Strength, Permeability and Carbonation properties of Concrete containing Kota Stone Slurry

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Abstract

Concrete and stone, both are the most commonly used building materials. Rapid development in infrastructure sector has boosted the demand of both, resulting in many environmental concerns. Energy consumption and CO_2 emission associated with the production of concrete and cement is a big concern. On the other side, there is a huge solid waste associated with the stone industry which has manifold environmental and financial concerns. For sustainable development, there is a need to utilize the stone waste as a partial replacement of cement (mineral admixture) in concrete so that so that the two problems simultaneously get solved. Kota stone slurry (KSS), which is abundantly available in area of Kota, Rajasthan was used as a partial replacement of the cement in this study. The objective of the present study is to determine strength and durability parameters of the concrete containing Kota stone slurry. The experimental programme consists of preparing concrete mixes with two water binder ratios: 0.40 and 0.50 with varying Kota stone slurry percentage as 0, 5, 10, 15, 20 and 25% partially replaced with cement. Compressive and flexural strength test, pull-off test were performed to evaluate strength and DIN 1048 water permeability test, carbonation test and abrasion test were performed to check the durability of concrete mixes. The results indicate that with the increase in Kota stone slurry content, the compressive and flexural strength decreased. There is a marginal decrease in permeability also but the mixes containing Kota stone slurry displayed better resistance to abrasion indicating their suitability as good floor and pavement material. The properties of concrete with Kota stone slurry indicates that it can serve as an alternating material in low cost rural pavements.

Keywords: *Kota stone slurry (KSS), permeability, carbonation, abrasion.*

I. INTRODUCTION

The crucial role of engineering for contemporary civilization is implicit in every aspect of our lives. Rapid progress in the development of the country post-independence has taken place through the application of engineering to different sectors: dams, irrigation systems, road networks and buildings which paved the way for industrial and green revolution. During this process of development concrete played a vital role. It is consumed in huge quantities throughout the world to shape the built environment. It has shaped everything from housing, schools, industry and water supplies, to roads and bridges. Civilisation is built on a concrete foundation. Thus, for global development there is a need to rely on concrete, although energy consumption associated with the cement and concrete production is a big concern.

Cement is the key ingredient in concrete manufacturing. As per Environment Building News, 1993, significant quantity of CO_2 are emitted as a part of cement production due to the energy intensive nature of the industry and the chemical process of calcining limestone into lime. Cement consumption in India is expected to rise by 8–9 per cent over the next year, taking the estimated cement consumption in 2015–16 to about 280–285 MT, from around 260 MT in the 2012–13 fiscal, as per the Cement Manufacturers Association (CMA). In addition, cement production in India is expected to touch 407 million tonnes (MT) by 2020.This increase in production of cement will result in emission of greenhouse gases and escalated energy demand. Furthermore, mining large quantities of raw materials such as limestone, clay, and fuel such as coal, often results in extensive deforestation and top-soil loss.
The cement industry has made significant progress in reducing CO_2 emissions through improvements in process and efficiency, but further improvements are limited because CO_2 production is inherent to the basic process of calcinating limestone. The cement industry does not fit the contemporary picture of a sustainable industry because it uses raw materials and energy that are non-renewable; extracts its raw materials by mining and manufactures a product that cannot be recycled. The environmental impact of the concrete industry can be reduced through resource productivity by conserving materials (cement,

aggregate) and energy for concrete-making and by improving the durability of concrete products. The task ahead is challenging but can be accomplished if pursued diligently.

For sustainable infrastructure development it is necessary to modify concrete material using pozzolanic and cementitious materials termed as mineral admixtures. Properties of concrete in fresh state, hardened state and the associated durability can be improved significantly by the incorporation of mineral admixtures. The pozzolanic and cementitious properties, which govern the strength development and permeability of concrete are the mineralogical characteristics, particle size and surface area of the mineral admixtures. Examples of cementitious materials admixtures are granulated blast furnace slag fly ash, silica fume, rice husk ash, wollastonite, kota stone slurry, etc.

