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Study on dimensional stones available in Southern Asia with specific reference to granite waste

Mayur Mewara
2017pcecemayur039@poornima.org
Poornima College of Engineering, Jaipur, Rajasthan

Mansi Agarwalla
2017pcecemansi037@poornima.org
Poornima College of Engineering, Jaipur, Rajasthan

Madhu Yadav
2017pcecemadhu036@poornima.org
Poornima College of Engineering, Jaipur, Rajasthan

Dr. Harshwardan Singh Chouhan
harsh.civil.rec@gmail.com
Poornima College of Engineering, Jaipur, Rajasthan

ABSTRACT

Dimensional stones are used primarily in buildings and construction industry. Almost all the buildings exhibit stones that are shaped, cut or polished for the walls, floors, columns and steps. There are a large number of dimensional stones available in southern Asia such as sandstone, slate, marble, granite, gneiss, etc. which produces huge amount of waste in their manufacturing, cutting and polishing. This waste is dumped in the fields openly and it causes major environmental problems such as land infertility, loss of land infiltration, air pollution, problem in breathing, etc. India has large reserves of granite and huge amount of waste is produced that's why we have worked on granite specifically. Granite is a coarse grained rock composed mostly of quartz, alkali, feldspar and plagioclase. Green granite is hard enough to resist abrasion, strong enough to bear significant weight, inert enough to resist weathering and it accepts a brilliant polish. Granite is an igneous volcanic rock having good compressive strength and it has always been used in the concrete as a replacement for fine aggregate. But in this research, we have replaced the granite with the cementitious material that is, the cement. For this, we have replaced the granite with cement by 0%, 5%, 10% and 15%. Detailed study has been done to investigate the fresh, mechanical and physical properties of granite waste powder, the compatibility of use of granite waste powder in concrete. Analysis of the fresh, mechanical and physical properties of concrete mixes designed with different mix proportioning quantities with the use of granite waste powder as a cementitious material.

Keywords: *Dimensional Stones, Granite, Granite Waste, Concrete Mix Design, Partial Replacement, Cementitious Material*

1. INTRODUCTION

General

Dimensional stone can be called as a natural rock material that has been chosen, trimmed or cut to a specified size and shape with or without one or more than one mechanically dressed surface. A dimensionalstone is used mainly in buildings and construction Industries. Today, at an average, all the buildings are made of stones that are shaped, cut and polished for the floors, steps, walls and columns. The constructionindustries use almost 80% of the finished products of dimensional stones. The following properties of the dimensional stones should be considered before choosing and finalising them for engineering purposes-

- Appearance: Appearance is a mandatory need for all types of stones. The capability toreceive polishing and colour are major factors.
- Bio-deterioration: Some trees and vines have their roots in the joints of the stones and haveboth mechanical and chemical effects. Special microbes can grow on the surface and in tiny crevices, their by-products causing peeling and discoloration.
- Colour: A stone with an attractive and uniform colour is durable if the grains are compact.Stones containing a lot of iron should be discouraged as the formation of iron oxides disfigures them and causes them to disintegrate. Marble and granite look beautiful when polished.
- Dressing: Giving the required shape to the stone is called dressing. It should be easy to getdressed to reduce the cost of dressing. However, care must be taken to ensure this does not come at the expense of the required strength and durability.
- Durability: The selected stones must be able to withstand the negative effects of naturalforces such as wind, rain and heat.
- Hardness: This is an important property to consider when stone is used for flooring and pavements. The stone used in floors and sidewalks must be able to withstand the abrasive forces caused by the movement of men and materials over them.
- Strength: Strength is an important property to consider before choosing stone as a buildingblock. The Indian standard code recommends a minimum crush strength of 3.5 N / mm2 for any building block.

