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# Analysis of Mechanical and Durability Characteristics of Concrete using Granite slurry waste and Metakaolin as a partial replacement of Cement

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**Abstract:** *Granite is the most widely used construction material which generates granite slurry through its cutting and polishing process. Disposal of this granite waste leads to health hazards like respiratory and allergy problems to the people in the world. Utilization of granite slurry waste and metakaolin in concrete can solve many problems related to waste generation, energy consumption problem, consumption of natural resources, $CO_2$ emission etc. Metakaolin is also a cementatious material andin cases where insufficient or poor curing concrete structure like the underground structure which undergo serve loss of compressive strength, use of metakaolin proves to be very useful to modify the properties of concrete.*

*In this work, systematic experimental study is carried out of concrete using granite slurry waste and metakaolin to replace cement at various replacement levels for water cement ratio of 0.45 and required specimens have been cast to check workability and various strength properties (compressive strength test and flexural strength test). From the results obtained by various studies, it can be concluded that by using granite slurry waste and metakaolin, modification in compressive strength is noted and maximum strength has been obtained depending upon replacement level and water cement ratio. Flexural strength is also influenced by the addition of granite slurry waste and in similar way as of compressive strength. A decrease in the slump value was also noted with the increase % of granite slurry waste and metakaolin in concrete.*

***Keywords:*** *Granite Slurry Waste(GSW), Metakaolin(MK), Workability, Compressive strength, Flexural strength, Fine aggregate, Coarse aggregate, Cement.*

## I. INTRODUCTION

The most vital environmental challenge which the world is facing today is Climatic change. Emission of various gases and ingredients from cement manufacturing Industries are one of the major contributors in global warming and climate change. Approximately 5% of global carbon dioxide emission is due to the manufacturing of cement, which is proving a great hazard to the planet. Replacement of cement is therefore urgently needed to save environment and the energy demand. Granite is a hard igneous rock which is most widely used as a construction material in various forms. Indian granite stone is now becoming the most popular material and very usable stone in the construction of building and contains very massive work in building, and it is very popular stone in the International market. Elegance and Aesthetic are the best quality of this stone, but the main property of this stone is durability.

The marble and granite dust is usually dumped on the riverbeds and this attracts major environmental concern. All these significantly affect the environment and micro ecosystems. **(Pappu*et al.*, 2007)**

The granite stone industry generates different types of waste. Granite stone slurry contains a semi liquid material having particles originated from the sawing and polishing process and water used to cool and lubricate the sawing and polishing machines. Environmental problems cause when these materials are directly exposed to the environment. When dumped on land, these wastes adversely affect the productivity of land due to decreased porosity, water absorption, water percolation etc. They cause serious environmental and dust pollution and require vast area of land for their disposal. **(Srinivasa*et al.*, 2015)**

Metakaolin improves concrete performance by reacting with available calcium hydroxide to produce secondary calcium silica hydrate (C-S-H) as well as other hydrates. In addition to improving concrete performance, metakaolin also makes concrete greener because metakaolin production does not produce chemical CO2 as opposed to cement (de-carbonating limestone) and also requires lower temperatures to produce (800$^{o}$C as compared to 1450$^{o}$C). When blended with Portland cement in appropriate amounts, typically below 20%, it will enhance the strength and durability of the concrete.

## II. EXPERIMENTAL INVESTIGATIONS

An Experimental program was designed to produce a high strength concrete by adding several combinations of granite slurry and Metakaolin. The materials used are described in the following section:

### 2.1 Materials

The following materials were employed:

**Cement: -**The ordinary portland cement of 43-grade was used for casting the specimens of all the concrete mixes. Same source of cement bags were used throughout the research work. Cement was free from the moisture and also free from any hard lumps. The cement was of uniform grey colour.

**Granite slurry: -**The granite slurry waste dust collected from cutting and polishing unit of M square stones, Kota was used for the experimental study.