Need of Study

Marble, granite, kotastone are the most commonly used building materials. The industry's disposal of the marble/granite/kotastone powder material, consisting of very fine particles, today constitutes to be one of the major environmental problems around the world. Marble / Granite blocks are cut into smaller blocks in order to give them the desired smooth shape. During the cutting process about 25% of the original stone mass is lost. Use of stone waste in various engineering applications can solve the problem of its disposal. Stone waste can be used in concrete to improve its strength and other durability parameters. This can be used as a partial replacement of cement, sand and coarse aggregate maintaining the premium properties of concrete. Use of such materials offer cost reduction, energy savings and superior products with fewer hazards to the environment.

Nature has gifted large deposits of stones such as marble, granite and wide variety of limestone. India ranks third in the world in stone production and subsequently in the production of stone slurry. Kota stone is a fine grained variety of limestone.

II. FORMULATION AND METHODOLOGY

In this study suitability of the materials used such as ordinary Portland cement, Kota stone slurry and aggregates are examined first. Physical properties of these materials viz. sieve analysis, specific gravity, free surface moisture content are examined. Reactivity of Kota stone slurry with lime and cement are then tested and finally concrete mix design is done using these materials. After fixing the proportions of different ingredients of the concrete mix two different series of mixes are prepared using 0.4 and 0.50 water -cement ratios and varying the Kota stone slurry (0 to 25%) replacing cement. Fifteen cubes sizing 10cm x 10cm x 10 cm are casted for 7 days. 28 days and 90 days compressive strength are noted. Carbonation test and pull off test are conducted. 9 beams of size 10cm x 10cm x 50 cm are casted in order to test 7, 28 and 90 days flexural strength and three cubes of size 15cm x 15cm x 15 cm are casted for DIN 1048 water permeability and steady state chloride ion migration test. The experimental programme is outlined in such a way that variation of the attributes like workability, strength and permeability of Kota stone slurry added concrete composite with respect to quantity of zero replacement of cement i.e. control mix is examined by means of parametric study.

III. RESULTS AND OBSERVATIONS

Results of different tests conducted as a part of methodology on concrete for the present investigation are represented here.

A. Compaction Factor

Results of compaction factor, on twelve concrete mixes with two different w/c ratios and varying kota stone slurry content into concrete mixes are shown in Table 1.1.

Table 1.1: Compaction Factor

S. No.	Specimen	Use of Super plasticizer %	Kota Stone Slurry %	W/C Ratio	Compaction Factor
1.	C10	1.25 % by weight of cement	0	0.40	0.89
2.	C11	-Do-	5	0.40	0.88
3.	C12	-Do-	10	0.40	0.88
4.	C13	-Do-	15	0.40	0.87
5.	C14	-Do-	20	0.40	0.85
6.	C15	1.5 %	25	0.40	0.85
7.	C20	1.0 % by weight of cement	0	0.50	0.93
8.	C21	-Do-	5	0.50	0.91
9.	C22	-Do-	10	0.50	0.90
10.	C23	-Do-	15	0.50	0.88
11.	C24	-Do-	20	0.50	0.88

12.	C25	1.25% by weight of cement	25	0.50	0.89

These results indicate that with the increase in Kota stone slurry content in the concrete mixes, workability of the mix reduces slightly, lowering compacting factor as in case of 0.40 w/c ratio. It can also affect strength properties of concrete. Super plasticizer is added to concrete to avoid the adverse effect of slurry on concrete workability.

B. Compressive Strength

The compressive strength test is performed by taking three cubes from each mixes after curing them in water for 7, 28 and 90 days. Results of compressive strength test, as shown in Fig. 1.1 and Fig. 1.2, at two different w/c ratios of concrete, with Kota stone slurry mixes indicates that with the increase in Kota stone slurry content in concrete, 7, 28 and 90 days compressive strength decreases. This decrease in strength is lower for higher w/c ratios when compared with control mixes.

