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Experimental Studies on Paver Block Concrete using Granite and Kota Stone Waste with Environmental effects on Strength

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ABSTRACT

The need to address the worldwide demand for the preservation of limited resources has prompted the exploration of alternate materials. The application of waste materials in the concrete sector is experiencing a growing trend due to its potential to mitigate costs and minimize environmental repercussions. This study aims to assess the appropriateness of utilizing waste materials from granite and Kota stone for the production of interlocking concrete paver blocks (ICPB). The current study examines the potential use of waste materials from granite and Kota stone as substitutes for natural aggregates in the production of concrete interlocking paving blocks. The focus is on applications that cater to pedestrians and non-traffic scenarios. Concrete blocks of M30-grade were cast for this study. The replacement percentages were ranged from 0% to 100% for Kota stone as coarse aggregates and from 0% to 40% for granite waste as fine aggregates and total of 543 samples were cast using the replacement level. The mix proportion ratio used was 1:1.57:2.76 (cement: sand: aggregates) while continuing a constant water-cement ratio of 0.45. Weathered Kota stone waste (0, 25, 50, 75, 100%) was also used as anauxiliary for coarse aggregates in M30-grade concrete. The tests conducted covered the physical characterization of the constituent materials, determination of compressive strength, split tensile strength, flexural strength, abrasion resistance, and water absorption tendency for both hardened concrete blocks and I-shaped interlocking pavers. The result indicates that while using stone waste (granite and Kota stone), the required compressive strength was achieved up to a replacement level of 100% Kota stone and 5% granite waste. Flexural strength and splitting tensile strength were also satisfactory at all replacement ratios, along with normal water absorption and minimum abrasion. Paver blocks were also cast from waste stones at various replacement levels. In this study, concrete blocks were also cast using weathered Kota stone waste, which also provided sufficient strength at some level of replacement. The findings suggest that waste stone may be a viable option for manufacturing interlocking pavers, contributing to the development of an environmentally conscious and sustainable pavement infrastructure.

Key words : *Granite Waste, Kota Stone Waste, Weathered Kota Stone, Paver Block, Waste recycling.*

Introduction

The utilization of waste materials is increasingly being adopted as a sustainable approach in the manufacturing process of concrete. The experimental investigations conducted on concrete fabricated with alternative materials have demonstrated the potential to achieve strengths that are relatively similar to those of conventional materials. The phenomenon of pollution and environmental issues is

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now on the rise in many emerging nations as a result of escalated urbanization, industrialization, and infrastructure advancements. The rise in this phenomenon has resulted in the production and discharge of various types of perilous and non-decomposable solid waste materials into the surrounding ecosystem. In recent times, there has been an increasing interest in utilizing various types of hazardous waste, including stone refuse, as a potential component in concrete composites.India is host to a diverse range of rocks and minerals, primarily sourced from the state of Rajasthan. The region exhibits significant reserves of various geological formations, including granite, marble, limestone, sandstone, quartzite, slate, and other similar materials. The stone industry significantly contributes to the generation of solid waste, resulting in the production of large quantities of such trash on a global scale.Significant quantities of trash are generated during the cutting and polishing processes of stones, resulting in their disposal in landfills, thereby consuming extensive areas of arable land. Landfills, in turn, emit detrimental gases that contribute to the phenomenon of climate change.The current study focuses on the partial substitution of natural sand with granite stone waste, and the additional of coarse aggregates with both Kota stone waste and aged Kota stone waste. This substitution is done in a manner that does not compromise the strength of the materials, while also conserving natural aggregates. This effort is regarded as a means of generating sustainable solutions for natural aggregates.

Mhamal and Savoikar (2023) explored the use of marble and granite stone dust by-products as a substitute for fine aggregates in concrete. A blend of marble and granite dust at varying weight percentages with 40% GGBS was used. It was found that substituting 20% of fine aggregates with the dust increased compressive strength by 23.34% and 14.4% compared to the control concrete. The study suggests that this substitution offers sand conservation and preserves natural resources.

Tangaramvong *et al.* (2021) studied on recycled granite aggregate in concrete found that it doesn't significantly affect compressive strength compared to normal concrete. However, incorporating 50% granite waste decreases tensile strength, especially in low-strength concrete mixtures. The study also found a decrease in slumps and set time for high-strength concrete with granite waste, with the lowest slump value in concrete containing 50% granite particles.

