Experimental study of concrete made with granite and marble powders as partial replacement of sand

A

Project Report

submitted

in partial fulfillment

for the award of the Degree of

Bachelor of technology

In

Civil Engineering

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DECLARATION

We hereby declare that the work, which is being presented in the dissertation, entitled **"Green Concrete"** in partial fulfillment for the award of degree of **"Bachelor of Technology"** in **Department of Civil Engineering and submitted to the Department of Civil Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan ,Jaipur, Rajasthan Technical University**, is a record of my own investigation carried under the guidance of **Er. Deepak Sharma, Assistant Professor, Department of Civil Engineering, Swami Keshvanand Institute of Technology, Management & Gramothan (SKIT), Jaipur.**

I have not submitted the matter presented in this dissertation anywhere for the award of any other degree.

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ABSTRACT

Concrete is an important construction material in the present world due to industrialization and urbanization. Concrete has become a basic need for every structure nowadays. The increasing population puts a lot of pressure on the civil engineer to develop a cost effective as well as an eco-friendly structure according to the need of the people. Concrete is a heterogeneous mixture of binding material (cement or lime), coarse aggregates, fine aggregates and water. In these components only cement is manufactured and both fine and coarse aggregate has been obtained naturally. Aggregates are the important constituents in concrete.

At the same time the accumulation of industrial waste generated from various industries faces serious problems of handling and disposal all over the world. If the waste materials are found suitable in replacing the components of concrete, it can reduce the cost of construction as well as provide a safe method of disposal.

The most commonly used fine aggregate across world is river sand. River sand is expensive due to excessive cost of transportation from natural sources. The use of sand in construction activities results in the excessive mining. Due to excessive mining, natural resources are getting exhausted; results in increase in scour depth and sometimes flood possibility. Thus becoming inevitable to use alternative material in concrete. Also large scale depletion of the source creates environmental problems as environmental transportation and other constraints make the availability and use of river sand less attractive.

A substitute or replacement product for concrete industry needs to be found. Granite is an igneous rock which is widely used as construction material in different forms. Granite and marble industries produce lot of dust and waste materials. The wastes from the granite polishing units are being disposed to environment which cause health hazard. Granite and marble fines are used as a filler material in the concrete, replacing the fine aggregate which will help in filling up the pores in the concrete. In this paper an attempt is made experimentally to investigate the strength and durability behavior of M20 grade concrete with the use of granite and marble fines as an additiv*e*. Concrete is prepared with granite and marble fines as a replacement of fine aggregate in 6 different proportions namely 0%, 5%, 10%, 15% and 20%. The test results indicate that granite powder as replacement fine aggregate has beneficial effect on the mechanical durability properties such as compressive strength, split tensile strength and flexural strength of concrete.

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CHAPTER – 1

INTRODUCTION

Concrete is the single most widely used construction material in the world today. It is used in buildings, bridges, sidewalks, highway pavements, house construction, dams, and many other applications. The key to a strong and durable concrete are the mix proportions between the various components. Less cement paste can lead to more voids, thus less strength and durability while more cement paste can lead to more shrinkage and less durability. The gradation and the ratio of fine aggregates to coarse aggregates can affect strength and porosity. The mix design should also achieve the desired workability of concrete so as to prevent segregation and allow for ease of placement. Typically, a concrete mix is about 10% to 15% cement, 25% to 30% sand, 40% to 45% percent aggregate and 15% to 20% water. Entrained air (5% to 7%) is also added to concrete to improve durability. Concrete should have enough compressive strength and flexural strength to support applied loads. At the same time it should have good durability to increase its design life and reduce maintenance costs. In general, durable concrete will have good resistance to freeze and thaw, abrasion, sulfate reactions, ultraviolet radiation, seawater, alkali-silica reaction, and chlorides. The gradation and maximum size of aggregates are important parameters in any concrete mix. They affect relative proportions in mix, workability, economy, porosity and shrinkage of concrete.

Fine aggregate is an essential component of concrete. The most commonly used fine aggregate is natural river sand. The global consumption of natural river sand is very high due to the extensive use of concrete. In particular, the demand of natural river sand is quite high in developed countries owing to infrastructural growth. The non-availability of sufficient quantity of ordinary river sand for making cement concrete is affecting the growth of construction industry in many parts of the country. Recently, Tamil Nadu government (India) has imposed restrictions on sand removal from the river beds due to its undesirable impact on the environment. On the other hand, the granite waste generated by the industry has accumulated over years. Only insignificant quantity has been utilized and the rest has been dumped unscrupulously resulting in pollution problems. With the enormous increase in the quantity of waste needing disposal, acute shortage of dumping sites, sharp increase in the transportation and dumping costs necessitate the need for effective utilization of this waste. The world wide of sand as fine aggregate in concrete production is very high, and several developing countries have encountered some strain in the supply of natural sand in order to meet the increasing needs of infrastructural development in recent years. A situation that is responsible for increase in the price of sand, and the cost of concrete. Expensive and scarcity of river sand which is one of the constituent material used in the production of conventional concrete was reported in

India. Granite powder, a waste material from the granite polishing industry, is a promising material for use in concrete similar to those of pozzolanic materials such as silica fume, fly ash, slag, and others. These products can be used as a filler material (substituting sand) to reduce the void content in concrete. Granite powder is an industrial byproduct obtained from crushing of granite stone and granite stone polishing industry in a powder form. It is also generated from recycling marble tops, terrazzo, granite pavers, and stone scraps and discards. If left on its own and is not properly collected and stored, the fine granite powder can be easily be airborne and will cause health problems and environmental pollution.