**Metakaolin: -**Metakaolin procured from M/S Navpad Sales, Surat, Gujrat was used for this research work.
**Fine aggregates: -**The fine aggregate used for investigation was procured from the local fine aggregate suppliers. Sieve analysis and specific gravity test were performed using standard testing procedure as per IS: 2386 (part-1) -1963 and IS: 2386 (part-3) -1963 respectively. The Fineness modulus obtained by Sieve analysis was 2.86. The results of this test were compared with the IS: 383-1970 code and it belongs to the zone II. The specific gravity test was also performed in the laboratory and it was calculated as 2.71.

**Coarse aggregates: -** Coarse aggregate of size 10mm was used in this study. The coarse aggregate used for investigation was procured from the local coarse aggregate supplier as per IS: 383-1970. The Fineness modulus and specific gravity tests were performed and the results obtained by respective tests were 6.04 and 2.8 respectively.

**Water: -** Ordinary clean and potable tape water, free from suspended particles and chemical substances was used throughout the investigation. It was used for mixing, casting and curing the concrete.

### 2.2 Mix proportions

The mix proportions for different mixes is shown below:

**Table 1:** Mix proportion of concrete containing granite waste slurry and metakaolin

| Specimen no | w/c ratio | Cement kg/m$^3$ | % of replacement cement by granite slurry waste | Granite slurry waste as partial replacement of cement Kg/m$^3$ | % of replacement cement by metakaolin | Metakaolin as partial replacement of cement Kg/m$^3$ | Fine aggregates Kg/m$^3$ | Coarse aggregates Kg/m$^3$ |
|---|---|---|---|---|---|---|---|---|
| A1 | 0.45 | 372.0 | 0 | 0.0 | 0 | 0.0 | 586 | 1279 |
| A2 | 0.45 | 353.4 | 5 | 18.6 | 0 | 0.0 | 586 | 1279 |
| A3 | 0.45 | 334.4 | 10 | 37.2 | 0 | 0.0 | 586 | 1279 |
| A4 | 0.45 | 316.2 | 15 | 55.8 | 0 | 0.0 | 586 | 1279 |
| A5 | 0.45 | 353.4 | 0 | 0.0 | 5 | 18.6 | 586 | 1279 |
| A6 | 0.45 | 334.4 | 5 | 18.6 | 5 | 18.6 | 586 | 1279 |
| A7 | 0.45 | 316.2 | 10 | 37.2 | 5 | 18.6 | 586 | 1279 |
| A8 | 0.45 | 297.6 | 15 | 55.8 | 5 | 18.6 | 586 | 1279 |
| A9 | 0.45 | 334.4 | 0 | 0.0 | 10 | 37.2 | 586 | 1279 |
| A10 | 0.45 | 316.2 | 5 | 18.6 | 10 | 37.2 | 586 | 1279 |
| A11 | 0.45 | 297.6 | 10 | 37.2 | 10 | 37.2 | 586 | 1279 |
| A12 | 0.45 | 279.0 | 15 | 55.8 | 10 | 37.2 | 586 | 1279 |
| A13 | 0.45 | 316.2 | 0 | 0.0 | 15 | 55.8 | 586 | 1279 |
| A14 | 0.45 | 297.6 | 5 | 18.6 | 15 | 55.8 | 586 | 1279 |
| A15 | 0.45 | 279.0 | 10 | 37.2 | 15 | 55.8 | 586 | 1279 |
| A16 | 0.45 | 260.4 | 15 | 55.8 | 15 | 55.8 | 586 | 1279 |

**Grade of concrete: -** The mix proportion for this investigation was **1: 1.57: 3.44** and **M25** grade of concrete was adopted.

### 2.3 Specimens and Curing

The following specimens were cast for each mixture:

 

**Table 2:** Concrete testing sample details

| Test | Shape and Dimensions of the Specimens | Time Duration (in days) | No. of Specimens |
|---|---|---|---|
| Compressive Strength | Cube : 100mm×100 mm×100mm | 7,28 | 96 |
| Flexural strength | Beam : 100mm×100mm×500mm | 28 | 48 |

All the specimens were cast on mechanical vibration table. After casting, all the specimens were left at room temperature for 24 hours. The specimens were demoulded after 24 hours of casting and were then cured in water at approximately 27 $^{0}$C until the testing day.