Thipparthi *et al*. (2021) studied the use of granite waste as a limited replacement for fine aggregate in M40 grade concrete. The study originate that the addition of granite powder significantly improved the compressive strength, split tensile strength, and flexural strength of the concrete. Thetest for compressive strength showed better results when 30% of the fine aggregate was replaced with granite powder.

Patil *et al.* (2019) investigated the mechanical characteristics of concrete by substituting natural sand with marble dust and coarse aggregate with kota stone. The study found that incorporating these materials enhanced strength and durability, with results of 89.30%, 86.09%, and 86.85% strength levels at 7, 14, and 28 days.

Materials and their properties

Cement: Cement serves as a binding agent within the composition of concrete. Ordinary Portland Cement (OPC) with a grade of 43 was utilized for this work. It was found that cement had a specific gravity of 3.09.

Fine Aggregates: The term "fine aggregate" encompasses natural or artificial sand, or a mixture thereof, comprising particles that are clean, durable, and possess a spherical or cubical shape. The dimensions of fine aggregates range from 0.075 to 4.75 mm. The sand utilized in this experiment contained a specific gravity of 2.64 and a water absorption rate of 0.80%.

Coarse Aggregates: The dimensions of coarse aggregates range from 20 to 4.75mm. The utilization of these additives enhances the overall quality and bonding properties of concrete, thus leading to an increased flexural strength. Two sizes of coarse aggregates, namely 12mm and 20 mm, were used in this study. The aggregates exhibited a specific gravity of 2.71 and a water absorption rate of 0.91%.

Granite Waste: Granite is classified as a phaneritic intrusive igneous rock, characterized by its coarse-grained texture. It mostly consists of quartz, alkali feldspar, and plagioclase minerals. The fine aggregates utilized in this investigation consisted of granite waste, which exhibited a specific gravity of 2.23 and a water absorption value of 1.24%.

Kota Stone: Kota Stone is a type of limestone known for its fine-grained texture, which is extracted from quarries located in the Kota area of Rajasthan, India. The present study utilized Kota stone waste as coarse aggregates, which exhibited a specific gravity of 2.67 and a water absorption value of 0.54%.

Weathered Kota Stone: Kota stone waste (weathered) has been collected from different sources like railway station, hospitals, community halls and residential houses etc. this stone waste divided into many grades according to visual inspection which are following.

Table 1. Gradation of Weathered Kota Stone

Grade of Kota Stone	Properties
Grade A	Excellentshape, size and moisture free
Grade B	Good shape with quit moisture content
Grade C	Organic matters presentwith uneven shape
Grade D	Muddy and excess organic matter present
Grade E	Very poor quality

Fig. 1. Experimental Materials

Mission of the research: According to the results of this research, waste materials can be used in the construction industry. The mission of this research is to reduce the consumption of natural aggregates and increase the use of waste stone in many construction projects as well as products. This research can be a big contributor to the 'Mission 2030' launched by the honorable chief minister of Rajasthan, Shree Ashok Gehlot ji, and will also fulfill the vision of Dr. Yuvraj Singh, the guide of this research.

Mix Design and Notation: The following figure1 shows the mix design for paver block concrete containing granite and Kota stone waste that was used in this research work.

Following Table 2 and 3 presents the composition notation for paver block concrete with a grade of M30.

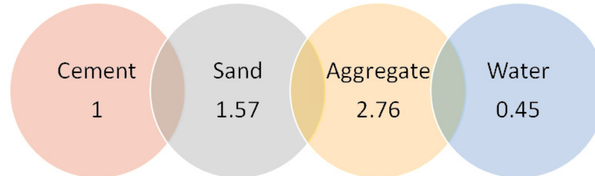

Fig. 2. Mix Proportion of Concrete (M30)

Table 2. Mix Notation of M30 Concrete

Concrete Mix	Coarse Aggregates replacement with Kota Stone	Fine Aggregates replacement with Granite Stone
A0	0	0
A01	25	5
A02	25	10
A03	25	20
A04	25	40
A05	50	5
A06	50	10
A07	50	20
A08	50	40
A09	75	5
A10	75	10
A11	75	20
A12	75	40
A13	100	5
A14	100	10
A15	100	20
A16	100	40