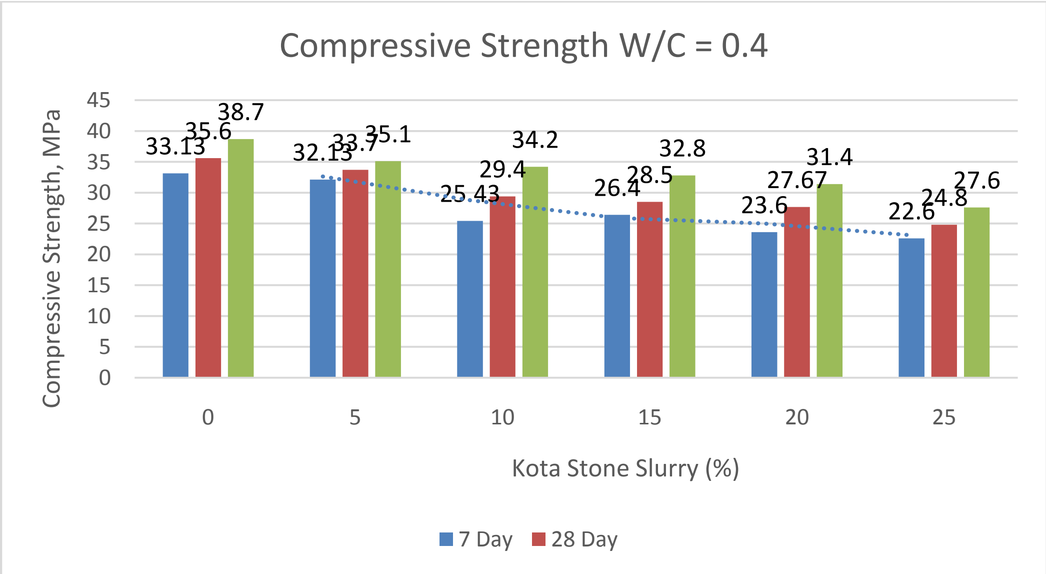

Fig. 1.1: Compressive Strength (Water Cement Ratio = 0.40)

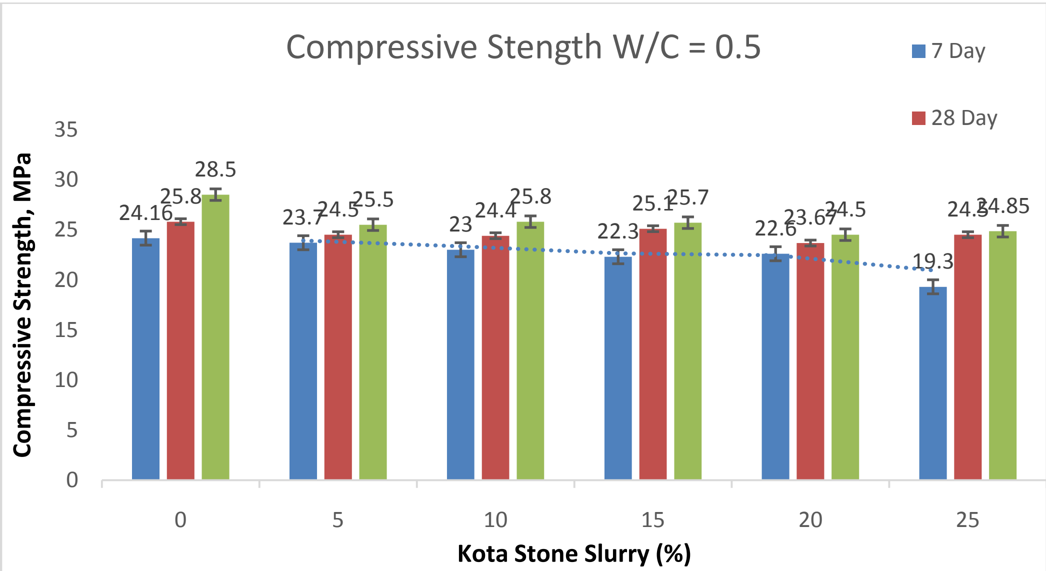

Fig. 1.2: Compressive Strength (Water Cement Ratio = 0.50)

C. Flexural Strength

The flexural strength test is performed by taking three beams from each mixes, after curing them in water for 28 and 90 days. The results are shown in Fig. 1.3 and Fig. 1.4.

