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Effective Reapplication on Concrete Mix Design of the Residues Found in Kota Stone Quarries

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Abstract

The emergence of industries nowadays shows a country's progress. The need for residue removal will surely rise as a result of this expansion. Land dumping is one of the more conservative methods of disposing of such industrial waste, but it requires a significant area of precious land. Because of the demand for sustainability, there are currently several possibilities that imply that these waste products will be used as construction materials in a range of civil engineering applications. Kota stone waste aggregate and slurry pollute the environment in mining and industrial locations. There is no mechanism for appropriately disposing of Kota stone waste. Several mounds of Kota stone waste aggregate have accumulated as a result of trash dumping in the area. A laboratory-based experimental study was conducted to decrease the environmental effect of various types of residuals with the objective of attaining sustainability by reducing, recycling, and reusing waste aggregates to their optimal purpose. Several research have claimed that stone mining and cutting detritus should be used as an aggregate in concrete compositions. To evaluate the material's efficacy, different percentages of kota stone aggregates (KSA) were replaced for natural aggregate (0%, 10%, 20%, 30%, 40%), and the mechanical characteristics of the concrete mix were evaluated.

Keywords: *Mechanical properties, Quarry waste, sustainability, Workability, Concrete mix, Compressive strength*

INTRODUCTION

When compared to consumption, the global rate of industrial residue generation surpasses its maximum limit. On the other hand, the construction rate is rising, which increases demand for natural aggregates; as a result, aggregates have become an essential commodity today (Berwal et al., 2014). Mining and extraction of these natural resources has increased dramatically, hastening depletion. As a result, finding an alternative supply of these natural aggregates is crucial. The earth gives us with a variety of natural stone beauty that we must respect as one-of-a-kind treasures. Granite, sandstone, slates, kota stones, quartzite, and kota stones come in a variety of colours, shapes, and sizes in India. The distinctive Kota stone selection is easily available in the natural surroundings and is unique to the Kota locale. Kota stones, which are constructed of limestone, are frequently utilised in apartment interior design. The fast growth of Kota stone firms creates a significant quantity of harmful slurry dust, which is a concern for the people surrounding them as well as an industrial pollution, harming the environment's ecological system. It is a type of solid waste generated by stone cutting and polishing.

Kota stone is found in the Rajasthan districts of Kota and Jhalawar and is commonly used as a decorative material in homes and workplaces in the form of tiles and floor coverings. Because of its enormous popularity among buyers and sellers, its mining and waste have grown significantly. Every year, approximately 2.50 to 3.00 million tonnes of stone polish (slurry) and 175 million tonnes of quarrying waste are produced, which are discharged into convenient local areas as stone chips, fine slurry powder, and boulders during the cutting and polishing process, posing significant environmental and ecological threats. The use of kota stone residue as a distinct type of construction material in civil engineering is being researched.

Recycling techniques are being employed to tackle waste material difficulties all over the world, and many nations have proved the beneficial use of these waste materials in building projects without hurting the environment or natural resources. Several studies in the literature demonstrate the utility of quarry and mine waste in partial aggregate substitution in concrete mixes, such as the efficacy of steel slag, glass, and marble waste in different pavement layers (Sharma et al., 2016; Behiry, 2013). Ibrahim et al. (2009)

use marble dust instead of fine aggregate. Bekoe[12] assessed the suitability of recycled concrete aggregate (RCA) in concrete pavement applications. Keun-Hyeok Yang et al.[13] investigated the effect of concrete features on the kind and amount of replacement of nine recycled quarry-based aggregate concretes and a control concrete constructed completely of natural aggregates. Likewise, and [1-10] demonstrated the use of quarry mining waste leftovers in the form of aggregates as a civil engineering building material.

Quarry-based aggregates, according to the lecturers, might be utilised as a partial replacement for natural aggregates (NA). The feasibility of substituting NA with different percentages of kota stone aggregates (KSA) (0%, 10%, 20%, 30%, 40%) and finding the ideal composition for concrete mixes was explored in this study.