Inhalation of granite powder fine particles is a health hazard and is a cause of lung diseases especially for people living near granite mills. In this present work, granite powder is used as partial replacement of sand in concrete in different percentage and the associated compressive strength, flexural, and splitting tensile strengths of concrete have been evaluated. By doing so, natural resources of sand can be preserved and the health hazards of these industrial wastes are minimized.

Recycling of granite dust will prevent these wastes from ending up in landfills and provides affordable, eco-friendly, solid stone for various uses. Recycled tiles made from recycled glass or wastes from mines or factories have been used for floors, countertops, and walls [2]. Ceramic tiles may be made from factory waste (known as post-industrial waste) generated by the production of conventional tiles. Debris series from fireclay tiles combine post-industrial and post-consumer recycled wastes. The Debris series tile consists of 26% recycled granite dust (post-industrial waste) from a granite cutting operation. It also contains 26% recycled glass (post-consumer waste).

Natural stones are quarried directly from the Earth’s crust and processed for various purposes. They are classified into two categories, namely, polished stones, including marble, granite,travertine, and onyx, and unpolished stones, such as basalt,schist, and tuff. Following extraction from the quarry, polished ones are cut into desirable sizes in the factories and workshops.These rocks are commercially referred to as marble, which I sfirst used thousands of years ago. In ancient times, marble was mainly utilized as a building stone. However, with the progression of civilization, marble began to be used for decorative purposesand in artistic designs. Marble has retained its importance to the present day. The world’s marble reserves are estimated to be inexcess of 15 billion cubic meters, and Turkey shares an estimated marble reserve of approximately 5.2 billion cubic meters. Marbleis being processed in numerous factories and workshops in almost 50 countries worldwide (Onargan et al., 2006; Çetin, 2003).The extraction and processing of marble as blocks are among the most important mining activities that are vital to the mining economy of countries. However, the rapid growth of the marble industry introduces concerns regarding the negative impact of marble quarrying on the environment, because marble cutting causes to sludge. Marble blocks are cut into blocks of different size and thickness in factories or workshops. Water is used during the cutting process to prevent the rock saw from overheating and to prevent dust. This process results in the mixing of dust with water, which forms marble sludge. The resulting waste material is dumped into the environment, either in its initial form or following dewatering in a treatment plant. Approximately 30-
40% of a quarried marble block becomes waste in the form of sludge. Annually, approximately 2.500.000 tons of marble sludge are generated as a by-product of marble production in Turkey

(Ayd n, 2013). Processing plants cannot easily store the increasing amounts of waste material. However, marble powder must be physically and chemically processed for use in these industries, and the utilization of marble powder is not sufficient to consume all waste material stocks. Concrete, on the other hand, is an advantageous construction material, whose production The present work is aimed at developing a concrete using the granite and marble scrap, an industrial waste as a replacement material for the fine aggregate. By doing so, the objective of reduction of cost of construction can be met and it will also help to overcome the problem associated with its disposal including the environmental problems of the region. Accordingly this project work will examine M20 grades of concrete were cast by varying the percentage replacement of sand with granite and marble fines.

One of the most important benefits of substituting granite powder in concrete is on human health. The controlled collection of granite dust from industrial facilities will reduce the amount of silica in the air thus reducing the risk of silicosis. Workers involved in manufacturing, grinding, finishing, and installing natural and manufactured stone and granite countertops are at risk for significant crystalline silica exposure. Studies have shown that workers who inhale very small crystalline silica particles are at risk for silicosis – an incurable, progressively disabling and sometimes fatal lung disease. The US Department of Labor and the US National Institute of Occupational Safety and Health (NIOSH) recommends that employers install and maintain engineering controls to eliminate or reduce the amount of silica in the air and the build-up of dust on equipment and surfaces. Examples of controls include: exhaust ventilation and dust collection systems, water sprays, wet drilling, enclosed cabs, and drill platform skirts. NIOSH recommends that employers control exposure to respirable crystalline silica so that no worker is exposed to a time-weighted average concentration of silica greater than 50 $\mu g/m^3$ of air, as determined by a full-shift sample for up to a 10-h workday of a 40-h workweek. The Occupational Safety and Health Administration (OSHA) permissible limit of pure quartz silica exposure is about 100 $\mu g/m^3$ [13]. Sirianni et al. reported significant differences in particle size distributions in silica content of granite quarries in Vermont depending on the extent of ventilation and the nature and activity of work performed. The researchers concluded that such variability in silica content raises concerns about the adequacy of silica exposure assessment.

CHAPTER – 2

REVIEW OF LITERATURE

Kanmalai Williams C et al (2008) examined the performance of concrete made with granite powder as fine aggregate. Sand was replaced with granite powder in steps of 0, 25, 50, 75 and 100% and cement was replaced with 7.5% Silica fume, 10% fly ash and 10% slag. They added 1% superplasticizer to improve the workability. The effects of curing temperature at 320 C and 1, 7, 14, 28, 56 and 90 days compressive strength, split tensile strength, modulus of elasticity, drying shrinkage and water penetration depth were found. Experimental results indicated that the increase in the proportions of granite powder resulted in a decrease in the compressive strength of concrete. The highest compressive strength was achieved in samples containing 25% granite powder concrete, which was 47.35 MPa after 90 days. The overall test performance revealed that granite powder can be utilized as a partial replacement of natural sand in high Performance concrete.