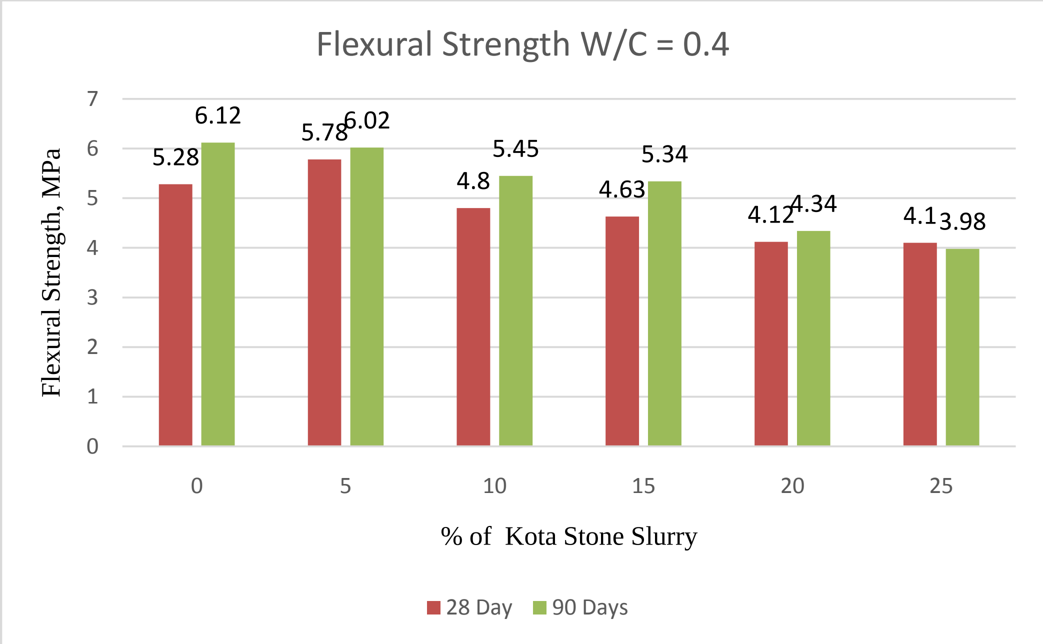

Fig. 1.3: Flexural Strength (Water Cement Ratio = 0.40)

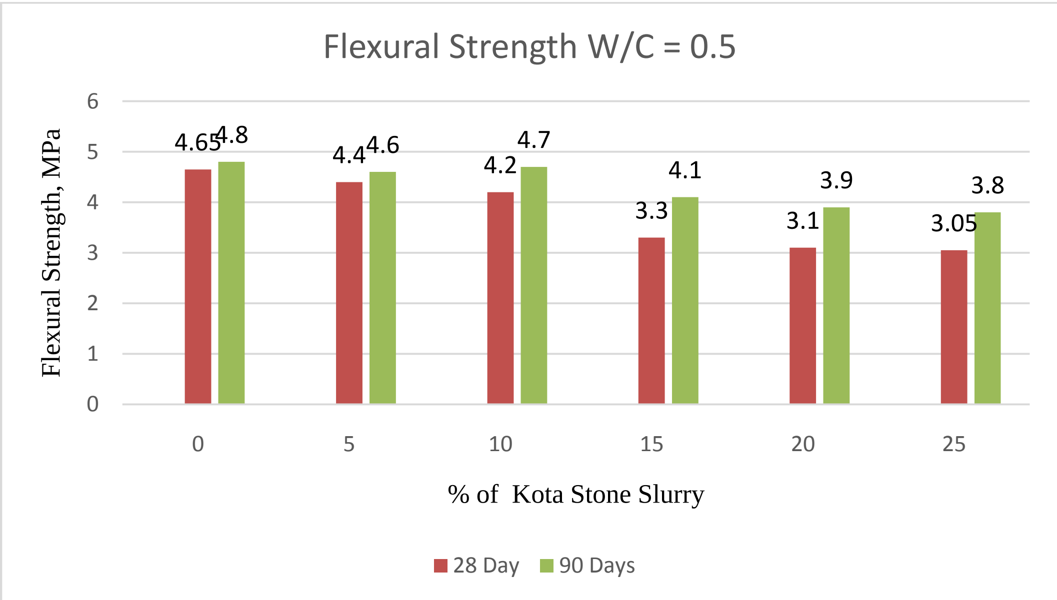

Fig. 1.4: Flexural Strength (Water Cement Ratio = 0.50)

Flexural strength test results are similar to that of compressive strength test results. With the increase in Kota Stone Slurry addition levels, flexural strength decreases upto 20% at the highest level of replacement in C25 mix. However, highest flexural strength amongst the replacement levels are shown on the level of 5% of Kota stone slurry replacement. A similar trend is also shown in the higher water cement ratio of 0.5.

