Sustainable Use of Granite Waste in Civil Engineering Applications: A Review

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Abstract- **In today's scenario, availability of natural resources is diminishing and simultaneously the waste generation due to cutting and polishing of stones is increasing considerably. Incorporation of these mining waste materials into construction process can provide a respite from both these issues. The waste generated from granite waste from mining industries are having texture similar to that of river sand, so it will be very beneficial for the environment to reutilize this waste for construction works. In this paper a review of contemporary practices of use of granite waste in different civil engineering applications has been done.**

Keywords: Granite Waste, Concrete, Mortar, Bituminous Mixes, Sustainability

1. INTRODUCTION

Rajasthan is a state rich in stones having 42 % of total granite reserves in India [1]. During the process of cutting, sawing and polishing of stones, around 50 – 70 % of stone waste is generated [2]. Rajasthan is the leading producer of marble, limestone, granite, sandstone etc. Granite is highly used as a dimensional stone as it possesses properties of hardness, durability, capability to take mirror polish and fascinating colors. There are various varieties of granite available in the market. Granite is highly used in flooring works. Granite has also been usedas a decorative stone and this has created a good export market for Indian Granite.

Granite includes silica, alumina, potassium oxide and sodium oxide in major composition. The density of granite ranges between 2.65 and 2.75 g/cc. The usual compressive strength is above 200 MPa. The melting point of granite is 1215 – 1260 ℃ [3]. In a study conducted by **Jain Abhishek et. al., (2022) [4]** SEM images of granite waste showed rough surface and angular texture.

There are a large number of granite cutting and processing units in Rajasthan. Major cities of Rajasthan having granite mines are Jalore, Sikar, Ajmer, Jaipur, Alwar, Pali, Udaipur, Shahpura, Chittorgarh, Jhunjhunu, Abu Road, Jodhpur etc [3]. In these units, a large amount of waste material is generated during cutting and polishing works.

The darker consequence of the stone sector is the massive amount of garbage produced each year, which is discarded in a hazardous manner. India is estimated to have 43,000 million cubic metres of granite reserves. It is 20 % of total granite reserves in the world. In Rajasthan 8 lakh metric tonnes of granite is mined annually. Around 15 % of total granite is discarded as waste during the cutting process [5]. Around 250 – 400 tons of granite waste is generated in India [6].

Proper collection and dumping of granite dust will reduce the amount of silica in the air This will reduce the risk of silicosis. Silicosis is an incurable, progressively disabling and sometimes fatal lung disease. Workers involved in the sandblasting, finishing, and installationof granite countertops are at risk of exposure to large amounts of crystalline silica. Workers who breathe in tiny particles of crystalline silica are at risk for silicosis.

Dumping stone waste on soil affects porosity, water absorption, and percolation, resulting in poor land quality. Calcium carbonate is collected in ditches and on the soil surface as a resultof stone slurry, leading to the creation of lime-cemented hardpans that hinder water infiltration and root penetration into the soil layer. Because of variations in pH, EC, salinity, and total dissolved solids (TDS), stone slurry waste lowers soil fertility [7].

During the rainy season, the disposal of dry mud and stone is transported as a stream ofwater; accumulates in a nearby fertile area, penetrates the earth, and mixes with local water sources, disrupting the environment. Respiratory diseases such as silicosis are common among indigenous peoples and workers living or working near mining sites [8].

2. SCOPE OF THE STUDY

This study focusses on the performance of granite waste obtained from stone processing units to be used for civil engineering applications. An organized literature study was done. Relevant literature was found using keyword-based search. Maximum data base was taken from Google Scholar and web of science. Attempt has been made to select latest research papers (After 2010). Emphasis is given to the effects on strength and durability properties of concrete after the addition of granite waste. The results are also presented in tabular form for easy understanding. At the end, final conclusions are drafted.