SCOPE AND OBJECTIVES

Kota stone waste aggregate and slurry pollute the environment in mining and industrial locations. The proper disposal of kota stone waste has not been achieved due to a lack of research and development on kota stone waste. Several mounds of kota stone waste aggregate have accumulated as a result of rubbish dumping around the region (Figure 1).

The major purpose of this research is to look at the usage of kota stone waste aggregates in concrete mixes and how they affect the mechanical and strength properties of the concrete produced. The goal of this study was to develop an optimal mix design for the use of KSA as a coarse aggregate, as well as to examine the compressive strength and characteristics of grade M20 concrete.

Figure 1

The following are the primary goals of this research:

- To investigate the mechanical properties of natural aggregate and kota stone aggregate.
- To investigate the compressive strength of Pavement Quality Concrete (PQC).
- Specimen testing for compressive strength after 7 days and PQC after 28 days.
- Determine the best dose of Kota stone aggregate for Mix Design.

MATERIALS AND METHODOLOGY

Materials Used

The following raw materials according to suitability and availability of source have been used which are described here:

Sand

In this study, Kalisindha river sand was collected locally and sieved to determine water absorption, surface moisture content, specific gravity, and gradation. Sandas in zone I were utilised in accordance with IRC15:2011 (Zone I).

Natural Aggregate (Na)

The basalt rock-based aggregates with nominal sizes of 10mm and 20mm were utilised in the ratio specified in the respective specification. The aggregates were collected locally and sieve analysed for water absorption, surface moisture content, specific gravity, and gradation.

Kota Stone Aggregate (Ksa)

Kota stone waste aggregate was gathered in the form of waste cutting stone from the local kota stone tile factory. Following that, the cutting stones were broken into little pieces with a crusher (Figure 2), and the gradation was completed with sieves to produce 10mm and 20mm aggregates. Kota stone aggregates are naturally resistant, durable, and compact. The physicochemical properties of KSA are shown in Table 1.

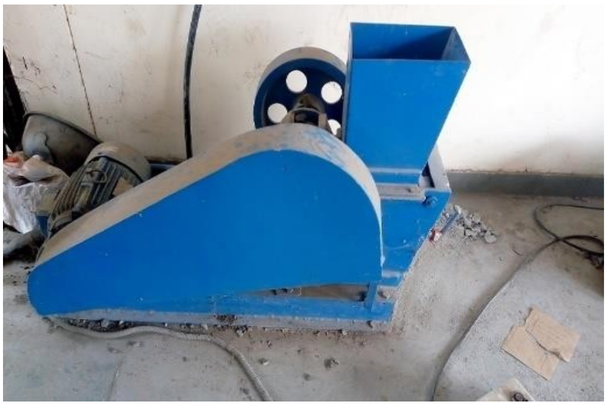

Fig.2:-Crusher used for crushing

Table 1:-Physical properties of kotastone

Properties	**Values**
Compressive Strength (kg/mm^2)	21.75
Abrasion value (%)	18.12
Oil Absorption (%)	Nil
Water Absorption (%)	0.31
Density (Kg/m^3)	2.5- 2.65
Porosity	Quite Low
Weather Impact	Resistant

Cement

According to IS: 1489-part-1, ordinary Portland cement of grade 33 (OPC33) was utilised (1991). The specific gravity of cement was calculated to be 3.19. Tables 2 and 3 show the physical and chemical properties of cement, respectively.