D. Pull-Off Strength

Pull-Off strength is evaluated at 28 days. It is a measurement of the tensile strength or tear resistance of a material applied to a substrate, such as wall cladding (finishing mortars, plasters or other). The result of Pull-Off Strength is shown in Fig. 1.5. It resulted highest on the level of the 15% replacement. Pull-Off Strength of the mixes at lower water cement ratio are observed to be greater than with the higher water cement ratio. The lowest Pull-Off strength is observed in the C25 mix with 25% replacement of Kota Stone Slurry.

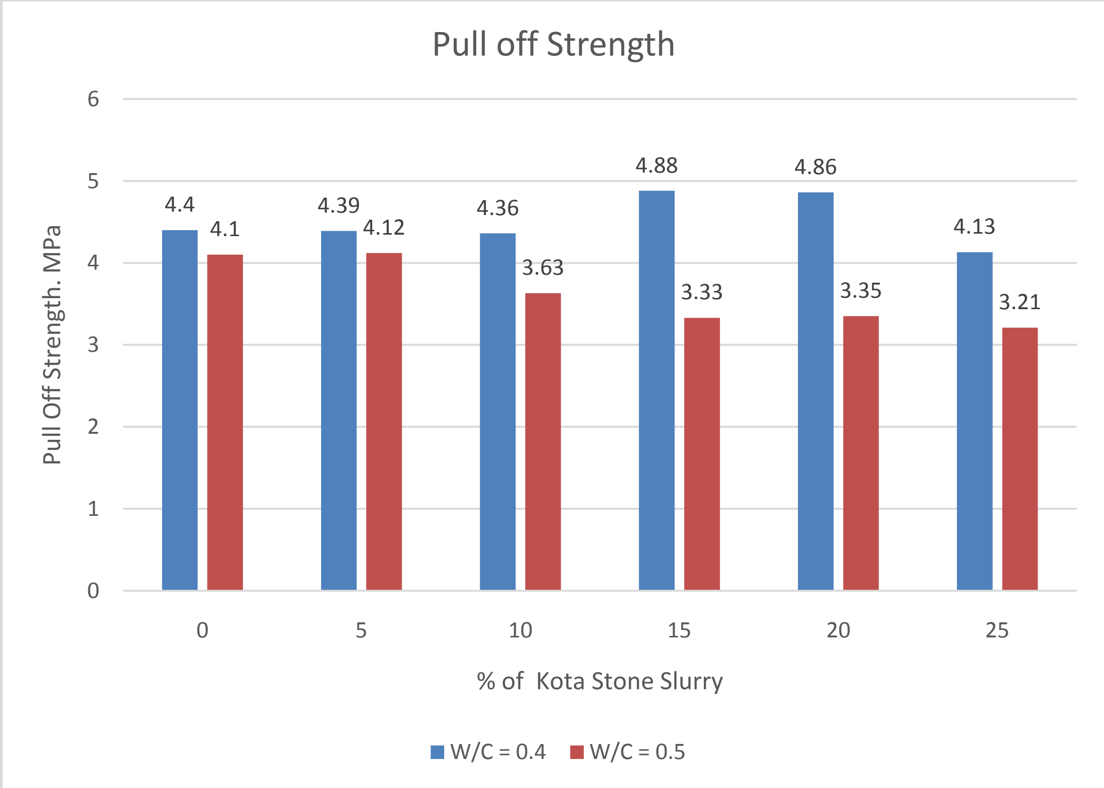

Fig. 1.5: Pull-off Strength (Water Cement Ratio =0.40 and 0.50)

E. DIN 1048 Permeability Test:

Results of 28-days water permeability of concrete mixes at three different w/c ratios are shown in Fig. 1.6. The results of permeability test varied from penetration depth of 44 mm to 55 mm and 50 mm to 69 mm at 0.4 and 0.5 W/C ratio respectively. Concrete with lower W/C ratio shows higher permeability on higher level of replacement with Kota Stone slurry. The extent of penetration depends on the permeability of the concrete (Ollivier et al., 1995). The permeability, in turn, is a function of the size, distribution and connectivity of the pores.