Oyekan G.L and Kamiyo O.M (2008) studied the performance of hollow sand create blocks containing cement, sharp sand and granite fines in varying propositions to determine their structural and hydrothermal properties. The percentage of granite fines by volume of the total fine aggregate was varied in steps of 5% to a maximum of 30%. Results of the tests indicated that the inclusion of granite fines in the sand-cement matrix has a very significant effect on the compressive strength of sand Crete blocks. It was also, observed that for both mix propositions, 15% granite fines content was the optimum value for improved structural performance.

Felixkala T and Partheeban P (2010) examined the possibility of using granite powder as replacement of sand along with partial replacement of cement with fly ash, silica fume and blast furnace slag. They reported that granite powder of marginal quantity as partial replacement to sand had beneficial effect on the mechanical properties such as compressive strength, split tensile strength and modulus of elasticity. They also reported that the values of plastic and drying shrinkage of concrete with granite powder were less than those of ordinary concrete specimens.

Shirule P.A et al (2012) determined the compressive strength and split tensile strength of concrete in which cement was partially replaced with marble dust powder (0%, 5%, 10%, 15%, 20%).The result indicated that the compressive strength of concrete increased with addition of waste marble powder up to 10% replaced by weight of cement and further addition of waste marble powder was found to decrease the compressive strength. The optimal percentage replacement was found to be 10%.

Perez et al conducted a study on the use of recycled marble tops as partial replacement of sand in concrete. The paper points out that the researchers have analyzed the effect of replacing cement, sand, and coarse aggregate with marble byproduct in many countries, but there is a lack of research analyzing the use of marble waste in the United States. This is especially true for postindustrial byproducts such as countertop installation waste, or postconsumer products after a building deconstruction. They highlight the advantages of using such recycled materials in concrete because of potential cost, regulatory and green certification benefits. In particular, they mention that the cost of delivering waste materials to landfills and the landfills' fees are especially high in localities that have stringent environmental regulations such as the San Francisco Bay Area. Results from their study showed that marble, terrazzo and granite countertop waste from construction finishes activities can be effectively used as a replacement for up to 30% coarse and fine aggregate in concrete without negatively affecting the slump, the 7-day compressive strength or the 28-day compressive strength. The use of such byproducts in concrete, rather than disposing them in a landfill, significantly reduces the impact of such materials on the environment. Their research concludes that the most practical, environmentally friendly, and cost efficient use of the recycled materials (marble, terrazzo and granite) in a project is to be a partial coarse aggregate substitute. According to the Leadership in Energy and Environmental Design (LEED) system developed by the US Green Building Council (USGBC), credits are given for reducing construction and demolition waste disposed in landfills and incineration facilities by recovering, reusing, and recycling materials. In addition, the main cost will be incurred in storing and collecting granite powder and iron powder hazard materials. Thus recycling these materials and using as partial replacement of sand in concrete will be beneficial both environmentally and economically.

Alyamaç and Ince (2009) demonstrated the feasibility marble powder usage as filler in self-compacting concrete and designed a practical concrete mixture to increase the use of marble powder in self-compacting concrete. Furthermore, marble powder has become widely used as filler in self-compacting concrete. Subsequently, marble powder is used successfully to develop self-compacting concrete that incorporates a rubber aggregate (Topçu and Bilir, 2009; Yung et al., 2013). Strength is as important for the performance of concrete durability. Many researchers have suggested that self-compacting concrete containing marble powder is more durable than reference concrete (Geso lu et al., 2012; Belaidi et al., 2012). Hameed et al. (2012) reported that self-compacting concrete produced with marble powder is the innovative concrete. Marble powder is also used to increase the strength and durability of construction materials, such as paving blocks with improvements in the mechanical strength, freeze-thaw durability, and abrasion resistance of the concrete. Gencel et al. (2012a) recommended the use of marble powder as a replacement for aggregate, whereas marble powder is used as a replacement for fine sand in conventional concrete (Demirel, 2010). The latter study is in good agreement with Gencel et al. (2012a), who showed that the marble powder improves the overall performance of concrete.

Vijayalakshmi et al. [15] evaluated the durability of concrete made with granite powder. They studied durability properties such as water permeability, rapid chloride penetration (RCPT), carbonation depth, sulfate resistance and electrical resistivity. Their results showed that the replacement of natural sand with granite powder (GP) waste up to 15% of any formulation is favorable for the concrete making without adversely affecting the strength and durability. They recommended to chemically bleaching the GP prior to blending in the concrete to increase the sulfate resistance.

Singh et al., suggested that 25–40% of river sand can be substituted by the granite cutting waste (GCW) with a favorable influence on the investigated parameters. Their results showed that the optimum amount of GCW to be used in concrete depends on the water-cement ratio of concrete. Singh et al. published a study reviewing past research on replacing sand with granite dust. Their review showed that granite dust has increased the mechanical properties of concrete and has the potential to produce durable concrete. Their review of previous research showed that granite dust concrete exhibits enhanced dense and compact concrete matrix at optimum percentage replacement levels. Zhao et al. studied the use of iron ore tailings in ultra-high strength concrete. Their results showed comparable results between the concrete with iron ore tailing less than 40% and the control concrete.

Results from this study and from studies by others referenced in this introduction showed that there are advantages to concrete when granite powder is used to partially replace sand in the concrete mix. The benefits of using granite powder as partial replacement of sand not only can enhance strength but also preserve the natural resources of sand and also keeps these powder particles from being airborne into the atmosphere causing health hazard to humans, in particular children.

