Feasibility Analysis of Marble and Granite Waste as Partial Replacement of Natural Sand in Mortar Mix

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Abstract: ***In this study an investigative experiment is reported on mechanical properties of mortar modified by marble and granite dust as replacement of fine aggregate or naturals and. An endeavor has been made to evaluate the compatibility of marble and granite dust as construction material. Properties of mortar are investigated for 1:4 mix proportions. Marble and granite waste is individually replaced till 50% at interval of 10% by natural sand. Water demand is examined for individual mixes and compared to control samples. To ensure the quality of various mixes compression, flexural strength and drying shrinkage is measured. Volume of voids and water absorption capacity are compared to ensure the durability of mortar mixes. Overall, it can be concluded from above observation that optimum 30% for marble and 20% for granite waste can be utilized individually in mortar mixes.***

Keywords: Marble Waste, Granite Waste, Mortar, Sustainable Construction etc.

1. Introduction

Marble Waste

In India, marble is the most popular dimension stone. When exposed to pressure and heat, it occurs naturally as a metamorphic rock created by calcite or dolostone minerals. As of 2010, the country's marble resources were 1655 Mega tonnes, with the state of Rajasthan accounting for 64% of this total.

Table 1.1: Percentage waste generated depending upon the mining technology used during processing (Source: MSME Development Institute, 2009)

Stage	Cutting	Grinding and polishing
Mechanised mines with gang saw cutting machines	10%	5%
Mechanised mines with using blasting	15%	5%
Semi – mechanised mines using blasting	18%	5%
Weighted average	15%	5%

Granite waste

Granite is igneous rock formed from the slow crystallization of magma present below the earth's crust. It majorly consists of quartz and feldspar. Approximately 250- 500 tonnes of granite waste were generated every year from the cutting and finishing of granite blocks in the form of granite slurry.

2. Literature Review

Lekshmi M.S. et al. (2021) experimented with mud to evaluate its feasibility as mortar; stabilizers like cow dung, cement, and lime were tested. Mud increased the water content of mortar to 42% from 10.5% in cement mortar (1:5).but adding cow dung brought down the water content to 30% on 10% replacement. Compressive strength also showed a decreasing trend with increasing mud in mortar.

Alexandra Olga Pintea et al. (2019) conducted study on new types of mortar used in various traditional buildings and discovered that Lime mortar masonry modified by addition of various additives led to improvements in some properties. The additive that has been investigated is Starch.

Nanqiao You et al. (2019) have done their experiment on slag mortar; the preparation of the slag mortar that is alkali-activated was done using substitution of fifty percent GGBS by weight with steel slag or ferronickel slag. In further discussion the steel slag will be denoted as SS and ferronickel slag will be denoted as FNS. Their study showed that mineral phases of C_3S and C_2S are found identical in SS as it found in the cement.

Lucie Fusade et al. (2019) examined the effects of using wood ash from a biomass boiler in lime mortar as replacement of aggregate. They have concluded that compressive strength property of the mix is greatly less than the material used in historical infrastructures for masonry purposes. The example of such material can be understood with the porous sandstone, this material has a compressive strength ranging from 25 to 60 N/mm^2.

L.K. Gupta and A.K. Vyas (2018) examined the use of granite sludge in cement mortar and various properties of mixes. The experimental mixes were studied and compared with the mixes that were prepared with ordinary river sand. The strength properties of the mixes can be enhanced when the 40 percent substitution of waste was incorporated in mixes.

3. Materials and Methodology

Raw Materials
Cement
Raw Materials
Cement
Fine Aggregate
Marble Waste
Granite Waste
Sulphate Attack
Acid attack
Acid attack
Preparations of Specimens

4. Results and Discussions

Table 4.1: Compression Strength of all mixes

Material	Mix ID	Replacement (%)	7 days	28 days
Natural	JNS	0	3.21	6.84
Marble	JMS10	10	3.99	7.12
	JMS20	20	5.21	8.52
	JMS30	30	6.11	9.26
	JMS40	40	5.82	8.98
	JMS50	50	4.46	7.78
Granite	JGS10	10	5.45	8.67
	JGS20	20	6.62	9.55
	JGS30	30	5.98	9.05
	JGS40	40	4.87	8.21
	JGS50	50	4.11	7.66