- Texture: Fine-grained stones with a homogeneous distribution look attractive and thereforeare used for carving.
- Porosity and Absorption: All stones have pores and therefore absorb water. The reaction ofwater with the stone material causes disintegration. The absorption test is specified as the percentage of water absorbed by the stone when it is immersed under water for 24 hours. For a good stone, it should be as small as possible and in no case more than 5. [5]

In this project, we have studied about the production of different dimensional stones available in different countries of southern Asia. After studying the production details, we have studied aboutthe different waste products that are being produced in the manufacturing of these dimensional stones such as limestone fines, marble dust, marble slurry, quarry rock dust, etc. The main aim ofour project was to study these waste materials and how evaluate how we could use these waste materials effectively in construction industry to produce good quality construction materials suchas concrete, mortar, bricks, etc.

Figure.1 Types of Stones [4]

2. LITERATURE

We studied fifteen research papers for evaluation of our project. The research papers were published by well-known authors from the field of civil engineering. The research papers were specifically chosen from the list of papers for the last fifteen years.

Detailed literature review

Binici et.al. (2007) stated that MD3 concrete samples have a higher compressive strength than anyother sample. The sodium sulfate resistance shown by the MD concrete was higher than that of theLD samples. The abrasion resistance of MD concrete with 5, 10 and 15% fine sand substitution was lower than that of LD concrete. In addition to the depth of water penetration, the amount of water that penetrated into the MD of 15% of the concrete was less than that of the other [1]. Galetakis and Raka (2004) have taken an experimental approach to the use of limestone dust to produce artificial stones which is the main focus of this work. The specimens were made by mixingcement and limestone dust, wetting them and compacting them under high pressure in cylindricalmolds. The factorial design method was used for the design of the test mix. The cement dust / limestone ratio was the main factor and the compressive strength was 7 MPa for all samples. It was also found that quarry cement powder mixtures can be used for the production of molded masonry bricks with acceptable mechanical properties [2]. Hameed and Sekar (2009) discussed the use of marble mud dust and quarry dust as a 100% substitute for natural sand in concrete to reduce environmental pollution and improve the durability of concrete. To reduce the void space in the concrete, the marble mortar powder filled the filler. Because there is no sludge and organiccontaminants, unlike natural sand, quarry dust can be used to achieve the desired fineness and gradation. Concrete made from quarry dust had 14% higher compressive strength, split tensile strength and durability than conventional concrete. The resistance of sulphates has also been significantly improved [3]. Huang and Lin (2010) studied a cementitious material made from twoindustrial wastes, steel slag (SS) and phosphonyl (PG), and two industrial by-products, limestone(LS) and granulated blast furnace slag (GGBFS). The 28-day compressive strength exceeded 40 MPa when a mixture of 45% PG, 10% SS, 35% GGBFS and 10% LS was tested. The C-S-H gel and electringite were the main liquefaction products. Part of the PG reacted with GGBFS and SS to form ettringitis, the remaining PG was enveloped with hydration products. SS in concrete actedas the basic activator. An overdose of SS can cause discomfort [8].

Li Beixing et.al. (2009) examined the results of limestone particles in low- and high-strength concrete produced (MS) concrete in terms of compressive strength, thaw strength, and chloride ion permeability. 15% and 10% limestone particles in partial replacement of low and high strengthconcrete respectively improved the compressive strength. With the increase in the proportion of limestone particles in L-MS concrete, the resistance to permeability to chloride ions has increasedand the thaw resistance has decreased. However, for H-MS concrete it shows little influence [9].