2.1 Research significance

Granite powder and marble powder are industrial byproducts resulting from the granite stone crushing and polishing and from the steel production respectively. These byproducts can be used as partial replacement of sand in concrete. When used in certain proportions, granite powder and iron powder have shown to increase the compressive strength, flexural strength, and splitting tensile strength of concrete. The experimental research conducted in this study showed the mechanical properties of concrete have improved when granite powder and iron powder were used as partial replacement of sand in specified percentages. In addition, the use of these powders as a partial replacement of sand will reduce the consumption of sand in the construction industry thus preserving more of these natural resources. Recycling of these byproducts and using them in concrete will reduce their health hazards and their impact on the environment.

Fig .1 granite powder

Fig. 2 Marble powder

CHAPTER-3

METHODOLOGY

3.1 Material used

3.1.1 Cement

Portland pozzolona cement is used for this experimental work. By the large construction and infrastructure development programm, world is using cement and steel but mostly cement is used due to its economical and low cost maintenance cost for high and early strength, PPC is best into use for work and also minimize the quantity of cement due to presence of fly ash when the design is performed for mix proportions with super plasticizer. PPC is eco-friendly and economical.

Table 3.1 Physical Properties of Cement

S. No.	Characteristics	Values Obtained	Standard Values
1.	Normal Consistency	30%	-
2.	Initial Setting Time	1 hours 50 min	Not to be less than 30 minutes
3.	Final Setting Time	3 hours 50 min	Not to be greater than 600 minutes
4.	Fineness	3.7%	<10%
5.	Specific Gravity	3.15	-
6.	Compressive Strength (3 days)	17 Mpa	16Mpa
7.	Compressive Strength(7 days)	24 Mpa	22 Mpa
8.	Compressive Strength(28 days)	36 Mpa	33 Mpa
9.	Soundness	9mm	10mm

3.1.2 Aggregates

An aggregate occupy approximately 80 % of total concrete mix weight and occupies 70-75% of total concrete mix volume. Optimum use of aggregates quality and size in required for better quality of concrete, coarse aggregates are mainly responsible in improving performance of concrete. To achieve higher degree of quality concrete, aggregates must be cleaned and by mechanical process such as crushing, screening, mixing and washing.

Cement paste should have a strong bond with concrete aggregate, it should not interfere with cement hardening nor any other negative appearance on concrete durability after setting time.

Coarse Aggregate

The following size of aggregates is used for this experimental programme

(a) 10mm

(b) 20mm

The coarse aggregate is obtained from locally available i.e Gunawata, Jaipur. It’s visual inspection is done for shape, texture, cleavage and angularity of coarse aggregate, shape and angularity of arrogate has shown the quality and standard which means that how the quality of coarse aggregate and how can be used the same.

The following codes are used for coarse aggregate

(1) IS-383-1970-Specifications for aggregates from natural source

(2) IS-2386 (Part-i)-1963-particle size and shape

(3) IS-2386 (Part-iii)-1963-specific gravity ,density& water absorption

Table 3.2 Physical Properties of Coarse Aggregate 20mm & 10mm

Physical Property	20mm	10mm
Density (OD)	1471Kg/m^3	1390Kg/m^3
Density(SSD)	1550Kg/m^3	1475Kg/m^3
Density(Apparent)	1480Kg/m^3	1410Kg/m^3
Sp. Gravity (OD)	2.79	2.80
Sp. Gravity (SSD)	2.82	2.82
Bulk density	1475Kg/m^3	1500Kg/m^3
Water absorption	0.5	0.6

Fig. 3 Coarse Aggregate

Fig. 4 Fine aggregates

Fine Aggregate

The material which passes through 4.75 mm sieve is known as fine aggregate.

As per IS-383 -1970, there are four grading zones for fine aggregate

1) Grading zone I
2) Grading zone II
3) Grading zone III
4) Grading zone IV

These grading zones are classified as per percentage passing material from several sieves and but only 600µ sieve describe what kind of zone of fine aggregate by using percentage passing limits.

Percentage of passing for 600µ sieve of all zones are given below :

(i) For grading zone I- 15% to 34%
(ii) For grading zone II- 55% to 59%
(iii) For grading zone III- 60% to 79%
(iv) For grading zone IV- 80% to 100%

Here, fine aggregate is taken from Banas, Tonk, Rajasthan and designated IS –Sieve for material passing through Zone II is found.

Table 3.3 Physical Properties of Sand

Physical Property	**Natural Sand (Banas)**
Density (OD)	1600Kg/m^3
Density(SSD)	1650Kg/m^3
Sp. Gravity (OD)	2.64
Sp. Gravity (SSD)	2.68
Sp. Gravity (SSD)	2.70
Bulk Density	1600Kg/m^3
Water Absorption	1.25

3.1.3 Water

According to IS 456-2000, the pH value of water should be in the range of 6-8. The sea water is generally saline, high quantity of sodium chloride (NaCl) is responsible for this salinity.

Many researchers have been done in order to study the corrosion problem of steel Embedded in concrete.

The Indian standard do not allow use of saline water for mixing or curing in reinforced Concrete constructions, but allows use of sea water only for plain cement concrete (PCC) work and that too under unavoidable circumstances. Generally the water that is used for mixing of concrete is also used for curing. Water containing impurities should not to be used where appearance is highly important. Iron, and organic matters are the most important elements that cause stains in the concrete. It is also found that even sea water also causes stains in concrete. Hence water containing iron, organic matters and also sea water should not be used for curing of concrete when appearance is also set as main criteria for the acceptance of concrete.