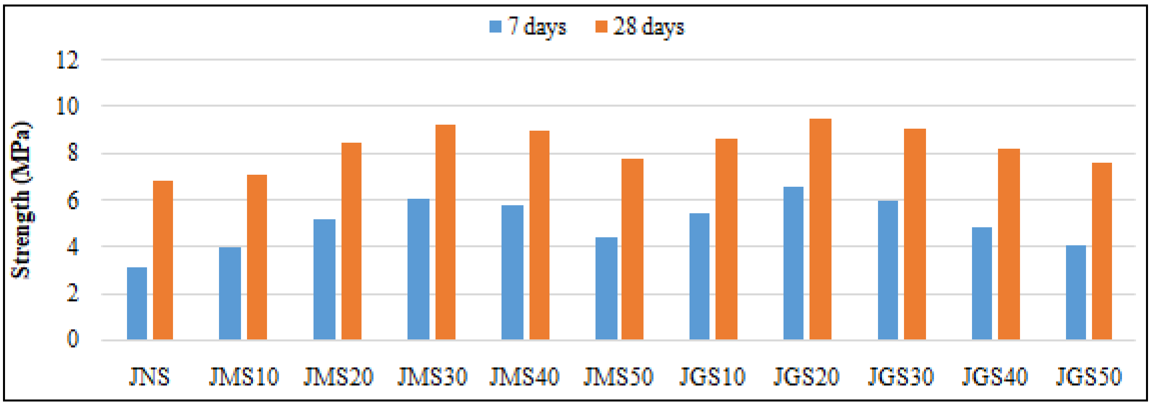


Figure 4.1: Compressive Strength v/s % of replacement after 7 and 28 days

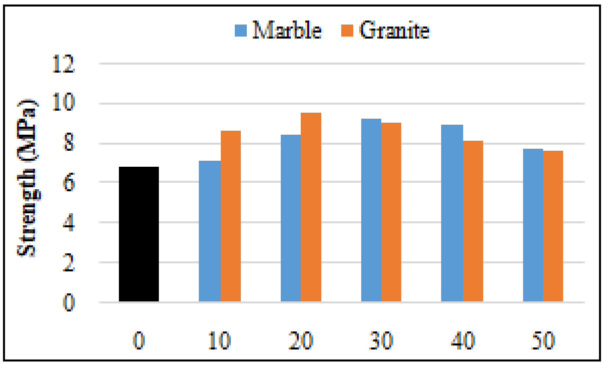


Figure 4.2: Variation in Compressive Strength for different material

Flexural Strength

Flexural strength of mortar samples is inspected as per the recommendation of **ASTM C348**, **1998**. Beam sample of 40x40x160mm size are tested after 7 and 28 day of water curing. Flexural strength for different mortar samples is displayed in table 4.4 with graphical representation in fig 4.8.The outcomes of control or conventional mix are 2.12 MPa and 3.52 MPa after 7 and 28 days of curing respectively.

Table 4.2: Flexural strength for different mixes

Material	Mix ID	Replacement (%)	7 days	28 days
Natural	JNS	0	2.12	3.52
Marble	JMS10	10	2.29	3.69
	JMS20	20	2.44	4.11
	JMS30	30	2.62	4.35
	JMS40	40	2.37	3.74
	JMS50	50	1.9	3.18
Granite	JGS10	10	2.34	3.95
	JGS20	20	2.69	4.42
	JGS30	30	2.25	4.09
	JGS40	40	2.32	3.73
	JGS50	50	2.09	3.44