Table 3. Mix Notation of M30 Concrete using Kota stone aggregates (weathered)

Concrete Mix	Coarse Aggregates replacement with Kota stone (Weathered)
WS25	25%
WS50	50%
WS75	75%
WS100	100%

Results and Discussion

Compressive Strength: Compressive strength tests were conducted on hardened cubes at the age of 28 days in accordance with the IS:516-1959 standard. The obtained findings are presented in Tables 4 and 5. Figures 3 and 4 depict the compressive strength observed after a period of 28 days.

Figures 3 and 4 represent the compressive strength values of various concrete mixtures after a curing period of 28 days. The data reported in the study indicates that the compressive strength of all

Table 4. Compressive Strength Test Results for M30 Concrete Mix at 28 Days

Paver Block Concrete Mixes	Coarse Aggregates Replacement With Kota Stone (%)	Fine Aggregates Replacement Granite Waste (%)	Compressive Strength (N/mm^2) (28 days)
A0	0	0	37.4
A01	25	5	37.1
A02	25	10	36.9
A03	25	20	36.7
A04	25	40	36.6
A05	50	5	36.2
A06	50	10	35.6
A07	50	20	34.4
A08	50	40	33.9
A09	75	5	33.5
A10	75	10	32.7
A11	75	20	32.1
A12	75	40	31.8
A13	100	5	31.2
A14	100	10	30.4
A15	100	20	29.2
A16	100	40	29.2

Table 5. Compressive Strength Test Results for M30 Concrete Mixusing Weathered Kota Stone Waste at 28 Days

Concrete Mixes	Coarse Aggregates Replacement With Kota Stone (%)	Compressive Strength (N/mm^2) (28 days)
WS25	25	35.3
WS50	50	32.1
WS75	75	30.6
WS100	100	29

the mixes containing granite and Kota stone waste exhibited a similar level of strength compared to the control mix. The experimental findings indicate that the greatest compressive strength is achieved when 25% and 5% of the coarse and fine aggregates are respectively substituted with Kota stone and granite waste. The compressive strength at 25% and 5% replacement after 28 days was determined to be 37.1 N/mm^2, which closely approximates the strength of the control mix. A reduction in strength of 22.54% was seen when replacing both coarse and fine aggregates with Kota stone and granite waste at levels of 100% and 20% respectively, as compared to the control mix outcomes. The optimal level of replacement for achieving the highest compressive strength of weathered Kota stone waste is found to be 25%.

Flexural Strength: Flexural strength tests were conducted on hardened cubes after 28 days, following the guidelines outlined in IS: 516-1959. The obtained data are presented in Tables 5 and 6. Figures 6 and 7 represent the flexural strength observed after a period of 28 days.

Figures 5 and 6 represent the flexural strength of various concrete mixtures after a curing period of 28 days. The reported data indicates that the flexural strength of all the mixes containing granite and Kota