Table 2:-Physical properties of cement

Cement Tests	Result	IS Standard Used
Fineness of Cement	2.86%	IS: 4031-part-1 (1996)
Consistency of Cement	29.24%	IS: 4031-part-4 (1988)
Initial Setting Time	30 minutes	IS: 4031-part-5 (1988)
Final setting time	600 minutes	IS: 4031-part-5 (1988)

Table 3:-Chemical characteristics of cement

Chemical Compositions	Value (%)
SiO2	20
Al2O3	6
Fe2O3	3
CaO	63
MgO	2
SO3	1.5
Na2O + K2O	1.2
Loss on ignition	3.3

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METHODOLOGY

The current work's methodology includes determining the mechanical properties of the raw materials used in mix design, preparing concrete mixes (substitution of various percentages of KSA along with NA), casting, curing, and testing of specimens, evaluating and analysing results, and discussing the results. First, an experimental study was carried out to establish the applicability of KSA over NA. Various aggregate parameters such as impact value, abrasion value, water absorption, and specific gravity were measured for various KSA and NA compositions using appropriate Indian Standards (Table 5). The workability of concrete mixes was then tested using KSA Aggregate. A concrete control mix with 466.67 kg/m3 of ordinary Portland Cement (OPC) and a water/cement (w/c) ratio of 0.40 was prepared. After that, the concrete mixes were made by replacing 0%, 10%, 20%, 30%, and 40% of the NA in the control mix with KSA. At 7 and 28 days, the workability and compressive strength of about 30 cubes of the aforementioned compositions were evaluated and recorded. The samples were submitted to the Compressive Strength Test of Hardened Concrete after 7 and 28 days of curing. For the compressive strength test, three cubes of nominal size 150x150x150mm are utilised, and their surface area is calculated by measuring the cube's dimensions. A sample's compressive strength is calculated by dividing its maximum load by its cross-sectional area. Before performing this test, the cross sectional area should be determined since tiny differences in area result in variances in compressive strength. The most severe load applied to each of the three samples was recorded, and the average of these three values was used to compute the compressive strength of the concrete sample.

MIX PROPORTIONING FOR CONCRETE MIX DESIGN

Table 4:-Material quantity for concrete mix design casting D0% to D40%

Particular	D0%	D10%	D20%	D30%	D40%
Cement (Kg)	466.67	466.67	466.67	466.67	466.67
NA 20 mm (Kg)	699.85	433.18	503.70	573.92	648
NA 10 mm (Kg)	699.85	433.18	503.70	573.92	648
Sand (Kg)	699.85	699.85	699.85	699.85	699.85
KSA 20 mm (Kg)	0	299.85	225.77	151.70	77.03
KSA 10 mm (Kg)	0	299.85	225.77	151.70	77.03
Water (l)	244.44	244.44	244.44	244.44	244.44

*D0%, 10%, D20%, D30%, and D40%represents 0, 10, 20, 30, and 40 replacement of KSA by NA

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The mix proportioning for the concrete mix design for M20 grade as per IS: 10262-2009 was completed in accordance with IRC: 15-2011. Table 4 shows the material quantities for the concrete mix design.

RESULT AND DISCUSSION

Aggregate Test

Various KSA and NA traits were analysed, documented, and tested for appropriateness for construction work.

Table 5 compares the physical parameters of NA and KSA observed in the laboratory. After that, different percentages of KSA were replaced with NA, and the same experiments were done with each combination of KSA and NA.

Effect of KSA on Impact Value of Aggregates

It may break down into smaller pieces as a result of the application of abrupt dynamic shock during and after the building of aggregates. The impact value test determines how much impact load a specific aggregate can withstand. As a result, aggregate should be strong enough to withstand impact disintegration. The impact value test is used to assess this distinguishing trait. Figure 3 depicts the variance in effect value of all KSA-NA mix compositions investigated. The impact test results demonstrate that substituting KSA with NSA up to 40% raises the effect value practically linearly but within the acceptable limits specified in Table 5.