Similarly, Moesgaard et al. (2011) investigated the applicability of calcium aluminosilicate glass (CAS) particles as a substitute for fly ash and blast furnace slag. CAS glass particles were used toreduce the carbon dioxide emissions of cement during its manufacture. Mixed cement mortars containing 30% by weight. The percentage of clinker replacement was identified in terms of workability and mechanical performance. By combining finely ground limestone and CAS, a realreduction in CO2 emissions of up to 20% and also high strength was observed [10]. Similarly, Omar et.al. (2012**)** did the replacement of Limestone powder (LPW) by 25%, 50% and 75% and Marble dust (MD) by 5%, 10% and 15%. Workability of green concrete was not affected by addition of anything. Replacement of 50% cement increased compressive strength by 12% at 28 days. By increasing cement content from 350kg/m^3 to 450kg/m^3 improved compressive strength by 6%. Mixture of LPW (50%) and MD (15%) increased compressive strength by (7%) tensile strength by (17%) and flexural strength by (8%). Optimum level of quantity was 50% of LPW and15% MD [11]. Opçu et.al. (2009) did the replacement of Marble Dust (MD) in Self Compacting Concrete (SCC) varying from 50,100,150,200,250 to 300kg/m^3. Test conducted on fresh concretewere L Box test, V Funnel test, Slump flow test. Test conducted on hardened concrete were Compressive strength, flexural strength, ultrasonic velocity, porosity and compactness. No changein workability is observed up to 200 kg/m$^{3.}$ Mechanical properties decrease at 28 days especially for specimen of 200 kg/m^3 and above [12]. Patel and Pitroda (2013) replaced Stone Waste (SW) in concrete at 0%, 10%, 20%, 30%, 40% and 50% and 6 specimens of M25 grade were made for the observations. This is majorly adopted in OPC cement to reduce the pollution effect. Compressive strength is noted with up to 30% increment at highest [13]. Also Rana et.al. (2015) Added marble slurry in 6 specimens by replacing 0%, 5%, 10%, 15%, 20%, 25%. Optimum levelof Marble slurry used in concrete was 10% [14].

Rana et al. (2017) used MS instead of river sand and thickened the microstructure of the concrete by reducing its porosity. Therefore, the use of sized limestone waste as a fine aggregate in concretewill also result in solid and durable concrete structures. The use of MS as a fine aggregate in concrete will promote sustainable development in stone mines, as it will use stone waste in large quantities. The use of such MS formulated with rock waste can shift the dependence from river beds to landfills; to meet the building sand needs in these countries [15]. Also Safi et al. (2013) presented the recycling and use of plastic waste (PET used to produce bags) as a fine aggregate in self-compacting mortars. They investigated that a type of plastic waste can be successfully used as a fine aggregate in self-compacting mortars. The compressive strength of the 28-day self- compacting mortar containing up to 50% plastic waste was acceptable for lightweight mortars witha bulk density of 1. The annular cylindrical shape of this plastic waste aided the physical adhesionof the plastic to the paste of concrete [16]. Safiuddin et.al. (2010) made efficient use of solid wastesin the production of alternative building materials, the detailed physicochemical, technical,thermal, mineralogical and morphological properties of this wastes need to be evaluated with good accuracy. The performance of solid waste building materials in actual construction also needs to be assessed before setting up a secondary industry for recycling and recovery of solid waste. Therefore, contractors and construction agencies must be encouraged to develop new products andprocesses using solid waste as a raw material, which will pave the way for an innovative way of creating a secondary industry [17]. Taves et al. (2005) stated that lime is a material that has long been used in mortar and mortar. Due to the growing need for faster construction in the 19th and 20th centuries, the market capacity of lime decreased. They also said that the widespread use of waterproof materials such as PC for exterior plasters and plasters has led to wall integrity issues, sustainability issues and a risk of mold. Although lime is considered a practical, sustainable and healthy alternative to concrete [18]. Torkaman et.al. (2014) replaced Rice husk waste (RHW) andLime stone powder (LPW) as fine aggregate up to 25% by weight which gave the best physio- chemical strength. By replacing 25% wt. the sudden breakage did not happened even at failure loads. It possesses high absorption energy with light weight. Compressive strength ($p<0.05$) and water absorption ($p<0.01$) were influenced mostly by addition of parameters. Wood fibre (WF) increased water absorption due to hydrophilic nature of fibres. Addition of WF and LPW up to 25% produced a 30% lighter block by weight [19].