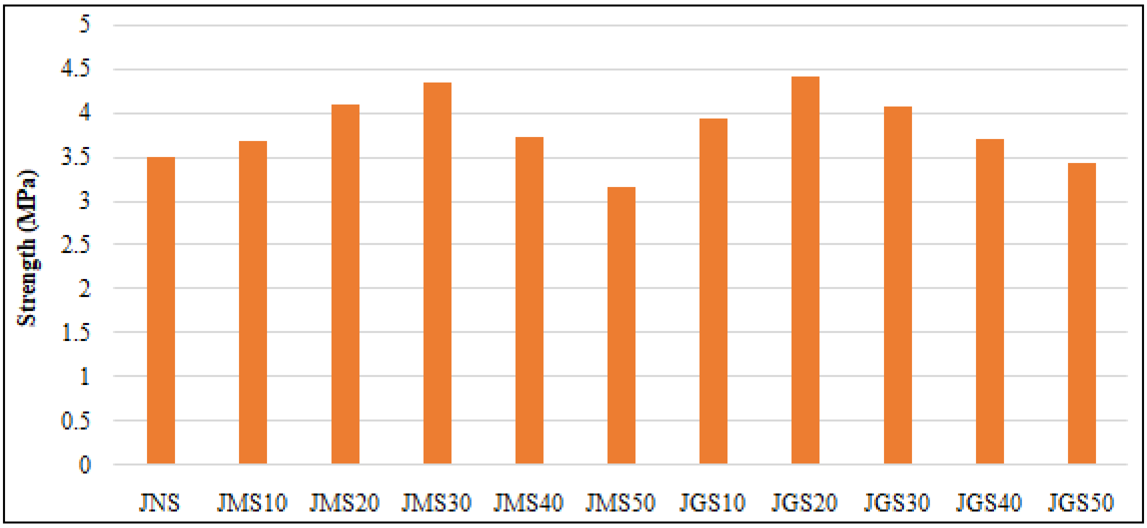


Figure 4.3: Flexural strength of concrete at different % of replacement

Water Absorption and Volume of Voids

Water absorption and volume of voids for different mixes are demonstrated in table4.6. Fig 4.12 shows that initial water absorption is decreased at certain level of replacement waste material after that increases. In JMS30 and JGS20 lowest water absorption is observed.

Table 4.3: Water absorption and volume of voids for different mixes

Material	Mix ID	Replacement (%)	Water Absorption	Volume of Voids
Natural	JNS	0	9.35	16.74
Marble	JMS10	10	7.78	14.15
	JMS20	20	6.18	11.68
	JMS30	30	7.91	15.11
	JMS40	40	10.49	19.30
	JMS50	50	13.02	23.04
Granite	JGS10	10	8.10	15.07
	JGS20	20	5.51	10.86
	JGS30	30	7.23	14.10
	JGS40	40	8.96	17.03
	JGS50	50	9.71	18.26