Table 5:-Physical properties of NA and KSA

Properties	**Indian Standard**	KSA	**NA**	**Permissible Limit**
Specific Gravity	IS:2386 PartIII	2.68	3.0	2.5 – 3.0
Impact Value (%)	IS:2386 PartIV	18.78	10.87	30
Crushing Value (%)	IS:2386 PartIV	23.21	16.42	30
Los Angeles Abrasion Value (%)	IS:2386 PartIV	26.82	14.87	35
Combined Flakiness and Elongation Index (%)	IS: 2386 PartI	31.26	22.52	35
Water Absorption (%)	IS:2386 PartIII	1.6	0.7	2%

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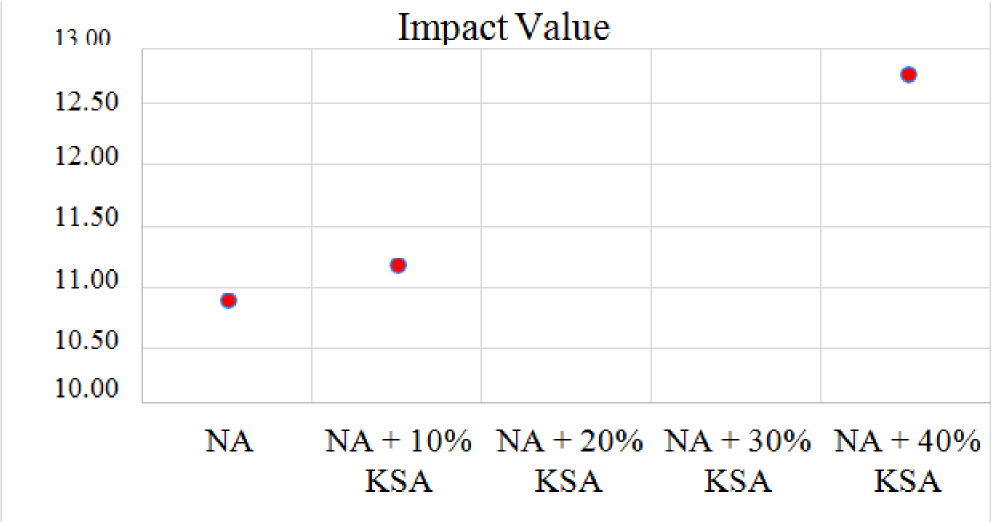

Fig.3:-Variation in impact value of all the studied compositions of KSA-NA mixes

EFFECT OF KSA ON ABRASION VALUE

Aggregate abrasion resistance shows the aggregate's hardness and ability to endure wear and tear. The Los Angeles abrasion test is intended to quantify the percentage wear generated by the relative rubbing action of aggregate and steel balls used as an abrasive charge. Figure 4 displays the abrasion value variance of all evaluated KSA-NA mix compositions.

The abrasion test findings show that after substituting KSA for NSA up to 40%, aggregate abrasion rises almost linearly, or in other words, the resistive effectiveness of aggregate blends loosens against abrasion while being within the allowable values as given in Table 5.

KSA's Influence on Specific Gravity and Water Absorption

The specific gravity test of aggregates is used to measure the material's strength or quality, whereas the water absorption test determines the water holding capacity of coarse and fine aggregates.

The variation in specific gravity and water absorption values of all KSA-NA mix compositions studied is depicted in Figure 5-6.

The results of the experiments demonstrate that substituting KSA for NSA up to 40% reduces aggregate specific gravity and increases water absorption values essentially linearly, although the results stay within the permitted ranges given in Table 5.

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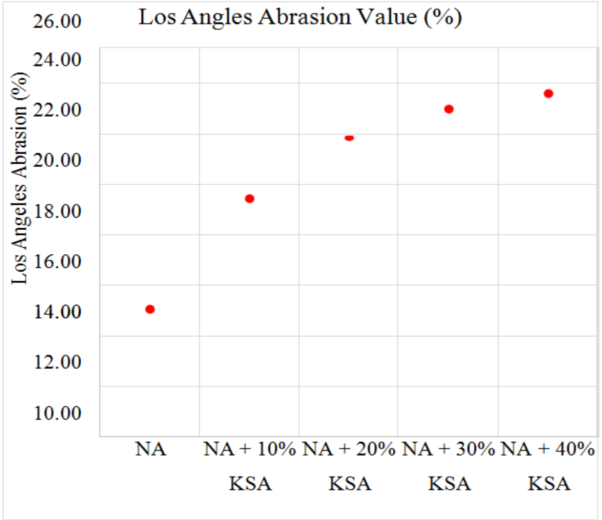