3.1.4 Gradation of Aggregate

The gradation or particle size distribution of aggregate is one of the most influencing characteristics determining that how aggregate will act in concrete and other applications of work. The size distribution is almost always critical importance that measures the material performance when it is taken in use. Gradation helps to determine the every property like workability, durability, permeability, stiffness and stability etc.

Fine Aggregate Grading

Banas sand of zone II was recommended for concrete mix.

Following sieves is used for gradation of banas sand (fine aggregate)

4.75mm,2.36mm,1.18mm,600micron,300micron,150micron

Table 3.4 Fine aggregate sieve analysis as per IS 383

IS Sieve	Percentage passing for			
	Grading zone I	**Grading zone II**	**Grading zone III**	**Grading zone IV**
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18	30-70	55-90	75-100	90-100
600micron	15-34	35-59	60-79	80-100
300 micron	5-20	8-30	12-40	15-50
150micron	0-10	0-10	0-10	0-15

3.2 TESTS PERFORMED:

3.2.1 Sieve Analysis:

A sieve analysis (or gradation test) is a practice or procedure used (commonly used in civil engineering) to assess the practical size distribution (also called gradation) of a granular material this is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different size particles left over different sieves.


Fig .5 Sieve analysis

3.2.2 Fine Aggregate Grading

As per IS-383:1970,Banas Sand of zone - II was recommended for concrete mix.The Sieves recommended for Gradation of Banas Sand are 10mm, 4.75mm, 2.36mm, 1.18mm, 600 micron, 300 micron and 150 micron.

Table 3.5 Sieve Analysis of Fine Aggregate (IS 383/2386)

Sieve size	**Retained (gm)**			**% Retained weight**	**Cumulative % Retained**	**Cumulative % Passing**	**Limit as per IS 383**
	Sample 1	**Sample 2**	**Average**				
10 mm	0	0	0	0	0	100	100
4.75 mm	58.5	56.5	57.5	2.87	2.87	97.13	90-100
2.36 mm	114.5	115.5	115	5.75	8.62	91.38	75-100
1.18 mm	319.5	317.5	318.5	15.92	24.54	75.46	55-90

600 micron	320.5	322.5	321.5	16.07	40.61	59.39	35-59
300 micron	1018	1016.5	1017.25	50.86	91.47	8.53	8.0-30
150 micron	155	159.5	157.25	7.88	99.35	0.65	0-10
PAN	14	12	13	0.65	**267.46**		
Total	2000	2000	2000	100			

Fineness Modulus = 267.46/100 = **2.67**

Grading Zone = II

Test accepted / rejected under clause-Accepted as per 4.3 (Table 4) of IS: 383- 1970

3.2.3 Coarse Aggregate Grading (10mm)

As per IS-383:1970,The Sieves recommended for gradation of gunawata coarse aggregate are 12.5mm, 10mm,4.75mm and 2.36mm.

Table 3.6 Sieve Analysis of 10 mm Aggregate (IS 383/2386)

Sieve size	**Retained (gm)**			**% Retained weight**	**Cumulative % Retained**	**Cumulative % Passing**	**Limit as per IS 383**
	Sample 1	**Sample 2**	**Average**				

12.5 mm	0	0	0	0	0	100	100
10 mm	84	90	87	4.35	4.35	97.99	85-100
4.75 mm	1386	1390	1388	69.4	73.75	29.84	0-20
2.36 mm	512	523	517.5	25.875	99.6	3.965	0-5
1.18 mm	14	6	10	0.5	100	0	0
600micron	0	0	0	0	100	0	0
300micron	0	0	0	0	100	0	0
150micron	0	0	0	0	100	0	0
PAN	0	0	0	0	**577.7**		
Total	2000	2000	2000	100.00			

Fineness Modulus = 577.7/100 = **5.77**

3.2.4 Coarse Aggregate Grading (20mm)

As per IS-383:1970,The Sieves recommended for gradation of gunawata coarse aggregate are 40mm, 20mm, 10mm, and 4.75mm.

Table 3.7 Sieve Analysis of 20 mm Aggregate (IS 383/2386)

Sieve size	**Retained (gm)**	**% Retained**	**Cumulative %**	**Cumulative**	**Limit as per**

	Sample 1	Sample 2	Average	weight	Retained	% Passing	IS 383
40 mm	0	0	0	0	0	100	100
20 mm	2327.5	2325.5	2326.5	46.53	46.53	53.47	85-100
10 mm	2154	2153	2153.5	43.07	89.60	10.4	0-20
4.75 mm	497	490	493.5	9.87	99.47	0.53	0-5
2.36 mm	21.5	31.5	26.5	0.53	100	0	0
1.18 mm	0	0	0	0	100	0	0
600 micron	0	0	0	0	100	0	0
300 micron	0	0	0	0	100	0	0
150 micron	0	0	0	0	100	0	0
PAN	0	0	0	0	**735.6**		
Total	5000	5000	5000	100			

Fineness Modulus = 735.6/100 = **7.35**

3.2.5 Impact value test

Determination of Aggregate Impact Value – Impact Test on Aggregates is done to carry out to:

- ✓ Determine the impact value of the road aggregates,
- ✓ Assess their suitability in road construction on the basis of impact value.