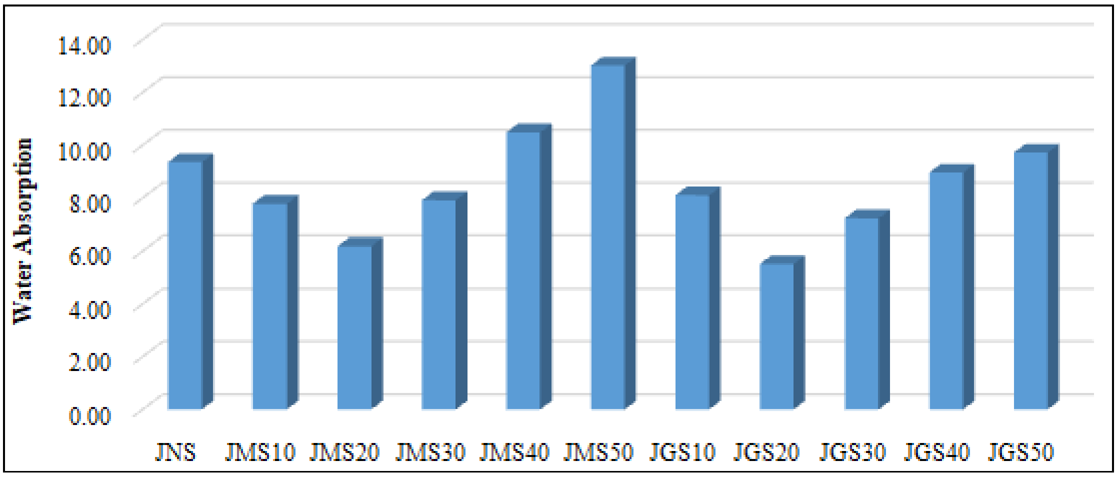


Figure 4.41: Water Absorption for different mortar mixes

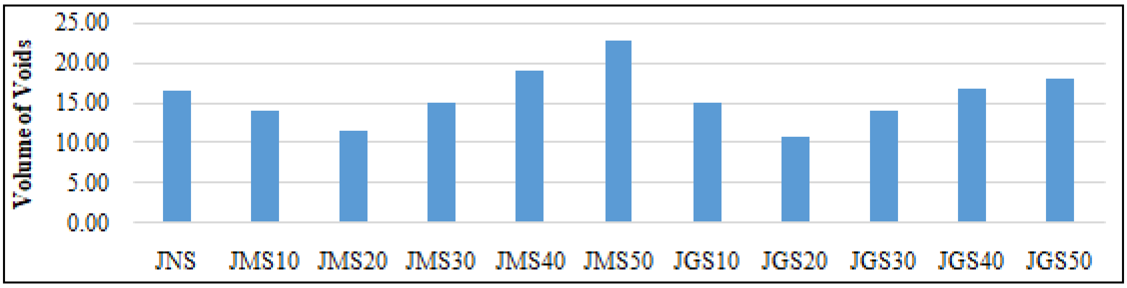


Figure 4.52: Volume of Voids for different mortar mixes

Acid exposure period between 7 to 28 days, considerable weight loss observed in all mortar mixes. It was noted that the mortar mix with 50% Marble and Granite has minimum weight loss in their respective series.

Table 4.4: Acid Attack results for different mixes

Mix ID	Strength loss			Mass loss		
	7 days	14 days	28 days	7 days	14 days	28 days
JNS	8.4%	11.7%	15.3%	2.1%	4.7%	8.4%
JMS10	7.9%	11.4%	14.8%	1.9%	4.3%	7.8%
JMS20	7.5%	10.6%	14.1%	1.7%	3.9%	7.2%
JMS30	7.1%	10.1%	13.6%	1.5%	3.4%	6.7%
JMS40	6.8%	9.7%	12.9%	1.3%	2.8%	5.9%
JMS50	6.3%	9.2%	12.4%	1.1%	2.4%	5.5%
JGS10	7.7%	11.2%	14.5%	1.8%	4.1%	7.4%
JGS20	7.3%	10.4%	13.9%	1.6%	3.6%	6.8%
JGS30	6.9%	9.9%	13.2%	1.3%	3.1%	6.0%
JGS40	6.5%	9.3%	12.5%	1.0%	2.6%	5.4%
JGS50	6.1%	8.8%	11.8%	0.8%	2.2%	5.1%

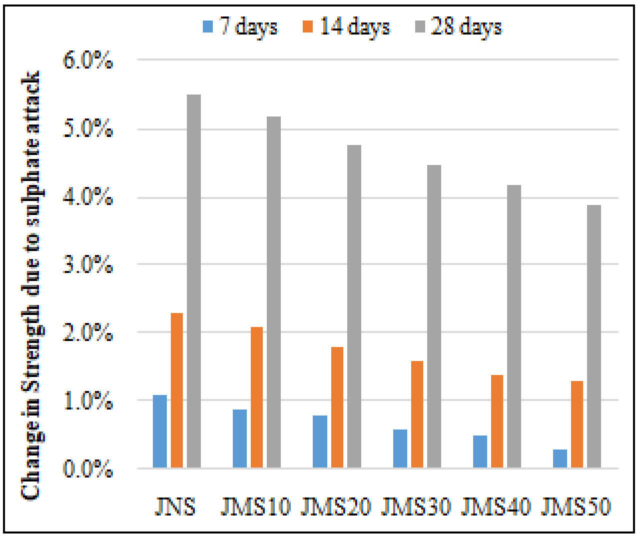
Sulphate Attack

Sulphate attack in mortar occurs due to reaction between sulphates presents in groundwater, drainage solutions and hydrated products (Ca(OH)2). This reaction leads to generate gypsum, expansive ettringite and thaumasite as byproduct responsible for deterioration of mortar.

Sulphate attack effect on different mortar mixes of marble and granite is evaluated in terms of change in compressive strength and weight as presented in Figure 4.18 and 4.19. There are no significant changes observed in compressive strength of mortar mixes when immersed in to sulphate solution between 7 to 28 days.