Fig.4:-Variation in abrasion value of all the studied compositions of KSA-NA mixes

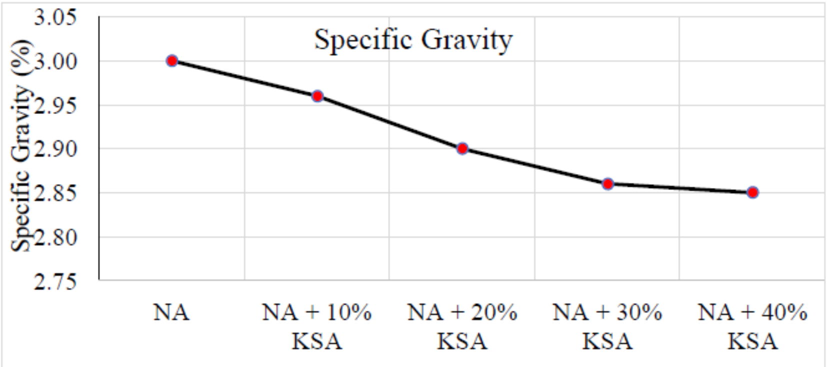

Fig.5:-Variation in specific gravity of all the studied compositions of KSA-NA mixes

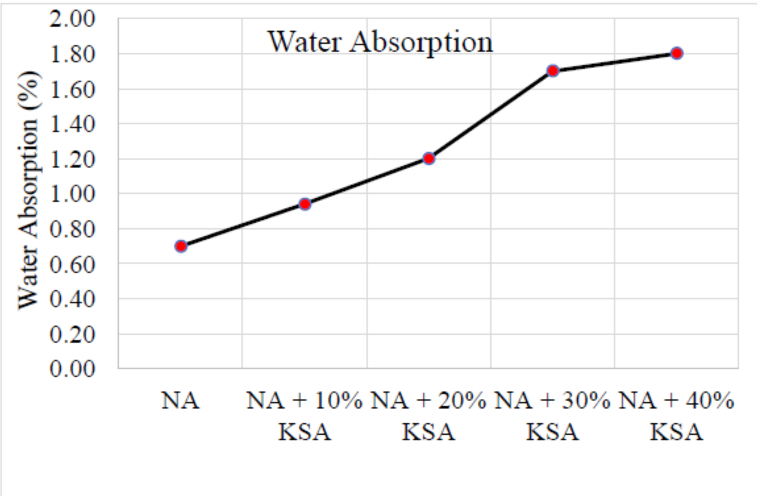

Fig.6:-Variation in water absorption value of all the studied compositions of KSA-NA mixes

Effect of KSA on Workability Slump Test

The IS: 1199-1959 criteria were used to evaluate the Slump Test's applicability. The slump of each concrete mix with 0%, 10%, 20%, 30%, and 40% KSA replacement was measured. The slump test results are depicted in Figure 7, which show that concrete manufactured with natural aggregates has a greater slump value, but concrete made with 40% KSA replacement has a lower slump value but is still within the permitted limit indicated in Table 5. KSA has a low slump because to the high water absorption of RCA during the blending process.