### 2.4 Experimental Procedures

The workability of the fresh concrete was measured by using standard slump cone test apparatus. The compressive strength was obtained at the age of 7 and 28 days on 3,000 kN machine. The average compressive strength of three specimens was considered for each age. The Flexural strength was tested on two point flexure testing machine at the age of 28 days.

**Fig. 1:** Compression testing machine

**Fig. 2:** Flexural testing machine

## III. RESULTS AND DISCUSSIONS

Tests were carried out in the laboratory to investigate various properties such as workability, compressive strength, flexural strength of the concrete containing granite slurry waste and metakaolin as a partial replacement of cement whose results are discussed below:

### 3.1 Workability

Workability is the prime factor for acceptance of any material for its probable use in the production of concrete. In this study, slump cone test was used to derermine the workability of the fresh concrere. Fig. 3 shows the slump values of concrete for w/c ratio 0.45 with replacement of cement by combination of granite slurry and metakaolin.
It can be seen from fig. 3, that the slump value has been decreased with the increase % of granite slurry waste and metakaolin in concrete. Ding et al. (2002) also reported the decrease in slump value with addition of metakaolin. The reduction in workability may be due to the filler effect of the metakaolin and granite slurry waste. Slump value for conventional concrete was observed as 80mm. The slump value for 5%, 10% and 15% replacement of cement with granite slurry waste was observed as 75mm,70mm and 65mm. Similarly, the slump value for 5%, 10% and 15% replacement of cement with metakaolin and Granite Slurry was found and is shown in the Graph below.

 

