
Fine aggregate	Specific gravity-2.71, Fineness modulus- 2.83
Coarse aggregate	Specific gravity-2.80, Fineness modulus- 6.29
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 attributes 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

Mixture Proportions of Concrete

The concrete mix design of M25 grade was prepared as per IS 10262-2009 [11] and IS 456-2000 [12]. The water cementitious material ratio (w/cm) is 0.50 for control concrete and concrete containing granite slurry waste and metakaolin. The cement replacement levels of granite slurry waste and metakaolin were 5% and 10% by weight of cement. Specimens were cast and cured for 28 days standard curing prior testing of specimens. Mixture proportions of various ingredients used in the study are presented in Table 3.

Table 3 Mixture 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

RESULTS AND DISCUSSION

Workability

Slump test is performed to determine the workability of concrete as per Indian Standard 1199-1989 [13]. Variation in slump of control concrete and other concrete mixtures have been shown in figure 1. It can be observed from the figure 1 that slump value decreases with an increase in replacement level of cement by GSW and MK. Slump value of control concrete mix is highest (75mm) whereas minimum slump value (35mm) is observed at 10%

replacement of both GSW and MK. Granite slurry waste and metakaolin consist of fine particle and ultrafine particle respectively, which increases the surface hydration of the modified concrete prepared, leading to the greater water absorption which intern decreases the workability of mix.

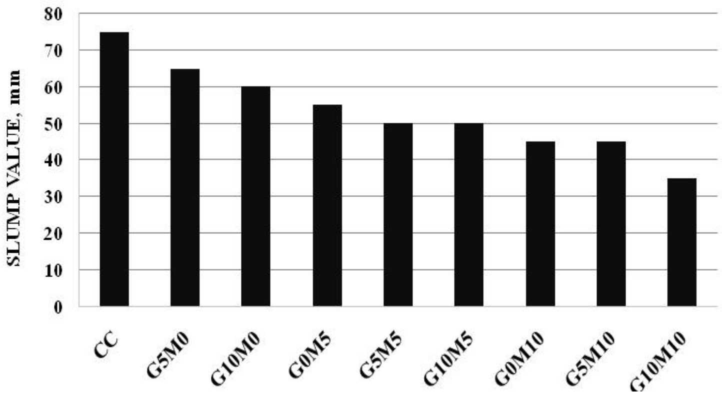

Figure 1 Slump value for granite slurry waste concrete with and without metakaolin

Compressive Strength

The effect of GSW and MK on 28 days compressive strength of concrete has been performed according to IS 516-1959 [14] and results are shown in figure 2. Test result from figure 2 revealed that compressive strength of concrete increases with increase in the replacement level up to 10% of granite slurry waste without use of metakaolin G10M0 (31.5 N/mm^2). However, addition of metakaolin leads to enhance 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 observed that the compressive strength for the mix G10M10 was determined as 30.10 N/mm^2 which was more than the control concrete mix 26.2 N/mm^2. Hence, to accomplish maximum replacement of cement and also at the same time maximum utilization of granite slurry waste, optimum replacement mixture proportion is G10M10.

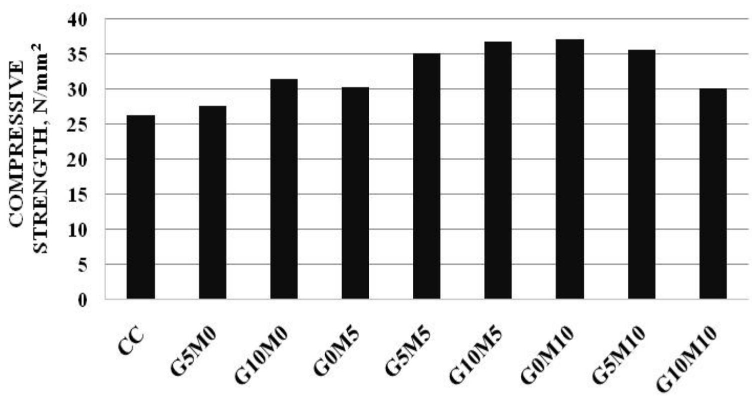

Figure 2 Compressive strength for granite slurry waste concrete with and without metakaolin

Flexural Strength

The effect of GSW and MK on 28 days flexural strength of control concrete has been performed according to IS 516-1959 [14] and test results are shown in figure 3. It can be observed from the test results that variation of flexural strength of concrete samples was analogous to that of compressive strength. In optimum replacement mixture proportion G10M10, the value of flexural strength is higher (4.50 N/mm^2) than that of control concrete mix (4.12 N/mm^2).

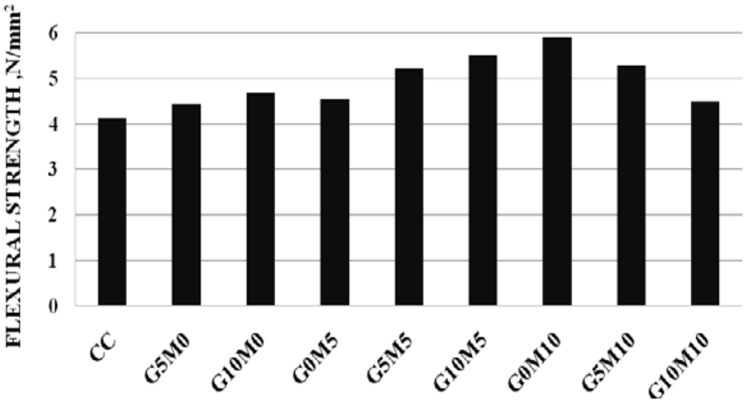

Figure 3 Flexural strength for granite slurry waste concrete with and without metakaolin

CONCLUDING REMARKS

Feasibility of granite slurry waste and metakaolin for the production of concrete has been evaluated in this experimental investigation. In this investigation, cement is partially replaced by granite slurry waste and metakaolin at varied replacement level ranging (0%, 5%, and 10%). The performance of granite slurry waste concrete was evaluated first, afterwards the addition of metakaolin at varied replacement level in the concrete was evaluated. Based on the above mentioned experimental results following conclusions can be drawn:

- The slump value of concrete decreases with the increasing replacement level of granite slurry waste. Further, inclusion of metakaolin decreases the slump value of concrete.
- The compressive and flexural strength of concrete increases with increasing replacement level of granite slurry waste. Moreover, addition of metakaolin improves the compressive and flexural of the concrete as compared to control concrete.

Based on the test results, it has been observed that the optimum replacement mixture proportion is G10M10. This mixture proportion is eco friendly and sustainable due to maximum replacement of cement and also maximum utilization of granite slurry waste in the concrete.

The production of this modified concrete will trim down the consumption of cement significantly which intern will conserve the natural resources and will reduce the emission of green house gases. Moreover, it will also solve the disposal and accumulation issues associated with the granite slurry waste. Hence, this new modified concrete will be sustainable and advantageous to the environment and civilization.

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