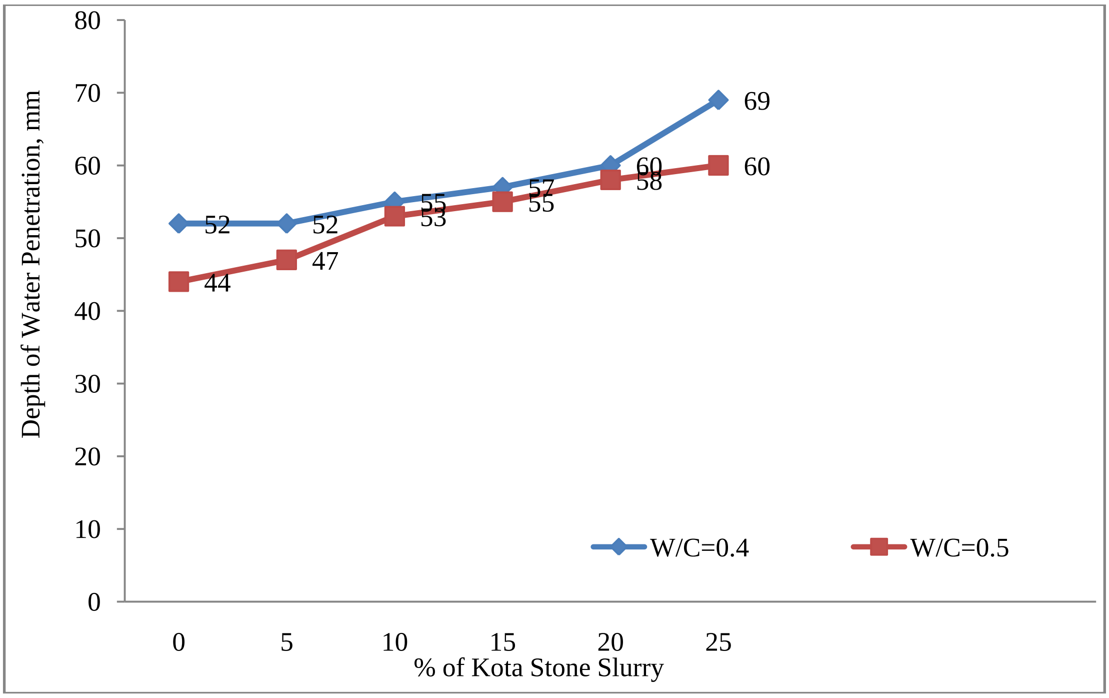

Fig. 1.6: Depth of Water Penetration, DIN 1048 Permeability Test (Water Cement Ratio = 0.40 and 0.50)

F. Carbonation Test:

Two samples from each mix are exposed to CO_2 in accelerated carbonation chamber for 7, 14, and 28 days. The results of depth of carbonation are shown in Fig. 1.7 and Fig. 1.8 at 0.40 and 0.50 water cement ratio respectively.

There are no signs of carbonation in the initial mixes after 7 day testing of the specimens at lower water cement ratio. Highest carbonation levels are observed at replacement level of 25% in mix C25. Carbonation coefficients of the mixes at 28 days are also calculated, results of which are shown in Fig. 1.9.