Research gap

- There are lot of studies, who aware the value of dimensional stones in construction industrybut parallel to this we are also facing a big problem due to stone waste processing like dumping of waste.
- This is the biggest challenge for us. With this aim our project proceeds to provide a comprehensive study on dimensional stone production industries and the problems associated with them specially a particular dimensional stone so that all the problems associated with its production and recycling of its industrial waste could be studied in detailas that is lacking at present.
- Studies are needed to be carried out about how the tones of wastes generated in the dimensional stone industries can actually help in preparation of high strength concrete as replacement material for reduction in the emission of carbon dioxide in the environment thus saving the ozone layer depletion.
- Effective use of granite stone waste in concrete have not been evaluated so far
- Detailed study is needed to investigate the Fresh, Mechanical and physical properties of Concrete containing granite waste powder.

Many studies are available on replacement of fine aggregate in normal concrete with waste granite powder. As per best knowledge of author, no study is available on replacement of granite waste powder as cementitious material in concrete.

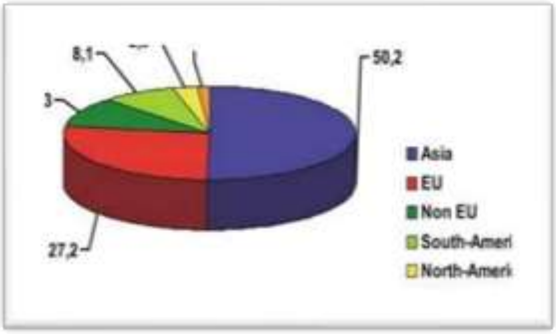

Figure.2 The percentage of stone production with respect to continents in a more general overview [7]

Objective of Research

- To study the physical, mechanical, and micro structural properties of the waste granite powder.
- To determine the compatibility of use of waste granite powder in concrete.
- To analyze the fresh, mechanical and physical properties of concrete mixes designed with different mix proportioning quantities with the use of waste granite powder as a cementitious material.

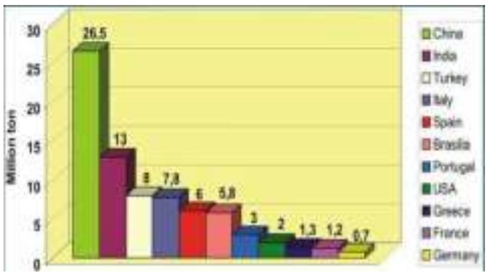

Figure 3 Leading nation in the production of dimension stones and the amount produced in million tons [7]

3. METHODOLOGY

3.1 Work Flow Chart

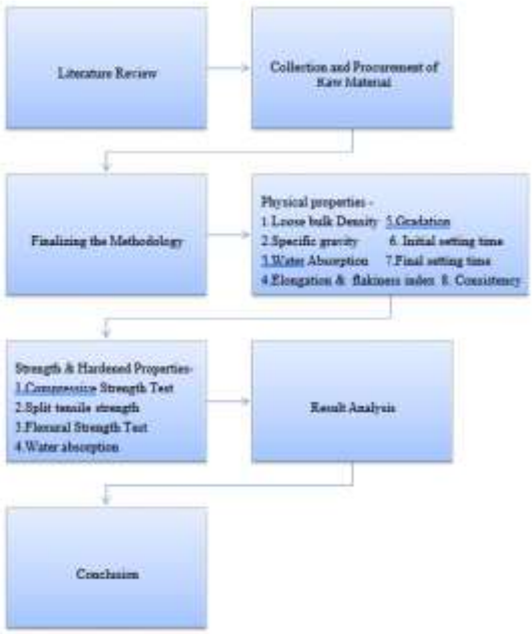

Figure.4 Initial setting time of cement

Figure.5 Specific gravity of cement

- Research papers were studied based on preparation of different concrete mixes using the industrial wastes generated at different dimensional stones manufacturing industries by different researchers.
- The millions of tons of wastes generated at dimensional stone manufacturing industries were evaluated and studied about so that we could understand as to how they could be used for construction purposes for lesser contribution to harmful emissions of gases while their dumping process continued. Today we cannot stop the dumping of the wastes but we can surely make sure that they are recycled and reused up to certain extent so that there is lesserthreat to the mankind by using them as replacement materials for preparation of concrete.
- The useful information was taken so as to prepare a concrete mix which was economical and different from what already had been prepared. The particular stone "Granite" was chosen for easy work and better understanding of the topic chosen.
- As per the research studies available granite had been used as a replacement for fine Aggregate in the concrete but in this research we focused on replacing the granite waste powder with the cementitious material i.e., cement.
- For this we replaced cement with granite waste powder by 5%, 10% and 15% and comparedwith the conventional control mix.
- Detailed study was done to investigate the fresh, mechanical and physical properties of theconcrete containing granite waste powder.

