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Development of New Grout Mix using Kota Stone Slurry for Sustainable Development

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Abstract. Grouting in Civil Engineering refers to the injection of pumpable materials into soil or rock formation to enhance its physical characteristics. The present study investigates the sustainable use of Kota-stone-waste in powder slurry form as partial replacement of cement in a Grout-mix. Kota stone is a fine-grained variety of limestone, quarried at Kota district, Rajasthan, India. The objective of the present study is to develop a Grout-mix using Kota-stone-powder-slurry based on its strength parameters. 1: 6 mortar was used for sample preparation with water-cement ratio of 0.8 decided by flow table test. Compressive strength tests on cubes of size 50 mm were conducted at 7 and 28 days as per Indian standards. The desired strength for cubes was taken as 9 MPa. The experimental program consisted of preparing Grout-mixes with Kota stone powder slurry with partial replacement of cement by 5 %, 10 %, 15 % and 20 %. Results indicated that the cement up to 10 % could be replaced without any loss in strength of Grout-mix. The study concludes that Kota-stone-slurry waste is a perfect alternative for partial replacement of cement which is produced every year in abundance.

Keywords: Grouting; Cement grouted sand; Limestone waste; Experimental Modeling; Waste to resource.

1 Introduction

Cement is commonly used as a binding material in grouting. On the other side, the stone industries generate large volume of solid waste which has financial and environmental concerns. So, the sustainable development demands the utilization of the solid waste in various engineering applications. This study focuses on the reuse of stone waste in cement grout mix as partial replacement.

The stone waste used as partial replacement of cement in this present study is Kota-stone-slurry, which is largely available in Kota, Rajasthan. The silica and limestone are the major constituents of Kota stone. Kota Stone is quarried at Kota district, Rajasthan, India in fine-grained form of limestone. There are many of mines are located in Ramganjmandi town and in the Kota district. Limestone comes in category of carbonate sedimentary rocks that is generally made of the skeletal fragments of marine organisms like: - molluscs, foraminifera and coral. The crystal forms of calcium car-

bonate (CaCO3) like: - aragonite and calcite are the major minerals of the Kota stone waste.

Limestone is approximately 10 % of the sedimentary rocks. The reason behind the erosion of limestone is karst landscape in which the limestone becomes soluble in water and weal acids. Most of the cave systems all around the world are through limestone rockbeds. Limestone has various uses: as an important constituent of concrete (Portland cement), in base/sub-base of roads as an aggregate, in building materials, as a chemical feedstock for the production of lime, as filler material in products such as toothpaste and paints, as a popular decorative addition to rock gardens or as a soil conditioner.

The Kota stone powder waste disposed from the industries cause adverse impact on surrounding environment. The desired smooth shape of Kota stone blocks is achieved by cutting them in smaller blocks. In cutting process of Kota stone blocks into finer blocks, about 25 % of the original stone mass is lost. The major objective of this present study is to evaluate the durability and strength parameters of the grout mix containing Kota stone slurry. The experimental program includes the preparing grout mixes with Kota stone slurry partially replaced with cement.

2 Literature Review

Hanley et al. (2008), the main aim of this study is to investigate the relationship between strength and workability of natural hydraulic lime mortar. This investigation is useful to find out optimum use of lime in buildings. In this study several mortar mix with different water contents were prepared. The workability, flexural strength and workability were tested for all the mortar mix.

Pati, et al. (2012) investigated the partial replacement of cement by fly ash in concrete mix and also as admixture. In **t**his research the case study for Deep Nagar thermal power plant of Jalgaon District in MS is performed. The concrete mixtures were prepared for fly ash addition from 5% to 25% and tested to find compressive strength. The test results indicated that the substitution of cement by fly ash leads to loss in compressive strength and also slow down its hardening. This investigation provides an environmental favourable fly ash disposal method for Deep Nagar. In this study, M20 grade concrete mix was utilized as per IS 456-2000. In this study the concrete includes the proportion of cement: fine aggregate: coarse aggregate as 1:1.5:3 and water cement ratio of 0.5.

Beemamol et al. (2013) examined the durability and strength of masonry mortar in which fine aggregates were replaced 50 % & 100 % by ceramic waste (locally called tailing sand). The industrial waste (fly ash) was also used as replacing material upto 25%. The workability of mortar was tested for 1:3 binders to sand ratio and 1:4 water to binder ratio. The experiment program includes the, Flexure strength test, Rapid Chloride Permeability Test, Strength test. On the basis of test results it was concluded that that the durability of mix increases due to replacement of fine aggregates by ceramic waste but the effect on strength was insignificant.