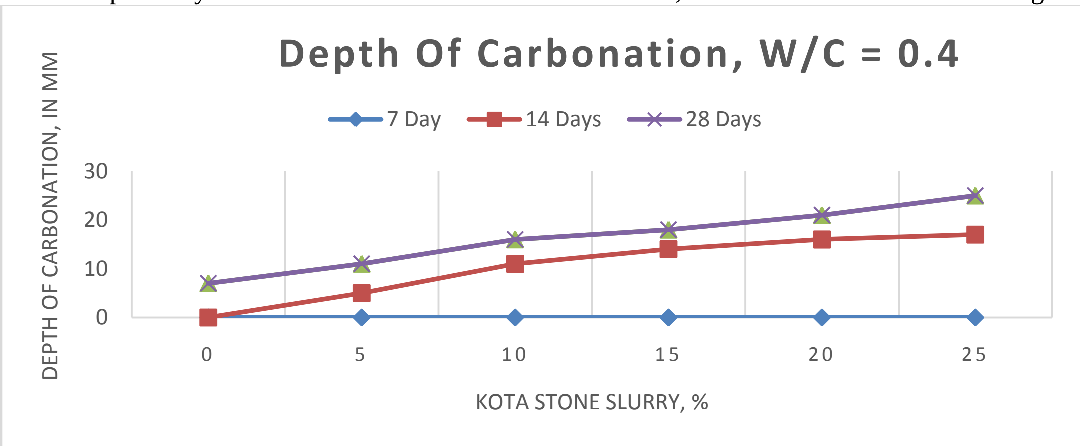

Fig. 1.7: Depth of Carbonation (Water Cement Ratio = 0.40)

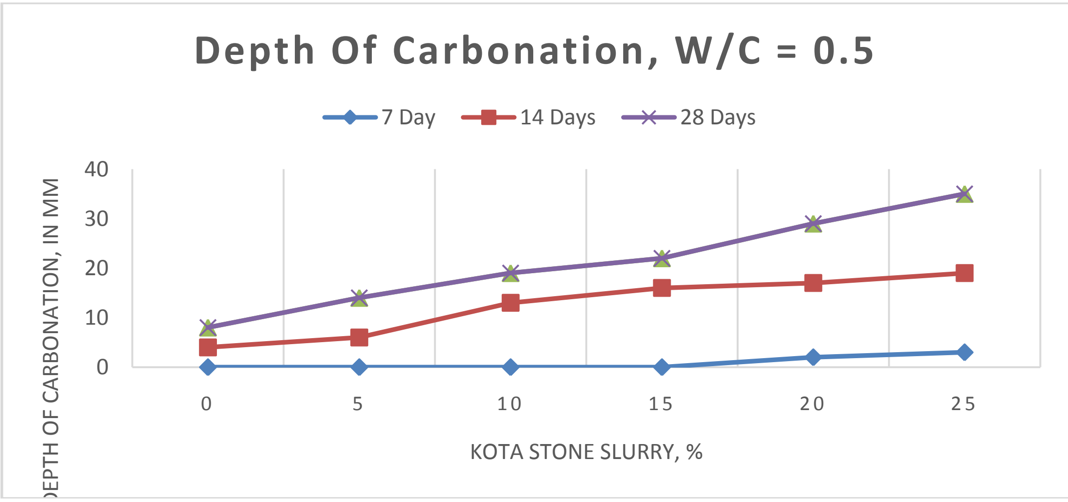

Fig. 1.8: Depth of Carbonation (Water Cement Ratio = 0.50)