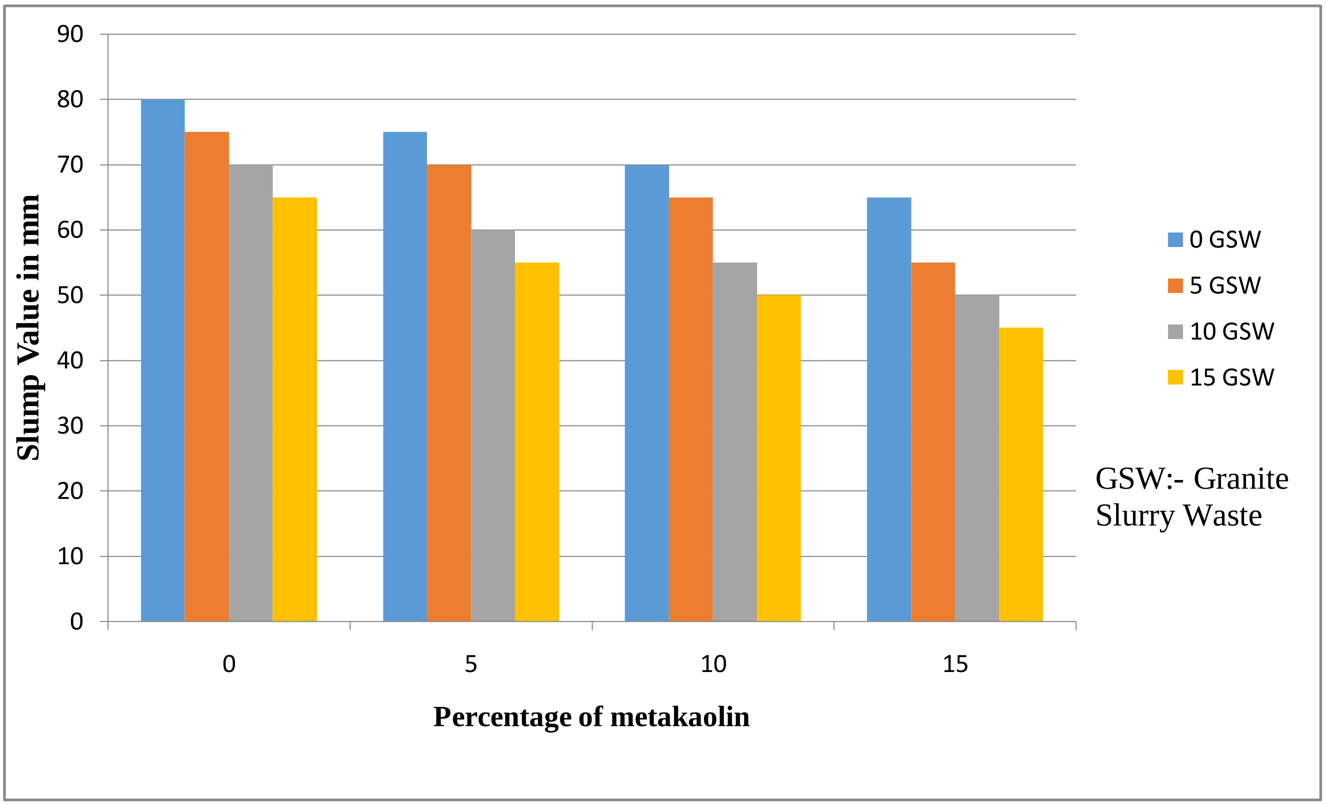


**Fig. 3: Slump values of concrete containing granite slurry waste and Metakaolin**

### 3.2 Compressive strength

Compressive strength of granite slurry waste concrete with and without metakaolin at 7 days and 28 days is presented in figures 4 and 5. It can be observed from fig. 5 (28 days compressive strength) that the compressive strength of concrete increases with increase in the percentage up to 10% of granite slurry waste. Increase in compressive strength with replacement of granite slurry waste is due to the fineness of granite slurry waste. Granite slurry waste has fine particles and it improves effective packing which in terms will improve microstructure. This improved microstructure will increase the compressive strength of concrete [Kumar et al (2015), Sharma et al (2016)]. The compressive strength for control mix was observed as 22.50 $N/mm^2$ which increases to 23.92$N/mm^2$ with 5% increases in replacement level of granite slurry waste.

When metakaolin was added in the concrete the compressive strength increases the increase in strength with replacement of metakaolin and modification in strength is due to the chemical reaction between $Ca(OH)_2$ and metakaolin, which results in the formation of additional CSH gel [Ding et al (2002), Aiswarya et al (2013)]. The compressive strength increases to 24.9 $N/mm^2$ as compare to control mix (22.50 $N/mm^2$) at 5% replacement of cement with metakaolin. It is observed that the maximum strength was found for the mix containing maximum utilization of metakaolin without granite slurry waste (GSW0% + MK15%). For this specimen the compressive strength was observed as 28.6$N/mm^2$.It can also be seen that the compressive strength for the combination GSW10% + MK10% was observed as 28.4 $N/mm^2$ which was more than the desired strength.

So that optimum combination to produce sustainable and eco-friendly concrete is GSW10% + MK10%, because of maximum utilization of both materials granite slurry waste and metakaolin to enhance the compressive strength of modified concrete.

The compressive strength variation after 7 days of curing at various replacement levels at w/c ratios 0.45 for concrete with and without metakaolin is shown in figure 4.

Fig. 4 shows the compressive strength after 7 days of curing. The compressive strength for control mix was obtained as 18.80 $N/mm^2$ for w/c ratio 0.45. Maximum strength (24.1 $N/mm^2$) was observed for the combination which containing 10% metakaolin and 10% granite slurry waste.

Suryawanshi et al (2015) also reported that cement replacement up-to 12% with metakaolin leads to increase in compressive strength of concrete at all ages of curing. Dinakar et al (2013) reported that metakaolin improve properties of concrete up to 10% replacement of cement at all ages of curing.