3. EFFECT OF GRANITE WASTE IN VARIOUS APPLICATIONS

3.1 Granite Waste in Concrete/ Self Compacting Concrete

Amudhavalli N. K. et. al., (2020) [9] conducted a study to check the potential of Granite Dust with M-Sand as a replacement for cement and river sand. The study was based on test results of compressive, split tensile and flexural strength. M-30 grade of concrete mix was prepared by replacing the cement and fine aggregates by granite dust and M-Sand in proportions of 0, 5, 10, 15 and 20 % by weight fine aggregate. Concrete samples were analyzed after 7 and 28 days of curing. Up to 10 % replacement of granite dust, significant improvement in compressive strength was observed. On further increasing the granite dust content, steep downfall in the strength was observed. It was also suggested that use of granite dust and M - Sand significantly lowers the cost of building. **Jain Abhishek et. al., (2019) [10]** investigated the performance of self-compacting concrete comprising granite waste as a fine aggregate. Self-compacting concrete (SCC) properties like fresh and hardened concrete were assessed in this paper. The result of hardened characteristics of SCC is also validated by microstructural analysis through X-ray diffractions(XRD) and Scanning electron microscope (SEM). Modified SCC shows satisfactory performance during hardened and fresh characteristics tests. Granite in the proportion of 20 % showed the highest flexural strength. The modified mix showed 40 % improved strength than the control mix. The quality of the SCC was confirmed by ultrasonic pulse velocity test. **Karmegham and Arunachalam (2018) [11]** reused Granite Sawing Waste (GSW) and polypropylene fibres (PP) in Fiber Reinforced Self-Compacting concrete (FRSCC). GSW was used as replacement of cement in proportions of 5 % – 20 % by a variation of 5 %. The volume fractions of PP Fiber were 0.05, 0.1, and 0.15 % respectively. SEM was employed to analyze the microstructure. The results of this study indicated good improvements in split tensile strength at all proportions of PP fibers. The gradual increase in GSW and PP fibers tends to increase the segregation resistance and viscosity of SCC. The fibers also play an important consideration in affecting the flow ability properties of SCC beyond 0.1 %. Thus, it was suggested that GSW can be used as a good substitute of cement in production of FRSCC. **Raja and Ramalingam (2016) [12]** replaced ordinary sand with a Granite dust and filler additives in high-performance concrete. Due to the small particle size, filler materials perform a filling function that allows them to penetrate between the concrete particles. In this study, the sample was poured by converting cement and Granite fines to 0, 10, 20, 30, 40, 50, and 100 % for the M20 mix proportion weight of cement. Strength properties such as compressive strength was evaluated and compared with test results for conventional concrete and modified concrete after different percentages of Granite dust. The highest compressive Strength was achieved in the sample containing 40 % of Granite dust. **Elangovan. G (2015) [13]** investigated the possible use of Granite Waste Powder (GWP) asa partial substitute of cement in concrete. The effectiveness of mixing granite dust powder with cement on fresh and hardened state properties of concrete was evaluated in this study. GWP was used in the proportion of 5, 10, 15, and 20 % of the cement's weight. Compaction factor and strength tests were run on each replacement to determine its workability. It was observed that concrete loses compressive strength when more than 15 % of the cement is replaced with GWP. The modified concrete mix has a compressive strength 44 % greater than ordinary concrete, and it costs 8.29 % less per cubic meter. Results showed that GWP in the proportion of 15 % is the most ideal mix when weighed against the other mixtures in terms of compressive strength, workability, and cost. Increase in compressive strength and reduction in drying shrinkage was observed on replacing granite waste as replacement of fine aggregates in concrete **[14]**.