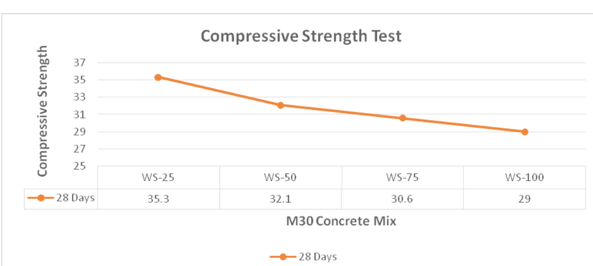

Fig. 3. Compressive Strength of M30 Concrete using Granite and Kota Stone Waste

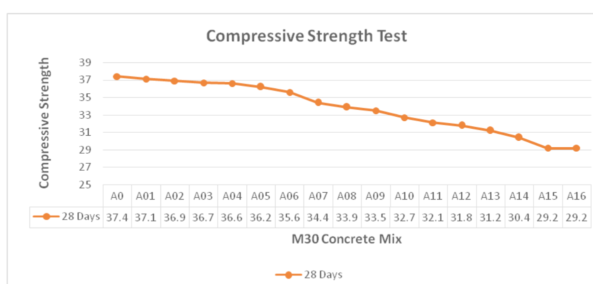

Fig. 4. Compressive Strength of M30 Concrete using Weathered Kota Stone Waste

Table 6. Flexural Strength Test Results for M30 Concrete Mix at 28 Days

Paver Block Concrete Mixes	Coarse Aggregates Replacement With Kota Stone (%)	Fine Aggregates Replacement Granite Waste (%)	Flexural Strength (N/mm^2) (28 days)
A0	0	0	4.8
A01	25	5	4.8
A02	25	10	4.8
A03	25	20	4.8
A04	25	40	4.8
A05	50	5	4.7
A06	50	10	4.7
A07	50	20	4.6
A08	50	40	4.6
A09	75	5	4.5
A10	75	10	4.5
A11	75	20	4.5
A12	75	40	4.4
A13	100	5	4.4
A14	100	10	4.4
A15	100	20	4.4
A16	100	40	4.4

Table 7. Flexural Strength Test Results for M30 Concrete Mix using Weathered Kota Stone Waste at 28 Days

Paver Block Concrete Mixes	Coarse Aggregates Replacement With Kota Stone (%)	Flexural Strength (N/mm^2) (28 days)
WS25	25	4.6
WS50	50	4.3
WS75	75	4.0
WS100	100	3.9

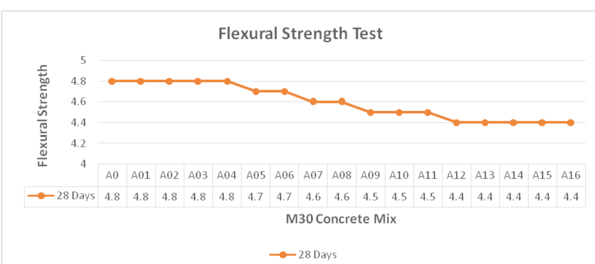

Fig. 5. Flexural Strength of M30 Concrete using Granite and Kota Stone Waste

stone waste exhibited a level of proximity to that of the control mix. The findings indicate that the greatest flexural strength is achieved when 25% of coarse and 5-40% of fine aggregates are replaced with kota stone waste and granite stone waste. The flexural strength at 25% and 5% replacement after 28 days was determined to be 4.8 N/mm^2, which closely approximates the flexural strength of the control

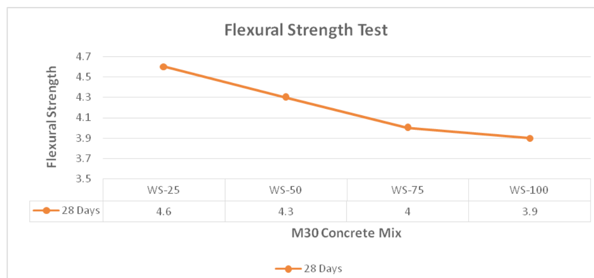

Fig. 6. Flexural Strength of M30 Concrete using Weathered Kota Stone Waste

mix. The highest flexural strength for weathered Kota stone waste is obtained at 25% replacement level.

Splitting Tensile Strength: The hardened cubes underwent Splitting Tensile Strength testing at 28 days, following the guidelines outlined in IS: 5816-1999. The obtained data have been presented in Tables 8 and 9. Figures 7 and 8 exhibit the Splitting Tensile Strength observed at the 28-day stage.

Figures 7 and 8 indicate the Splitting Tensile Strength of various concrete mixtures after a curing period of 28 days. The data presented in the study indicates that the Splitting Tensile Strength of all the mixes containing granite and Kota stone waste exhibited a similar level of strength compared to the control mix. Results show that highest Splitting Tensile Strength is obtained at 25% and 5% replacement of coarse and fine aggregates with Kota stone and