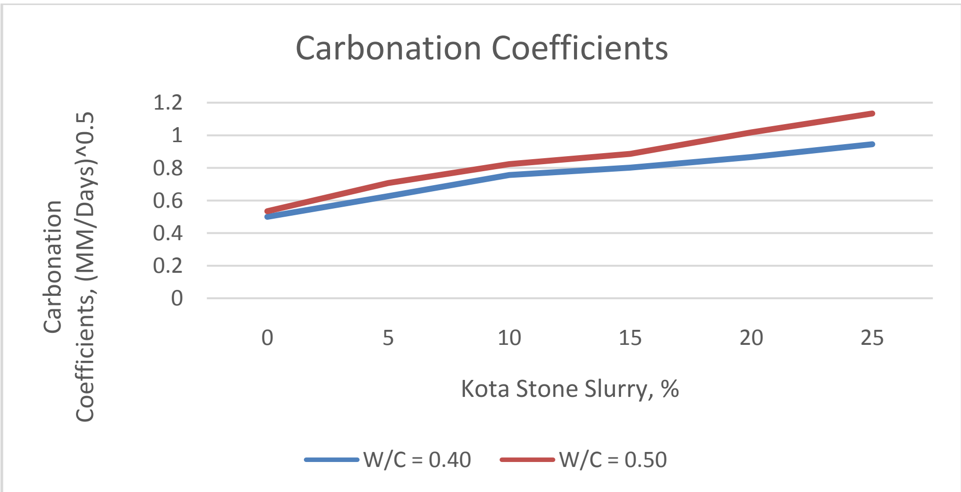

Fig. 1.9: Carbonation Coefficients (Water Cement Ratio = 0.40 and 0.50)

G. *Abrasion Test:*

Results of abrasion test are shown in Fig. 1.10.With the increase in Kota Stone Slurry, mixes are found to be more susceptible to abrasion. Weight loss and wearing length after abrasion are lesser at high replacement levels. A similar trend is observed on both of the water cement ratios of 0.40 and 0.50.

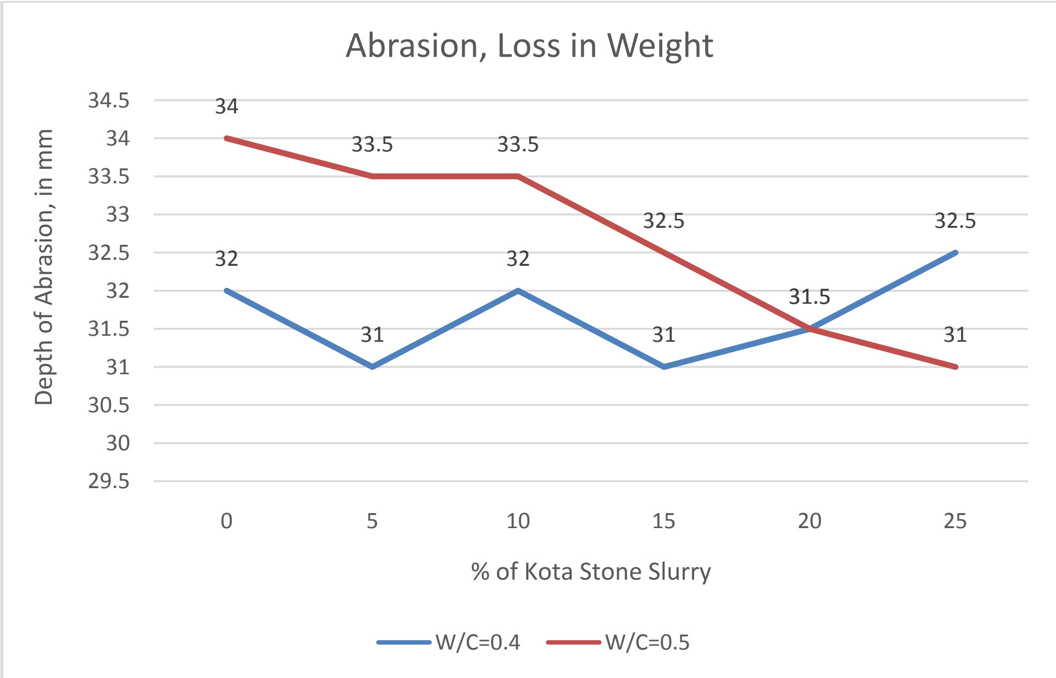

Fig. 1.10: Depth of Abrasion, Abrasion Test

IV. CONCLUSIONS

Based on the experimental results we can conclude that the compressive strength and flexural strength of concrete mixes with Kota stone slurry decreases with increase in Kota stone slurry content. Addition of Kota Stone slurry performs better in abrasion. The effect of Kota Stone slurry in concrete is to be be studied when replaced by fine aggregates and also for other water cement ratios. Other durability parameters like corrosion, carbonation for long duration and freeze-thaw test are to be conducted to study the performance of concrete containing kota stone slurry. The kota stone slurry concrete can be used in construction of rigid pavements in low cost roads, as it has performed better in abrasion.

Conflict of Interest: The authors declare that they have no conflict of interest.

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