Braga et al. (2014) studied the replacement of cement content in mortars by crushed concrete aggregates. Number of standard tests was performed in this study to determine binding properties of concrete fines in mortar. The experiment program include the following tests:- Compressive strength test, Bulk density, Adhesive strength test, Consistency test, Flexure strength test, Water retentivity test, Permeability test, Dimensional instability test. The mortar mix designs were prepared with water cement ratio 1:3, 1:4 and 1:5. The test results were also compared with reference mortars with fine wastes.

Melichar et al. (2014) explored the basic mechanical and physical parameters of cement-polymer blended materials. The influence of admixtures on the aggregates was also observed. Further it was observed that micro silica represent 5% to 7.5% of cement weight in terms of thermal resistance. A polymer-cement paste of the proportion 3:7:1 is prepared by replacement of basic material with polymer. The tests performed to evaluate strength are Flexure strength test, Compressive Strength test and Bulk Density test.

Rai et al. (2014) evaluated the transverse strength and compressive strength of a 1:3 ratio mortar mix in which cement were replaced by low calcium fly ash as 15%, 20%, 25%, 33% and natural sand were replaced by quarry dust as 20%, 50% and 100%. The test results indicated that due to pozzolonic activity and efficient micro filling ability, the combined fly ash and quarry dust provided the excellent performance in mortar mix.

Thaker et al. (2014) developed a correlation between very low workable mix and high workable mix. The tests performed in this study were marsh cone test and Mini flow table test. Marsh cone test is applicable for cement paste having W/C ratio beyond 0.50 whereas same flow diameter was achieved in mini flow table test above 0.50 W/C ratio. By modifying cement paste cone volume, it is possible to evaluate flow behavior of cement paste up to W/C ratio 0.62.

Singh et al. (2015) investigated the replacement of cement or sand in concrete mix by certain percentage of silica fumes. The test results indicate that silica fume improve mechanical properties of concrete as it contains pozzolonic material silica in non-crystalline form. Three concrete mix were designed as proportions 1:3, 1:4 and 1:6 and tested for compressive strength. The experiments results indicated that the addition of silica fume in concrete mix improves the compressive strength**.**

Satyapriya (2017) evaluated the optimum percentage of partially replacement of cement in mortar by rice husk ash. The following tests were conducted in this study:- initial setting time, normal consistency, bulk density test, final setting time, compressive strength test, water absorption test, density test. The test results concluded that the optimum percentage og rice husk ash as partially replacement of cement in mortar mix is 0 to 20%.

Panda et al. (2017) investigated mix design process of high strength concrete with 60 N/mm^2 specified characteristic compressive strength as per IS-10262:1982. In this study the coarse aggregates in concrete mix were partially replaced by marble chips. Super-plasticizers were also used in High strength concrete design. This study concluded that high strength in concrete mix can achieved by utilizing good quality ingredients, by proper mixing and using low water - cement ratio and by proper casting

and testing & by following calculations of mix design. This study also concluded that by addition of super-plasticizers in ordinary concrete improve its properties like: durability, strength etc.

Sun et al. (2018) investigated the properties of high performance cement mortar (HPCM) and its optimum formulation. The grouting of cement mortar was also studied in this research. The results indicate that expansion admixture, poly carboxylate super plasticizer, and accelerators have different impact on the strength, workability and the shrinkage in HPCM, and the workability of HPCM is improved by adding these three admixtures. This study also concluded that the grouting rate more than 90% the semi flexible material provided the better pavement performance.

3 Waste Material

There are several Kota stone mines are located in district Kota of Rajasthan. The places where the Kota stone are quarried in Rajasthan are Kota, Ramgajmandi, Chechat, Jhalawar, Modak, Kherabad etc. Two type of wastes are generated first is quarry/sawing/cutting from in-situ stone site and second is polishing waste from construction sites. The raw stone blocks are cut either into slabs or tiles of various thickness (generally 2 or 4 cm), by using diamond blades. During this processing of stone, the blades of the cutter needed the shower of water for cooling and to absorb dust. The waste water comes through the stone processing is very alkaline in nature and affect the polishing of slabs when reuse in processing. The volume of this waste water is very large so it is stored in large pits where suspended particles settle down and the slurry is collected in trucks for disposal. This waste water stone slurry contains high amount of stone powder in it. So, this waste Kota stone slurry is used in this present study in grout mix. The types of stone waste and generation process are presented in Fig. 1 and Fig. 2.