Table 8. Splitting Tensile Strength Test Results for M30 Concrete Mix at 28 Days

Paver Block Concrete Mixes	Coarse Aggregates Replacement With Kota Stone (%)	Fine Aggregates Replacement Granite Waste (%)	Flexural Strength (N/mm^2) (28 days)
A0	0	0	2.77
A01	25	5	2.76
A02	25	10	2.75
A03	25	20	2.75
A04	25	40	2.74
A05	50	5	2.74
A06	50	10	2.73
A07	50	20	2.73
A08	50	40	2.73
A09	75	5	2.72
A10	75	10	2.72
A11	75	20	2.71
A12	75	40	2.70
A13	100	5	2.70
A14	100	10	2.70
A15	100	20	2.69
A16	100	40	2.67

Table 9. Splitting Tensile Strength Test Results for M30 Concrete Mix using Weathered Kota Stone Waste at 28 Days

Paver Block Concrete Mixes	Aggregates Replacement With Kota Stone (%)	Splitting Tensile Strength (N/mm^2) (28 days)
WS25	25	2.7
WS50	50	2.7
WS75	75	2.6
WS100	100	2.6

granite waste. Splitting Tensile Strength at 25% and 5% replacement at 28 days was found to be 2.76 N/mm^2 which is near to control mix. The highest Splitting Tensile Strength for weathered Kota stone waste is obtained at 25% replacement level.

Abrasion Resistance Test: Abrasion Resistance Tests were carried out on selected concrete mix

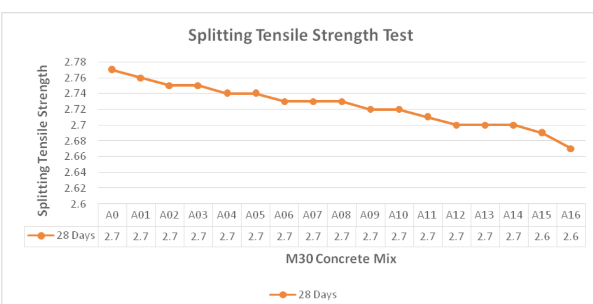

Fig. 7. Splitting Tensile Strength of Concrete using Granite and Kota Stone Waste

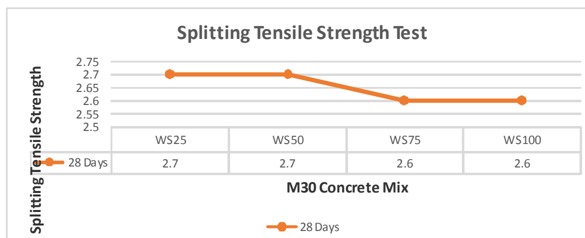

Fig. 8. Splitting Tensile Strength of M30 Concrete using Weathered Kota Stone Waste

paver blocks at 28 days as per IS: 15658-2021 and outcomes are given in Table 10 and 11. Figure 9 and 10 shows the abrasion resistance at 28 days.

Figures 9 and 10 depict the Abrasion Resistance of various concrete formulations after a curing period of 28 days. The available data indicates that the Abrasion Resistance of all the mixtures containing

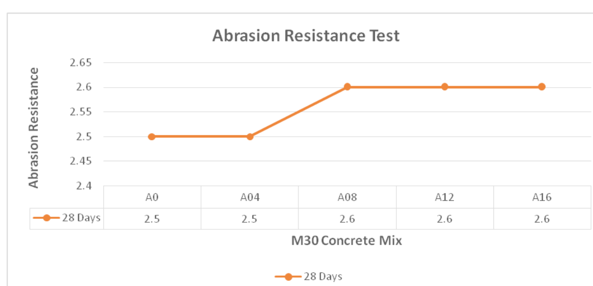

Fig. 9. Abrasion Resistance of Concrete using Granite and Kota Stone Waste

Table 10. Abrasion Resistance Test Results for M30 Concrete Mix at 28 Days

Paver Block Concrete Mixes	Coarse Aggregates Replacement With Kota Stone (%)	Fine Aggregates Replacement Granite Waste (%)	Average Abrasion Losst (mm)
A0	0	0	2.5
A04	25	40	2.5
A08	50	40	2.6
A12	75	40	2.6
A16	100	40	2.6

Table 11. Abrasion Resistance Test Results for M30 Concrete Mix using Weathered Kota Stone Waste at 28 Days

Paver Block Concrete Mixes	Aggregates Replacement With weathered Kota Stone	Average Abrasion Losst (mm)
WS25	25	2.63
WS50	50	2.65
WS75	75	2.69
WS100	100	2.71

granite and kota stone waste exhibited a similar level of resistance compared to the control mixture. Results show that lowest Abrasionis gained at 25% and 40% replacement of coarse and fine aggregates with Kota stone and granite waste. Abrasion Resistance at 25% and 40% replacementat 28 days was found to be 2.5 mm which is near to control mix. The lowest Abrasion for weathered Kota stone waste is obtained at 25% replacement level.