Figure.6 Ancient stone head of Bayon temple, Cambodia [6]

3.2 Materials

Following are the materials which are being used in the preparation of the concrete containing granite waste powder-

2.1 *Sand*

Sand usually known as fine aggregate was taken from the river beds. The zone of fine aggregate was II zone. Sand plays a vital role in concrete in filling the voids properly and making the concrete compact andstrong.

Figure.7 Aggregate

3.2.2 *Aggregate*

Concrete is composed of aggregates of size ranging from 10-20 mm. This range of aggregate size providesthe concrete with sufficient strength. It is recommended that size of aggregate should be selected while keeping in mind that how the composition of that aggregate will affect the performance of concrete. For instance, the presence of inimical substances like chert and clay affect the bonding between aggregates andthe cement paste. It should be kept in mind that the physical properties of the aggregates used in the conventional concrete and the concrete with granite waste powder should be same. Permeability, durabilityand mechanical characteristics are being directed by the size, distribution and shape of the aggregates that are used.

Figure.8 Sand

3.2.3 *Binding Material*

Pozzolana Portland Cement (PPC) of rock strong brand is used for the preparation of the concrete. The main objective of the cementing material is to provide a coating to the aggregates to enhance the durabilityof the concrete.

Figure.9 PPC Cement

Granite

Granite is an igneous volcanic rock formed by the deposition of magma over the earth's surface. Granite has high compressive strength and is used in the construction of piers, abutments, retaining walls of the bridges. Granite is a coarse grained rock composed mostly of quartz, alkali, feldspar and plagioclase. Greengranite is hard enough to resist abrasion, strong enough to bear significant weight, inert enough to resist weathering and it accepts a brilliant polish. Most reserves are located in Indian states of Andhra Pradesh, Jharkhand, Karnataka, Orissa and Tamil Nadu. Given that India is the largest granite exporter in the southern Asia.

Figure.10 Granite waste powder

3.3 Test methods

Given below are some properties of the concrete containing granite waste powder which were studied during the research.

Fresh Properties

Workability- Workability is a characteristic of raw or fresh concrete mixture. In straight forward words, workability means the effortlessness of placement and workable concrete means the concrete which can be placed and can be compacted easily without any segregation. Workability is an essential property of concrete and associated with compaction as well as strength. The desired workability is not same for all types of concrete.More workability is required for a thin inaccessible section or heavily reinforced section rather than a massconcrete body. Hence, we can't set a standard workability for all casting works. For determining workability, slump flow test is performed.

Figure.10 Slump flow test

Strength properties

Compressive strength: Compressive strength is the maximum load that a material or a structure can carry on its surface without showing any crack or deflection in the structure. A material under compression considers reducing the size. All the characteristics of the concrete can be determined by the compressive strength test. The compressive strength test depends on various factors such as water-cement ratio,cement strength, quality of concrete material, and quality control during the production ofconcrete, etc.

For performing compressive strength test of concrete containing waste granite powder, three cubesamples of 150*150*150 mm were prepared. These three samples were tested in the Universal Testing Machine (UTM) after 7 days curing or 28 days curing and the average of these three samples was taken as the load at which the concrete specimen fails. The compressive strength is calculated in MPa as follows:

$$F = P/A$$

Here,
P= Load at which specimen fails
A = Area of cross-section of specimen

3.3.1.1 *Split tensile strength-*

Split tensile strength is a method of resolving the tensile strength of concrete by making use of a cylindrical sample of concrete which splits across the vertical diameter. It is a secondary method of testing tensile strength of concrete.