Aggregate Impact Value on Coarse Aggregates

The apparatus as per IS: 2386 (Part IV) – 1963 consists of:

1. A testing machine weighing 45 to 60 kg and having a metal base with a painted lower surface of not less than 30 cm in diameter. It is supported on level and plane concrete floor of minimum 45 cm thickness. The machine should also have provisions for fixing its base.
2. A cylindrical steel cup of internal diameter 102 mm, depth 50 mm and minimum thickness 6.3 mm. .
3. A metal hammer or tup weighing 13.5 to 14.0 kg the lower end being cylindrical in shape, 50 mm long, 100.0 mm in diameter, with a 2 mm chamfer at the lower edge and case hardened. The hammer should slide freely between vertical guides and be concentric with the cup. Free fall of hammer should be within 380±5 mm.
4. A cylindrical metal measure having internal diameter 75 mm and depth 50 mm for measuring aggregates.
5. Tamping rod 10 mm in diameter and 230 mm long, rounded at one end.
6. A balance of capacity not less than 500g, readable and accurate up to 0.1 g.

Fig. 6 aggregate impact value test

Theory of Aggregate Impact Test

The property of a material to resist impact is known as toughness. Due to movement of vehicles on the road the aggregates are subjected to impact resulting in their breaking down into smaller pieces. The aggregates should therefore have sufficient toughness to resist their disintegration due to impact. This characteristic is measured by impact value test. The aggregate impact value is a measure of resistance to sudden impact or shock, which may differ from its resistance to gradually applied compressive load.

Procedure of Aggregate Impact Test

The test sample consists of aggregates sized 10.0 mm 12.5 mm. Aggregates may be dried by heating at 100-110° C for a period of 4 hours and cooled.

1 Sieve the material through 12.5 mm and 10.0mm IS sieves. The aggregates passing through 12.5mm sieve and retained on 10.0mm sieve comprises the test material.

2 Pour the aggregates to fill about just 1/3 rd depth of measuring cylinder.

3 Compact the material by giving 25 gentle blows with the rounded end of the tamping rod.

4 Add two more layers in similar manner, so that cylinder is full.

5 Strike off the surplus aggregates.

6 Determine the net weight of the aggregates to the nearest gram(W).

7 Bring the impact machine to rest without wedging or packing up on the level plate, block or floor, so that it is rigid and the hammer guide columns are vertical.

8 Fix the cup firmly in position on the base of machine and place whole of the test sample in it and compact by giving 25 gentle strokes with tamping rod.

9 Raise the hammer until its lower face is 380 mm above the surface of aggregate sample in the cup and allow it to fall freely on the aggregate sample. Give 15 such blows at an interval of not less than one second between successive falls.

10 Remove the crushed aggregate from the cup and sieve it through 2.36 mm IS sieves until no further significant amount passes in one minute. Weigh the fraction passing the sieve to an accuracy of 1 gm. Also, weigh the fraction retained in the sieve.

Compute the aggregate impact value. The mean of two observations, rounded to nearest whole number is reported as the Aggregate Impact Value.

Result of Impact Test

Total weight of dry sample (W_1 gm)

Weight of portion passing 2.36 mm sieve (W_2 gm)

Aggregate Impact Value (percent) = W_2 / W_1 X 100

Aggregate Impact Value = 15.82%

3.2.6 Abrasion Value

Los Angeles abrasion test on aggregates is the measure of aggregate toughness and abrasion resistance such as crushing, degradation and disintegration. This test is carried out by AASHTO T 96 or ASTM C 131: Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine.

The aggregate used in surface course of the highway pavements are subjected to wearing due to movement of traffic.

When vehicles move on the road, the soil particles present between the pneumatic tyres and road surface cause abrasion of road aggregates. The steel rimmed wheels of animal driven vehicles also cause considerable abrasion of the road surface.

Therefore, the road aggregates should be hard enough to resist abrasion. Resistance to abrasion of aggregate is determined in laboratory by Los Angeles test machine.

The principle of Los Angeles abrasion test is to produce abrasive action by use of standard steel balls which when mixed with aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates.

The percentage wear of the aggregates due to rubbing with steel balls is determined and is known as Los Angeles Abrasion Value.

Crushing value test

Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. Coarse aggregate crushing value is the percentage by weight of the crushed material obtained when test aggregates are subjected to a specified load under standardized conditions. Aggregate crushing value is a numerical index of the strength of the aggregate and it is used in construction of roads and pavements. Crushing value of aggregates indicates its strength. Lower crushing value is recommended for roads and pavements as it indicates a lower crushed fraction under load and would give a longer service life and a more economical performance. The aggregates used in roads and pavement construction must be strong enough to withstand crushing under roller and traffic. If the aggregate crushing value is 30 or higher' the result may be anomalous and in such cases the ten percent fines value should be determined instead.

Apparatus

1 **.**A steel cylinder 15 cm diameter with plunger and base plate.

2. A straight metal tampering rod 16mm diameter and 45 to 60cm long rounded at one end.

3. A balance of capacity 3 kg readable and accurate to one gram.

4 .IS sieves of sizes 12.5mm, 10mm and 2.36mm

5. A compression testing machine.

6. Cylindrical metal measure of sufficient rigidity to retain its from under rough usage and of 11.5cm diameter and 18cm height.