Table 1: Review of Prominent Literature on Utilization of Granite Waste in Concrete/Self Compacting Concrete

Author/s	Year of Publication	Evaluated Parameters	Outlines/ Conclusion	Refs.
Amudhavalli N. K. et. al.	2020	Compressive Strength, Cost Analysis	- It was seen that the strength of the concrete greatly increased after adding GDC. - Granite dust can be used to replace up to 10 % of cement before a significant reduction is detected. - Using GDC and M - Sand significantly lowers the cost of building.	[9]
Jain Abhishek et. al.	2019	Flexural Strength, Compressive Strength, Ultrasonic Pulse Velocity Test	- Granite in proportion of 20 % showed highest flexural strength. - The strength was higher than control mix up to 40 % substitutions level. - The ultrasonic pulse velocity test confirm the excellent quality of granite modified SCC sample.	[10]
Karmegham and Arunachalam	2018	Split Tensile Strength, SEM	- Granite Sawing Waste (GSW) and polypropylene fibres (PP) in Fiber Reinforced Self-Compacting concrete (FRSCC). - GSW was used as replacement of cement in proportions of 5 % – 20 % by a variation of 5 %. The volume fractions of PP Fiber were 0.05, 0.1, and 0.15 % respectively. - The results of this study indicated good improvements in split tensile strength at all proportions of PP fibers. - The gradual increase in GSW and PP fibers tends to increase the segregation resistance and viscosity of SCC. - The fibers also play an important consideration in affecting the flow ability properties of SCC beyond 0.1 %.	[11]
Raja and Ramalingam	2016	Compressive Strength	- Strength properties such as compressive strength are evaluated and compared with test results for concrete and conventional concrete, and different percentages of Granite dust after 7, 14 and 28 days of testing. - Highest compressive Strength was achieved in sample containing 40% of Granite dust.	[12]
Elangovan. G	2015	Compressive Strength, Cost Analysis	- The concrete mix has a compressive strength that is 44% greater than ordinary concrete, and it costs 8.29% less per cubic meter. - Results showed that GWP in proportion of 15% is the most ideal mix when weighed against the other mixtures in terms of compressive strength, workability, and cost.	[13]
Felixkala and Partheeban	2010	Compressive Strength, Drying Shrinkage	- The test findings showed that mechanical parameters like compressive strength benefitted by partial sand substitution. - The granite powder concrete specimens' drying shrinkage of concrete was minimal compared to that of ordinary concrete. - The concrete having 25 % granite powder had strength of 2 to 9 % greater than nominal mix throughout the entire period 26 °C and 38 °C curing temperature.	[14]

3.2 Granite Waste in Mortar

Nascimento Anny Salonny et. al., (2020) [15] studied the effect of granite waste on properties of mortar. The results were drafted based on consistency index and apparent density, flexural and compressive strength, apparent density and water absorption test results. It was resulted that improvement in strength characteristics was observed at 20 % substitution level. No significant changes were observed in other properties. **Chen J. J. et. al., (2020) [16]** also conducted a similar study but analyzed the packing density, rheology, strength and impermeability characteristics of mortar. It was resulted that at 15 % - 25 % replacement levels, the fresh state properties of mortar improved. At same replacement levels, the compressive strength and impermeability characteristics of modified mortar mix was better than the conventional mix. In a different study conducted by same authors, it was observed that granite polishing waste can also replace cement by 5 %. It was observed based on flowability, strength and durability properties. It was stated that the finer size of waste resulted in improved packing of the mix. All improvements were majorly due to this property only **[17]**. **Gupta and Vyas, (2018) [18]** studied the impact of waste granite powder (WGP) on the mechanical properties of cement sand mortar. Fine aggregates in cement mortar were partially replaced by WGP. On incorporation of WGP, compressive strength increased by 4 %, tensile bond strength increased by 23 % and adhesive strength also increased by 23 % as compared to the mix proportion 1: 4 control mortar. The volume of hydrated cement was increased as a result of the substitution with WGP, and this was confirmed by Fourier Transform infrared spectroscopy (FTIR). The use of WGP in concrete mortar as a composite fine aggregate has increased

the mechanical properties of mortar and the use of WGP as a constituent will contribute to the sustainable production of cement mortar.