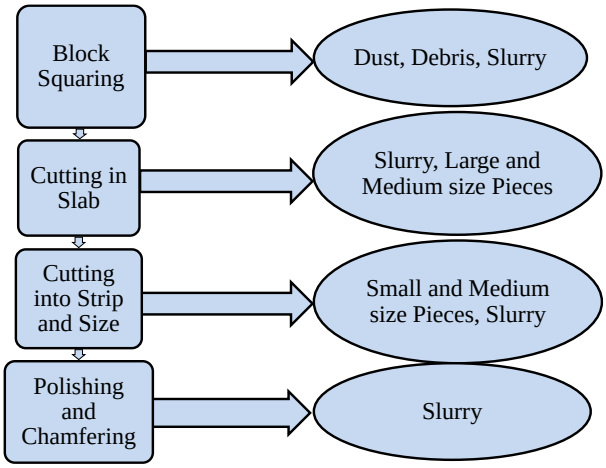

Fig. 1. Generation of Kota Stone waste.

Chemically Kota stone is siliceous calcium carbonate rocks. The chemical composition is as given in Table 1.

Fig. 2. Forms of Kota Stone waste.

Table 1. Chemical formation of Kota Stone.

Chemical	Percentage
Silica (SiO_2)	20-25 %
Lime (CaO)	38-42 %
Alumina (Al_2O_3)	2-4 %
Magnesium oxide	4.13 %
Potassium oxide	0.40 %
Ferrous oxide	0.85 %
Titanium di-oxide	0.05 %
Sodium oxide	1.21%
Loss on Ignition	30-32 %

4 Experimental Investigation and Results

4.1 Tests performed on Kota stone waste

Sieve analysis (IS 2720-part IV): Kota-stone-waste in powder slurry form is collected from a dumping field in Kota. **S**ieve analysis test is conducted on its sample. The test results are presented as particle size distribution curve given in Fig. 3. The waste can be classified as poorly graded sand (SP) based on the shape of the curve.

Specific gravity by pycnometer (IS 2720-part III): The average specific gravity of the three samples of Kota stone waste is determined as **2.15.**

Liquid limit by cone penetrometer (IS 2720- part V): The cone penetration test results on the Kota stone waste samples are presented in Fig. 4**.** Liquid limit (L.L.) of the waste is determined as **43.4 %**.

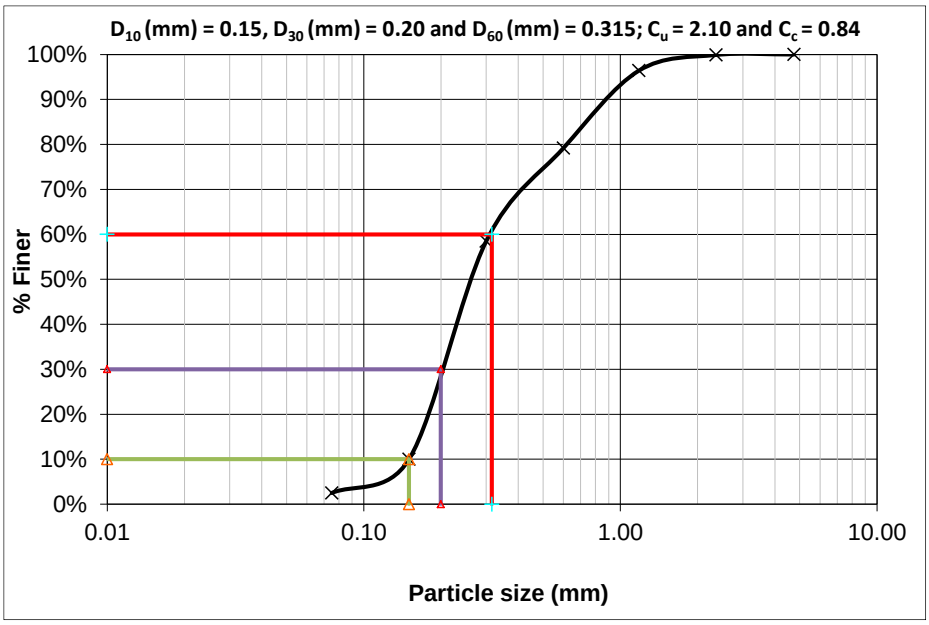

Fig. 3. Particle Size Distribution Curve of Kota-stone-waste.