7 .Dial gauge

Sampling of Aggregates

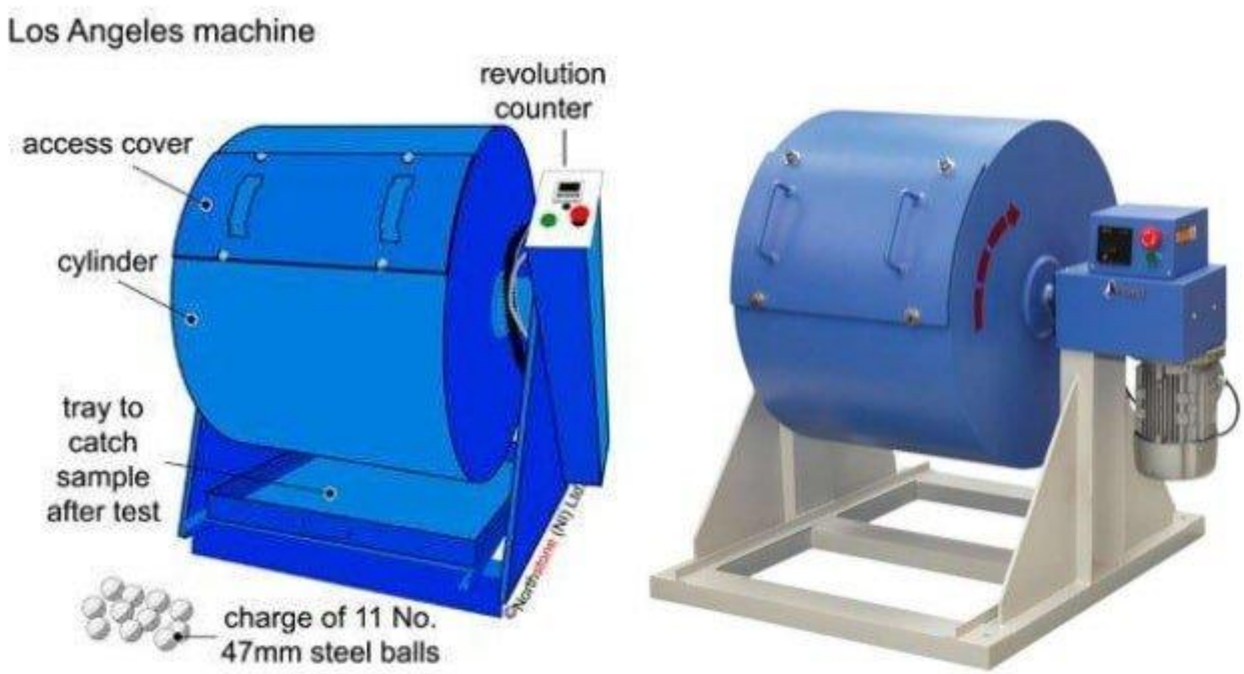
Coarse aggregate passing 12.5mm IS sieve and retained on a10mm IS sieve are selected and heated at 100 to 110°C for 4 hours and cooled to room temperature. The quantity of aggregate shall be such that the depth of material in the cylinder, after tamping as described below shall be 10 cm. The appropriate quantity may be found conveniently by filling the cylinder. Measure in three layers of approximately equal depth, each layer being tempered 25 times with the tamping rod and finally leveled off using the tamping rod as straight edge .Care being taken in the case of weaker materials not to break the particles. The weight of the material comprising the test sample shall be determined (weight A) and the same weight of sample shall be taken for the repeat test.

Procedure of Aggregate Crushing Value Test

1. Put the cylinder in position on the base plate and weigh it (W).
2. Put the sample in 3 layers, each layer being subjected to 25 strokes using the tamping rod. Care being taken in the case of weak materials not to break the particles and weigh it (W1).
3. Level the surface of aggregate carefully and insert the plunger so that it rests horizontally on the surface. Care being taken to ensure that the plunger does not jam in the cylinder.
4. Place the cylinder with plunger on the loading platform of the compression testing machine.
5. Apply load at a uniform rate so that a total load of 40T is applied in 10 minutes.
6. Release the load and remove the material from the cylinder.
7. Sieve the material with 2.36mm IS sieve, care being taken to avoid loss of fines.
8. Weigh the fraction passing through the IS sieve (W2).

Result

The aggregate crushing value of the given sample = **(W2 x 100) / (W1-W) =** 3.01%



Los Angeles abrasion test setup

Fig .7 Los angeles abrasion test

Determination of Los Angeles Abrasion Value

The Los Angeles abrasion test on aggregates is done for following purposes:

1. To determine the Los Angeles abrasion value.
2. To find the suitability of aggregates for use in road construction.

Apparatus for Los Angeles Test

The apparatus as per IS: 2386 (Part IV) – 1963 consists of:

1. Los Angeles Machine
2. Abrasive charge: Cast iron or steel balls, approximately 48mm in diameter and each weighing between 390 to 445 g; six to twelve balls are required.
3. Sieve: 1.70, 2.36, 4.75, 6.3, 10, 12.5, 20, 25, 40, 50, 63, 80 mm IS Sieves.
4. Balance of capacity 5 kg or 10 kg
5. Drying oven
6. Miscellaneous like tray

Procedure for Los Angeles Test

The test sample consists of clean aggregates dried in oven at 105° – 110°C. The sample should conform to any of the grading shown in table 1.

1. Select the grading to be used in the test such that it conforms to the grading to be used in construction, to the maximum extent possible.
2. Take 5 kg of sample for grading A, B, C & D and 10 kg for grading E, F & G.
3. Choose the abrasive charge as per Table 2 depending on grading of aggregates.
4. Place the aggregates and abrasive charge on the cylinder and fix the cover.