Water Absorption Test: Water absorption tests were conducted on specific concrete mix paver blocks after 28 days in accordance with the IS: 15658-2021 standard. The outcomes of these tests are presented in Table 12. Figure 11 depicts the water absorption at the 28 Days.

Figure 11 illustrates the Water Absorption percentages of various concrete compositions after a curing period of 28 days. The data reported in the study indicates that the water absorption of all the mixes using granite and Kota stone waste exhibited a similar level of water absorption compared to the control mix. Results show that lowest Water Absorption is obtained at 25% and 40% replacementof coarse and fine aggregates with Kota stone and granite waste. Water Absorption at 25% and 40% replacementat 28 days was found to be 3.22% which

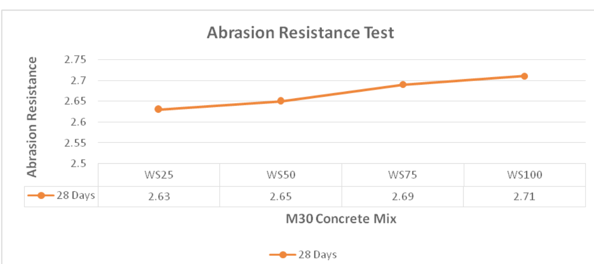

Fig. 10. Abrasion Resistance Test of Concrete using Weathered Kota Stone Waste

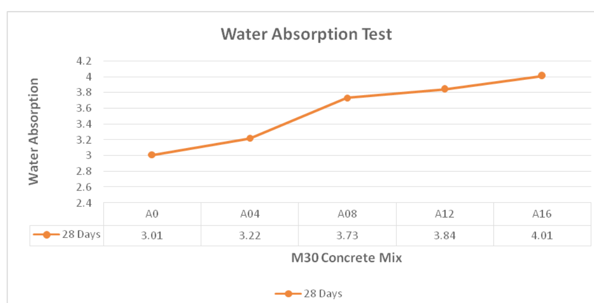

Fig. 11. Water Absorption of Concrete using Granite and Kota Stone Waste

Table 12. Water Absorption Test Results for M30 Concrete Mix at 28 Days

Paver Block Concrete Mixes	Coarse Aggregates Replacement With Kota Stone (%)	Fine Aggregates Replacement Granite Waste (%)	Water Absorption%
A0	0	0	3.01
A4	25	40	3.22
A8	50	40	3.73
A12	75	40	3.84
A16	100	40	4.01

is near to control mix.

Conclusion

The compressive strength test demonstrates a declining pattern as the proportion of fine and coarse aggregates replaced with granite waste and Kota stone waste aggregates increases. At 28 days, the required compressive strength of concrete is obtained up to 100% kota stone and 10% granite waste replacement of aggregates than conventional concrete. Compressive strength of weathered Kota stone concrete also provided best strength upto the replacement level of 75% of coarse aggregates. The results indicate that all concrete mix provided good flexural and splitting tensile strength. The concrete blocks show the best results at the replacement level of 25% Kota stone, along with 5–40% of granite waste with coarse and fine aggregates. Required flexural and splitting tensile strength for all weathered kota stone concrete achieved at all replacement level (0-100%). Concrete with granite and Kota stone replacement also shows best results for abrasion resistance. Minimum abrasion was observed at all replacement levels. Water absorption was minimum for all paver block concrete mixes. The act of preserving natural sand is of significant importance as it undoubtedly contributes to the protection of river sand, a precious resource that holds implications for the ecosystem. Therefore, using Kota stone and granite waste as a partial substitute for natural aggregates can be viewed as a sustainable option because it conserves a significant amount of natural aggregate and reduces the need for storage space, both of which would otherwise result in pollution issues if dumped in an open manner.

Conflict of interest: None

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