Table 4.5: Sulphate Attack results for different mixes

Mix ID	Strength loss			Mass loss		
	7 days	14 days	28 days	7 days	14 days	28 days
JNS	1.1%	2.3%	5.5%	2.9%	7.4%	11.3%
JMS10	0.9%	2.1%	5.2%	2.4%	6.8%	10.5%
JMS20	0.8%	1.8%	4.8%	2.1%	6.2%	9.9%
JMS30	0.6%	1.6%	4.5%	1.7%	5.7%	8.7%
JMS40	0.5%	1.4%	4.2%	1.3%	4.8%	7.5%
JMS50	0.3%	1.3%	3.9%	0.9%	4.2%	6.6%
JGS10	1.1%	2.3%	5.5%	2.9%	7.4%	11.3%
JGS20	0.8%	2.0%	5.0%	2.2%	6.3%	10.2%
JGS30	0.7%	1.7%	4.6%	1.9%	5.8%	9.3%
JGS40	0.5%	1.3%	4.1%	1.5%	5.1%	8.3%
JGS50	0.4%	1.1%	3.8%	0.9%	4.5%	7.4%



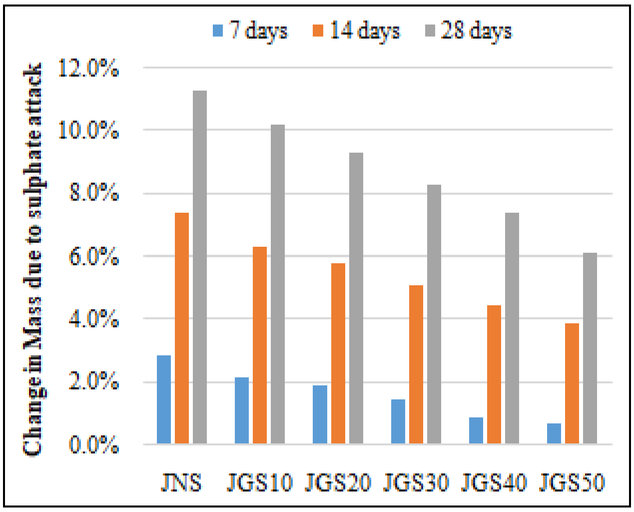


Figure 4.6: Change in mass due sulphate exposure (a) Marble (b) Granite

5. Conclusion

- The outcomes of control or conventional mix are 3.21 MPa and 6.84 MPa after 7 and 28 days of curing respectively. Maximum compressive strength is achieved at partial replacement of 30% and 20% by marble and granite respectively. Increment in compressive strength with respect to control sample is 35.4% and 39.6% higher for marble and granite respectively. Utmost compressive strength is achieved in JMS30 and JGS20 mixes. Whereas, compressive strength of maximum replacement level is greater than control sample. This increment in strength is due filler effect and densification of mixes.
- Flexural strength increases till 30% of replacement by marble waste similarly till 20% for granite waste. Increment in flexural strength with respect to control sample is 23.6% and 25.6% higher for marble and granite respectively. Similarly, for flexural strength maximum strength is achieved at 20% for granite and 30% for marble waste incorporation. At 50 % replacement for both materials flexural strength is lower to conventional mortar mix. But for 40% replacement strength is comparably higher to control sample. Correlation between compression and flexural strength

is adequately good.

- Volume of voids are reduced with substantial level of incorporation of marble and granite in mortar mixes. Lowest volume of voids is examined in JMS20 and JGS30 mixes.
- Similarly, water absorption capacity of mortar mixes is reduced at certain level of replacement. Lowest water absorption is noted for 20% of replacement by marble and granite individual in mixes. Strong correlation was established between volume of voids and rate of water absorption.
- Strength loss was reduced for both marble and granite mixed mortar in exposure to acid solution. Higher the waste content lesser the effect was observed. Similarly, mass loss was reduced with increase of marble and granite content in mortar mixes.

Overall, it can be concluded from above observation that optimum 30% for marble and 20% for granite waste can be utilized individually in mortar mixes.

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