The tensile strength test of concrete containing waste granite powder was done using Universal Testing Machine (UTM). All samples were tested for a specified time of 7 days and 28 days. For each sample breaking load was recorded and computed the tensile stress in MPa as follows:

$$\text{Split tensile strength} = 2P/(3.14 * D*L)$$

Here,

P= Load at which specimen fails

D= Diameter of specimen

L= Length of specimen

3.3.1.2 *Flexural strength*

Flexural strength is the estimate of the tensile strength of concrete. It is a computation of an unreinforced concrete beam or slab to counter the failure in bending. Flexural strength of cement mortars containing waste granite powder was determined using flexural beam of size 100*100*500mm and compression testing machine with the flexural testing device. Three specimens were prepared for each mortar mix.

The maximum load on machine was noted and the flexural strengthwas calculated in MPa as follows:

$$\text{Flexural strength} = PL/bd^2$$

Here,

P= Load at which specimen fails

D= Diameter of specimen

L= Length of specimen

3.3.1.3 *Water absorption*

Water absorption test is used to calculate the amount of water that pierce into concrete samples when submersed in water. The test procedure necessitates drying of a specimen to a persistent weight, weighing it, submerging it in water for specified amount of time, and weighting it again. The enlargement in weight as a percentage of the original weight is expressed as its absorption. Water absorption is calculated in percentage as follows:

$$W = (W_1 - W_2) \times 100 / W_2$$

Here,

W_1= Weight of saturated surface dried sample

W_2= Weight of oven dried sample

Table-1 Specimen size for tests

Test	Samples Each Mix (mm)	Reference Code/ Guideline
Compressive Strength	3 cubes (150×150×150)	IS:1121 (1974)
Density and water absorption	3 cubes (150×150×150)	IS:1124 (1974)
Split tensile strength	3 cylinders (Diameter = 150 , Height = 300)	IS:5816 (1999)
Flexural strength	3 Beams (100×100×500)	IS:3316 (1974)
Workability (slump cone test)	M30 Mix design	IS:1199 (1959)

Figure.11Casted specimen

Figure.12 Cube specimens

Figure.13 Specimen in curing tank

Table-2 Gradation of fine aggregate

Sieve Size	Weight retained (gm)	Cumulative Weight retained (gm)	% of Weight Passing
4.75 mm	208	208	95.84
2.36 mm	210.5	418.5	91.63
1.18 mm	572	990.5	80.19
600 µ	1584.5	2575	48.5
300 µ	794	3369	32.62
150 µ	1497	4866	2.68
Pan	134	5000	0
	∑ 5000	∑ 17427	

Table-3 Final Proportion (kg/m³)

Mix ID	PCC Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)	Water (kg)	Water/Cement Ratio
Control Mix (M30)	18	27	47	8	0.42

Table-4 Details of mix proportion

Replacement of Cement (%)	Cement (kg)	Granite (kg)	Sand (kg)	Aggregate (kg)	Water (kg)
0%	18	0	27	47	8
5%	17.1	0.9	27	47	8
10%	16.2	1.8	27	47	8
15%	15.3	2.7	27	47	8

4. RESULTS AND DISCUSSION

Physical parameters of materials

Using Le-Chatelier flask, the specific gravity of cement was found out and for the same property of granite, we used the conventional method with respect to Kerosene as standard liquid. The water absorption of granite was found to be quite greater than that of both kinds of aggregates.The fineness modulus was an important characteristic to be pre-determined before undergoing any tests further. The initial and final setting time of cement was determined and turned out to be60 minutes and 435 minutes respectively.