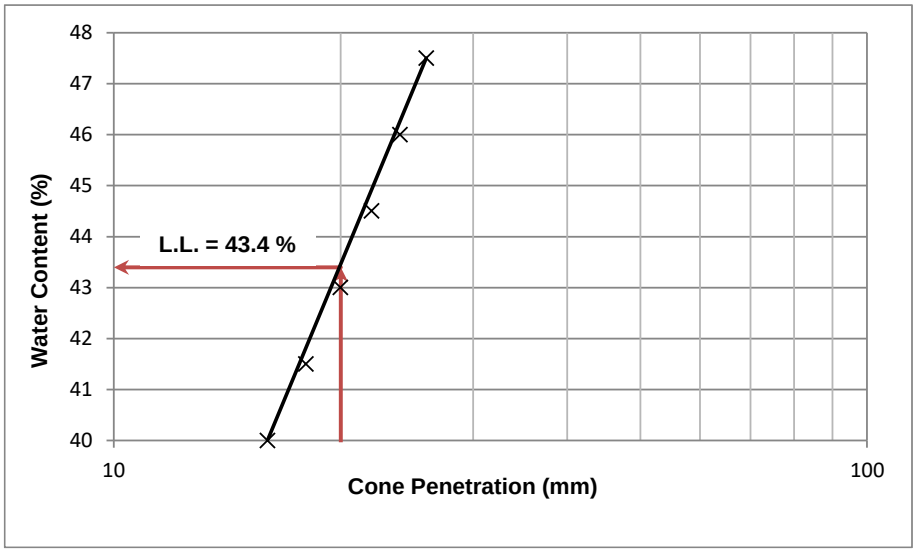

Fig. 4. Plot of Cone penetration test.

4.2 Tests performed on the mortar

Sample preparation: There are five different mix samples were tested by replacing the cement content by Kota-stone-slurry in various percentage. Water cement ratios in various mixes are according to proportion (1:6). Table 2 presents the details of the sample preparation.

Table 2. Different proportions of materials by weight.

Mix No.	Percentage Replacement	Cement (kg)	Kota-Stone -Slurry (kg)	Sand (kg)	Water (kg)	Water cement ratio
1	0	1.00	0.00	8.7	0.8	0.8
2	5	0.95	0.05	8.7	0.8	0.83
3	10	0.90	0.10	8.7	0.8	0.89
4	15	0.85	0.15	8.7	0.8	0.94
5	20	0.80	0.20	8.7	0.8	1

Compressive strength test results: Compressive strength test on cubes of size 50 mm was conducted at the age of 7 and 28 days as per Indian standards (IS 2250: 1981). The desired strength for cubes was taken as 9 MPa. The test results of all the mixes are shown in Fig. 5. 28 days compressive strength of all the mixes is lying above 7.5 MPa or above so the mixes can be grade as MM 7.5 (clause 6.1, IS 2250: 1981). As per table 4 water cement ratio increases with Mix. No. 1 to 5, accordingly compressive strength should fall from mix 1 to mix 5. On the other hand replacement of cement with Kota-stone-slurry may impart some additional strength as of that compressive strength does not fall. The optimum value has been obtained for mix 3 which gives value of 8.78 MPa at the age of 28 days.

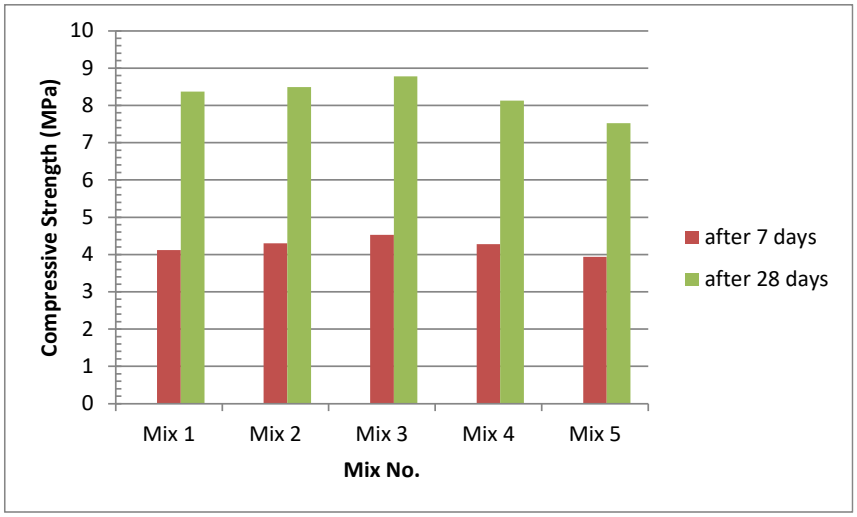

Fig. 5. Compressive strength comparison after 7 & 28 days.

5 Conclusions

1. Test results show that the compressive strength of the mortar was increased up to 10% replacement of cement by Kota-Stone-Slurry, after that it was decreased. So it is adequate to replace cement up to 10% without any loss in strength. Thus, Kota stone slurry can be a perfect alternative for partial replacement of cement.
2. Kota-Stone-Slurry as a substitute for cement will not only increase the strength, but also it will decrease the waste which is produced every year in abundance. The use of Kota-Stone Slurry will reduce the quantity of CO_2 produced in the manufacturing process of cement which is very harmful for nature. This emission of carbon dioxide can be reduced by sustainable use of the waste as a binding material in the mortar.
3. The present study focused on investigation of workability and preliminary compressive strength of the mixtures prepared with Kota-Stone-Slurry replacements. As future recommendation, the durability can also be checked by performing microscopic studies.

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