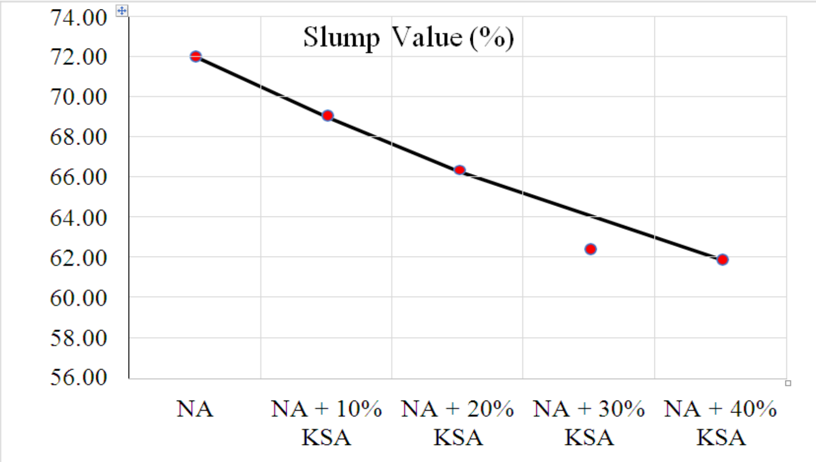

Fig.7:-Graph for Slump value at different % replacement of RA with NA

EFFECT OF KSA ON COMPRESSIVE STRENGTH

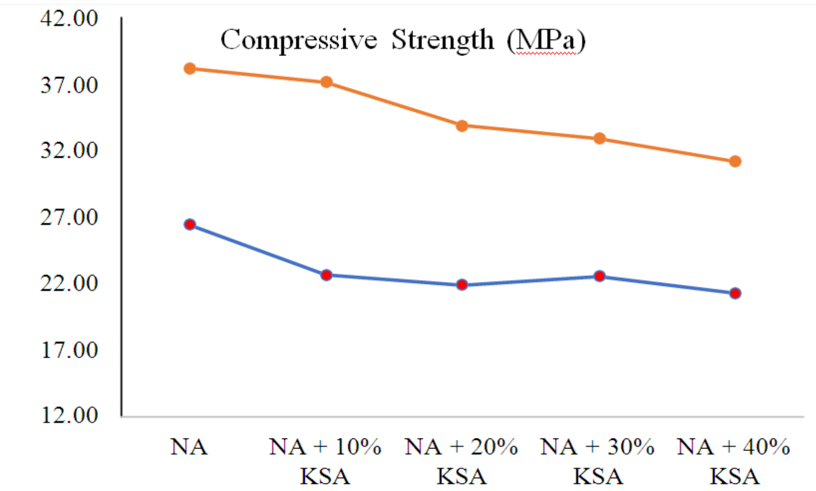

Fig.8:-Variation in compressive strength of all the studied compositions of KSA-NA mixes

The findings of the Compressive Strength Test at various degrees of NA substitution with KSA are shown below. Figure 8 depicts the fluctuation in compressive strength of concrete cast with various KSA over NA compositions and cured at 7 and 28 days, respectively. It is clear from the results that concrete constructed with natural aggregates has higher compressive strength values than concrete manufactured with 40% KSA substitution. But the results for compressive strength were good enough to let the user or engineer choose the right amount of KSA-NA mixes to get the needed compressive strength.

CONCLUSIONS

The result of this extensive, scientifically based laboratory research effort investigates the idea of employing kota stone waste instead of precious natural aggregate. The purpose of this study was to assess the extent to which NA might be substituted with KSA in concrete work in order to develop new applications that would explore the path to natural aggregate and effective utilisation of kota stone aggregate waste, hence minimising industrial waste. The following findings were achieved by replacing NA in the concrete layer with varied amounts of KSA:

The impact and abrasion value of various KSA-NA blends improve as KSA substitution rises by up to 40%. The effect value increases roughly linearly, but within safe bounds.

The specific gravity and water absorption values of various KSA-NA blends grew and dropped linearly as KSA substitution increased by up to 40%.

Based on the statistics shown thus far, it appears that up to 40% KSA can be utilised. For 40% of KSA, the compressive strength of the requisite 28-day characteristics remained within the limits of the average compressive strength of three samples of not less than 20 MPa.

The results indicate that substituting NA by 20-40% with KSA is better since its compressive strength and workability are within acceptable levels. An engineer/user, on the other hand, may easily pick the proper NA-KSA mix compositions based on the desired strength.

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