 

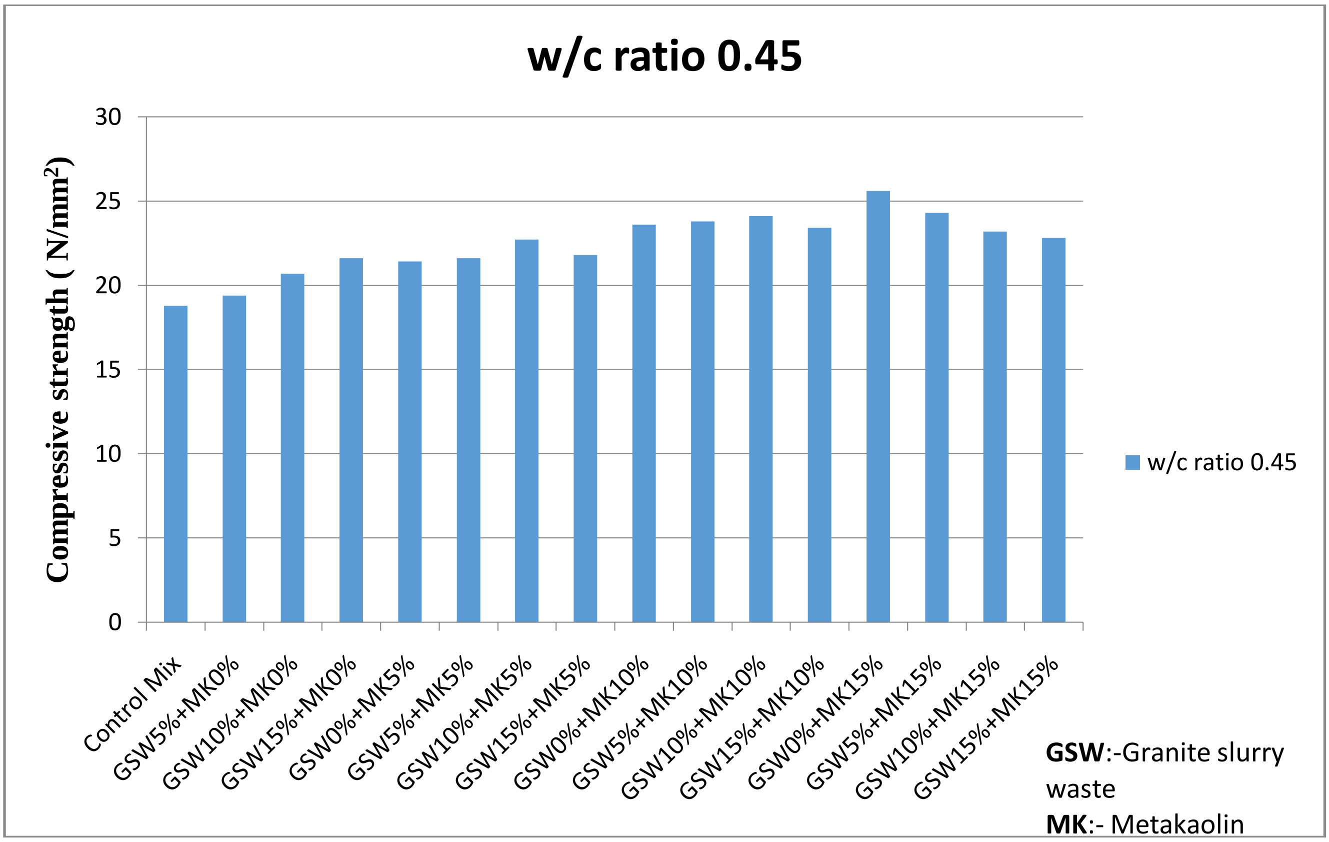


**Fig.4 CompressiveStrength of concrete using granite slurry waste and Metakaolin at 7 days**

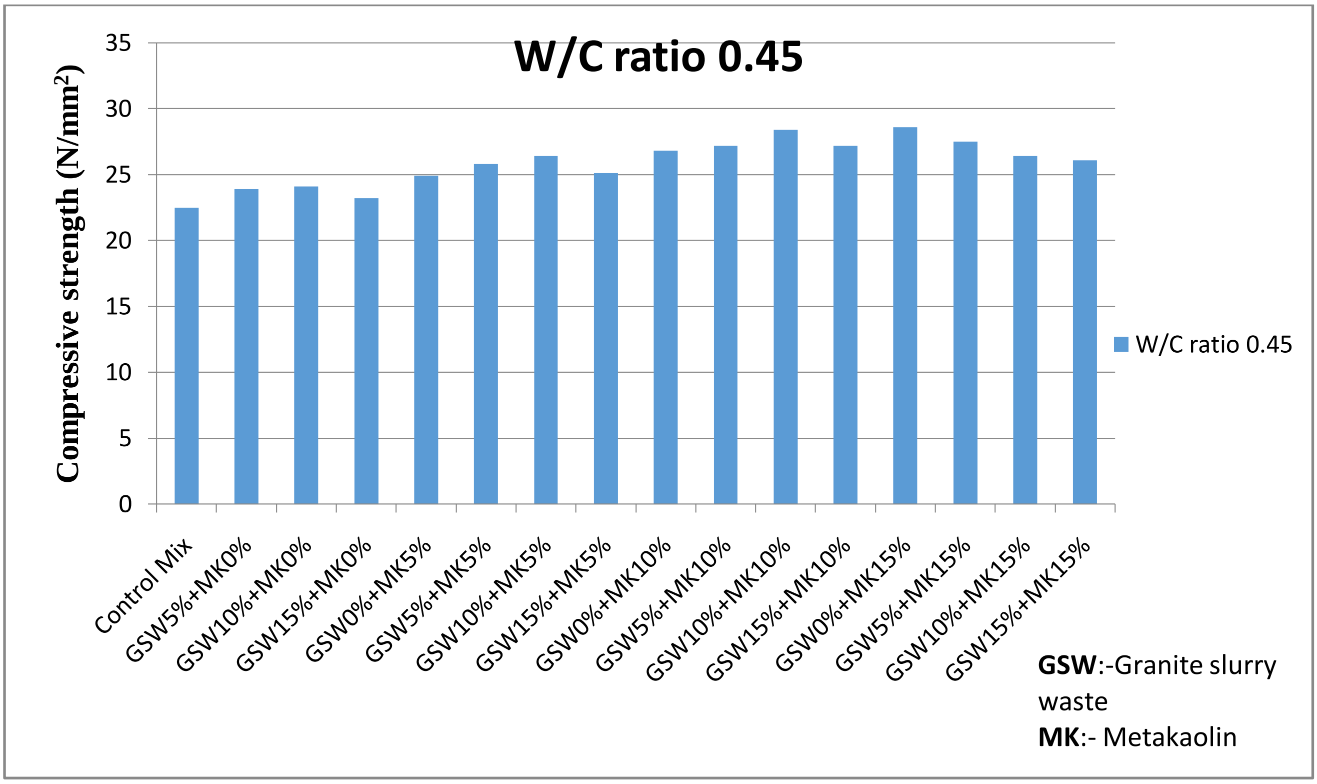


**Fig. 5: Compressive Strength of concrete using granite slurry waste and Metakaolin at 28 days**

 

### 3.3 Flexural Strength

28 days flexural strength of the modified concrete with granite slurry waste and metakaolin is shown in fig. 6 for w/c ratio 0.45. It is observed that the flexural strength of concrete increases with increase in percentage of granite slurry waste. Granite slurry waste and metakaolin have fine particles which ensure effective packing and reduce the space of free water with the results towards better bonding in concrete matrix, which increase the strength of concrete up to a limit. The flexural strength of the referral mix was obtained as 3.28N/mm$^2$ and that for the combination of GSW10%+MK0% was 3.56N/mm$^2$.

Increase in flexural strength was also noticed with increase in percentage of metakaolin. Flexural strength of concrete increases to 4.21N/mm$^2$ as compared to control mix (3.28N/mm$^2$) at 5% replacement level of metakaolin. Increase in 10% GSW along with 5% MK results in increase the flexural strength to 4.68N/mm$^2$. At the optimum replacement level GSW10%+MK10%, maximum flexural strength was observed as 5.64N/mm$^2$. This combination is suitable due to maximum replacement of cement.