Table 2: Review of Prominent Literature on Utilization of Granite Waste in Mortar Mixes

Author/s	Year of Publication	Evaluated Parameters	Outlines/ Conclusion	Refs.
Nascimento Anny Salonny et. al.	2020	Consistency Index and Apparent Density, Flexural and Compressive Strength, Water Absorption	- Increase in consistency by 4.8 % was observed. - No change in mass density was observed. - Reduction in flexural and compressive strength was observed when granite waste was used as a replacement of cement. - Improvement in all properties was observed when used as replacement of sand. - Optimum dosage of 20 % was observed.	[15]
Chen J. J. et. al.,	2020	Packing Density, Rheology, Strength and Impermeability Characteristics	- It was resulted that at 15 % - 25 % replacement levels, the fresh state properties of mortar improved. - At same replacement levels, the compressive strength and impermeability characteristics of modified mortar mix was better than the conventional mix.	[16]
Chen J. J. et. al.,	2020	Flowability, Strength and Durability	- 5 % replacement of cement by granite waste resulted in enhanced flowability, strength and durability. - Finer size of granite waste leads to denser packing of the mix.	[17]
Gupta and Vyas	2018	Compressive Strength, Tensile Bond Strength	- Increase in compressive and tensile bond strength was observed. - Volume of hydrated cement was increased on substituting with granite waste.	[18]

3.3 Granite Waste in Bituminous Mixes

Oesman M et. al., (2021) [19] utilized granite stone dust as filler in the asphalt concrete mixes. Granite dust was used in the proportion of 3 %, 4.5 %, 6 %, 7.5 % and 9 %. Test results were compared with cement filler mixes. Results were drafted based on wheel tracking machine results. Optimum dosage of granite dust was determined as 3 % as compared to 7.5 % cement. **Chandra and Choudhary, (2013) [20]** utilized stone dust, marble dust, granite dust, fly ash and hydrated lime as fillers in bituminous mixes. Static wheel, wheel tracking, flexural fatigue and moisture susceptibility tests were conducted in this study. The results suggested that all three stone industry waste have potential to be used as filler materials. Marble stone was predominant amongst all the waste materials used in this study. **Akbulut Huseyin et. al., (2012) [21]** utilized granite waste as filler in proportion of 0 %, 2 %, 4 %, 6 % and 8 % in bituminous mixes. Results were determined based on Marshall parameters and indirect tensile strength. It resulted that 7.3 % of granite waste showed optimum results.

Table 3: Review of Prominent Literature on Utilization of Granite Waste in Bituminous Mixes

Author/s	Year of Publication	Evaluated Parameters	Outlines/ Conclusion	Refs.
Oesman M et. al.	2021	Marshall Stability, Wheel Tracking Machine	- Optimum dosage of granite dust was determined as 3 % as compared to 7.5 % cement.	[19]
Chandra and Choudhary	2013	Static Wheel, Wheel Tracking, Flexural Fatigue and Moisture Susceptibility	- All stone industry waste showed convincing results. - Marble waste was predominant amongst all.	[20]
Akbulut Huseyin et. al.	2012	Marshall Stability, Indirect Tensile Strength	- Optimum dosage of granite waste was found out to be 7.3 %.	[21]

4. CONCLUSION

Following conclusions are drafted from the above research work:

1. From previous studies it is clear that granite waste can be used in concrete, mortar and bituminous mixes.
2. Granite waste in the range of 5 %-25 % can be used as a replacement of fine aggregates in concrete mixes.
3. Studies have established that 5 %-15 % of granite waste can also act as a replacement of cement in concrete mixes.

4. Granite waste in range of 5 %-25 % can result in improved flowability, strength, durability and impermeability characteristics of mortar mixes.
5. Convincing results were obtained in studies on utilizing granite waste as filler in bituminous mixes. 6 %-8 % of granite waste resulted in improved moisture susceptibility, creep and rut properties of bituminous mixes.

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