Table-5

Test	Cement (PPC)	Sand	Aggregate	Granite
Specific gravity	2.91	2.65	2.68	2.65
Loose bulk Density (kg/m3)	1440	1660.30	1309.90	1470
Water Absorption (%)	-	2.8	2.5	4.2
Fineness modulus	-	3.2	3.8	-
Consistency (%)	32	-	-	-
Elongation & flakiness index	-	-	25.68 & 8.55	-
Initial & final setting time	Initial- 60 min. Final- 435 min.	-	-	-

Fresh property of concrete

Slump flow test was done to know about the workability of different mixes that were being prepared i.e. control mix and mixes with 5%, 10%, 15% replacements of granite respectively. The slump values gave the estimate of workability of our mixes. This test was easy and conventional and the values are listed below.

Table-

Mix ID	Slump value (mm)
Control Mix	72
OS 5	70
OS 10	67
OS 15	62

Strength properties

The compressive strength, flexural strength and split tensile strength were determined after casting of all the three types of specimens and the results showed that there was considerable increase in the three types of strengths of the concrete when cement was replaced with granitefrom 5-10% but the strengths went on decreasing as we replaced cement with granite by 15%.

Compressive strength: For the current study, this test was directed on 150 mm concrete cubes and their results after 7and 28 days are presented in table no.7 below. After 7 days, compressive strength was found for 5-10% replacement of cement with waste granite powder and it was observed that there wasan increase in compressive strength on replacement with waste granite powder and after 28 days, almost 90% of strength was gained by the concrete. The results however showed fluctuations when 15% replacement was done.

Table-

Tests ⇨	*Compressive Strength (MPa)*	
Mix ID ⇩	*7 days*	*28 days*
Control mix	13.03	29.7
OS 5	13.68	27
OS 10	14.22	27.6
OS 15	13.5	26.7

Figure 14 Compressive test using UTM

Split tensile strength: Samples of the concrete containing waste granite powder for the tensile strength test were tested in the Universal Testing Machine (UTM). These samples were tested at the end of 7 days and 28 days curing. Results from this test are presented in table 8, which shows that tensile strength was increased when the 5-10% cement was replaced with waste granite powder.

Table- 8

Tests ⇨	*Split tensile Strength (MPa)*	
Mix ID ⇩	*7 days*	*28 days*
Control mix	2.31	4.14
OS 5	2.62	4.08
OS 10	2.8	4.11
OS 15	2.5	3.98

Figure 15 Split tensile strength using UTM

Flexural strength: Flexural strength of concrete is another key parameter to estimate the suitability of concrete forany tructure. This test was performed on 100x100x500 mm beam. The patterns of the flexuralstrength for concrete beams at 7and 28 days are given in table 9. Flexural strength of concrete increased when 5-10% cement was replaced with waste granite powder.

[illegible]

Tests ⇨	*Flexural Strength (MPa)*	
Mix ID ⇩	7 days	28 days
Control mix	2.67	3.83
OS 5	2.85	3.79
OS 10	2.93	3.81
OS 15	2.69	3.77

5. CONCLUSION

- We have exclusively focused our study on one dimensional stone i.e., Granite. After studying all the dimensional stones available in southern Asia, we concluded that granite isfound in abundance and has got high strength so, we used granite waste powder as a replacement of cement in different proportions.
- The cementitious material i.e., cement was replaced with granite waste powder in differentmix proportions of 5 %, 10 % and 15 % by weight.
- Detailed study to investigate the fresh, mechanical and physical properties of granite wastepowder, the compatibility of use of granite waste powder in concrete was done carefully.
- Analysis of the fresh, mechanical and physical properties of

concrete mixes designed with different mix proportioning quantities with the use of granite waste powder as a cementitious material was done.

- 5-10% replacement of cement with granite waste powder by weight showed high compressive strength, flexural strength and split tensile strength as compared to conventional concrete.
- We used waste granite powder as partial replacement of cement in the proportions of 5%, 10% and 15%. We had tested and calculated the physical parameter of materials used in the research before the presentation. After the presentation, we had casted the concrete specimens and tested the strength properties of concrete for control mix and OS 5,10 at 15at 7 and 28 days.
- Study concluded that othe granite waste upto 5-10% as cement replacement in concrete gave better results in terms of compressive strength, split tensile strength and flexural strength as compared to control mix.

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