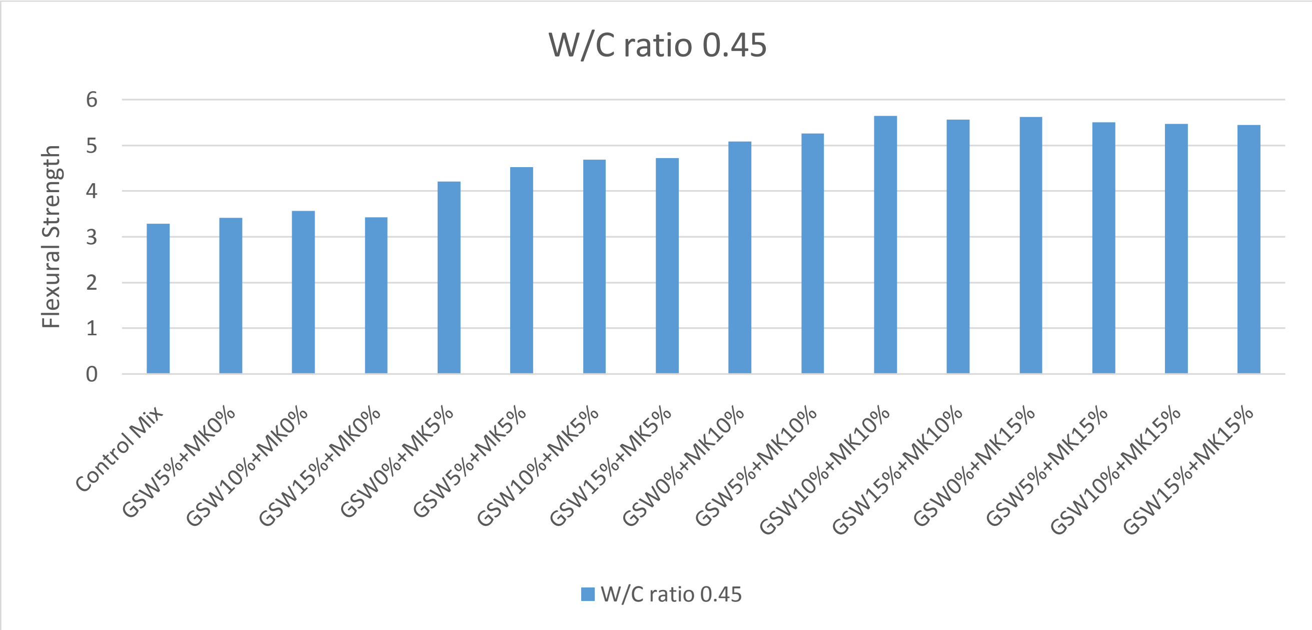


**Fig. 6: Flexural Strength of concrete using granite slurry waste and Metakaolin at 7 days**

## IV. CONCLUSION

Cement was partially replaced by granite slurry waste and metakaolin at varied replacement level ranging (0%, 5%, 10% and 15%). The behaviour of concrete for the combination of both materials GSW and MK was investigated and following conclusions can be drawn from the current study:

(a) The Slump value of concrete decreased with the increasing percentage of granite slurry waste. Further decrease in the workability was also observed with increasing percentage of metakaolin.
(b) The Compressive strength of concrete increased with increasing replacement level percentage of granite slurry waste up to 10% at all ages of curing. Further increase in compressive strength was observed with increase in replacement level of metakaolin. The suitable combination was found to be at GSW10% + MK10% on the basis of utilization of both the materials.
(c) The Flexural strength of concrete containing granite slurry waste increased with increase in the replacement level up to 10% of granite slurry waste. Same behaviour was found for the concrete containing metakaolin. Further flexural strength of concrete increases with increase in the percentage of metakaolin. Maximum flexural strength was observed for the combination of GSW10% + MK10%. So the suitable combination was found to be at GSW10% + MK10% on the basis of optimum utilization of the materials.
(d) Various tests performed on concrete using granite slurry waste and metakaolin demonstrate that the modified concrete will perform well at partial replacement level of cement by 10% granite slurry waste and 10% metakaolin. This concrete combination will be eco-friendly and sustainable as compare to parental concrete due to the optimum utilization of both materials.

 

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