5. Rotate the machine at a speed of 30 to 33 revolutions per minute. The number of revolutions is 500 for grading A, B, C & D and 1000 for grading E, F & G. The machine should be balanced and driven such that there is uniform peripheral speed.
6. The machine is stopped after the desired number of revolutions and material is discharged to a tray.
7. The entire stone dust is sieved on 1.70 mm IS sieve.
8. The material coarser than 1.7mm size is weighed correct to one gram.

Table 3.8 Limitation of Various Test of Aggregate

S. No.	Name of Test	Value	Limit
1	Water Absorption of CA	0.75%	0.1- 2%
2	Water Absorption FA	1.15%	0.1- 2%
3	Specific Gravity CA	2.67	2.5-3.0
4	Specific Gravity FA	2.64	2.5-3.0
5	Crushing Value	3.01%	Less Than 30%
6	Impact Value	15.82%	Less Than 30%
7	Abrasion Value	21.99%	Less Than 30%
8	Combined Flaky & Elongation	8.09%	Less Than 30%

Granite Powder

Granite belongs to igneous rock family. The density of the granite is between 2.65 to 2.75 g/cm^3 and compressive strength will be greater than 200MPa. Granite powder obtained from the polishing units and the properties were found. Since the granite powder was fine, hydrometer analysis was carried out on the powder to determine the particle size distribution. From hydrometer analysis it was found that coefficient of curvature was 1.95 and coefficient of uniformity was 7.82. The specific gravity of granite powder was found to be 2.5.

MARBLE POWDER

Marble Dust Powder is a metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite. Marble may be foliated. Geologists use the term "marble" to refer to metamorphosed limestone; however, stonemasons use the term more broadly to encompass un-metamorphosed limestone. Marble is commonly used for sculpture and as a building material

Properties	Marble Powder
Specific gravity (g/cm^3)	2.71
Surface by blaine (cm^2/g)	4372
SiO_2 (%)	0.94
Fe_2O_3 (%)	0.46
$CaCO_3$ (%)	97.35

Table 3.9 properties of marble powder

3.2.7 Details of concrete mix:

Mix of M20 grade concrete was designed as per Indian Standard 10262: 2009 and the specimens were cast. During the present study, the fine aggregate was replaced with granite powder and the percentages of granite powder added were 0, 10, 15 and 20% of fine aggregate.

Table 3.10 mix proportion

Mix	Cement	Sand (FA)	Coarse agg (CA)	Water	SP	Mix proportion C: W: FA: CA: MG
MG0	410	620	1250	165	0	1: 0.4: 1.51: 3.05: 0.000
MG5	410	589	1250	165	31	1: 0.4: 1.43: 3.05: 0.075
MG10	410	558	1250	165	62	1: 0.4: 1.36: 3.05: 0.150
MG15	410	525	1250	165	95	1: 0.4: 1.28: 3.05: 0.225

Mix	Cement	Sand (FA)	Coarse agg (CA)	Water	SP	Mix proportion C: W: FA: CA: MG
MG20	410	496	1250	165	124	1: 0.4: 1.20: 3.05: 0.305

C—Cement; W—Water; FA—Fine aggregate; CA—Coarse aggregate; MG—Granite and marble powder MG-marble and granite percent

3.2.8 Concrete Mixing Procedure

1) First of all aggregates are added for short period of time, after that cementious material is added and mixed till the dry mix exhibits uniform color.

2) The water was mixed in the mixer while it was rotating. The mix was rotated for 3 minute, left to rest for 3 min. and again rotated for 2 min.

3) Mix was examined carefully.

4) After addition of all material, slump test was performed in order to determine and compare desired slump and current slump .When desired slump was not achieved, Another slump test was done and repeated until desired slump was not achieved.

Fig .8 students preparing fresh concrete

3.2.9 Procedure for Testing of Fresh Concrete

Tests have been done for workability for fresh concrete by slump test.

Slump test was done as per the guidelines of IS 1191:1959 and procedure adopted is given below

- The internal dimensions of slump cone 10cm×20cm×30cm are thoroughly cleaned, freed from superfluous moisture and set concrete is removed before starting this test.
- The slump cone is placed on a smooth, horizontal, rigid and non-absorbent base plate.
- The slump cone mould is filled in four layers, each approximately one-quarter of the height (30cm) of the mould.
- Each layer is tampered 25 times by tamping rod, taking care to distribute strokes evenly over the cross-section of slump cone.

- The slump cone is removed from the concrete immediately by raising and rotating it slowly and carefully in a vertical direction.
- This allows concrete to subside to lack of support.
- The difference in the level between the height of the mould and that of highest point of subsided concrete is measured.
- The difference in height of concrete is taken as slump value of concrete.

The water demand for a specific level of workability is influenced by the size, shape and texture and gradation of aggregates and the volume and nature of cementitious and fine materials.

Fig .9 students performing slump test

3.2.10 Procedure for Testing of Hardened Concrete

The following tests were performed on hardened concrete:

Compressive Strength

The compressive strength tests result are preliminary used to determine that concrete mixture as delivered needs the requirement of the specified strength in the job specification.IS 456:2000 indicates that any test result should be average of at least 3 standard cured strength specimens made from the same concrete sample and tested at the same age.

The procedure adopted for the tests were as follows -

- The compressive strength of all mixes was casted with cube specimen of size 150mm (length) x 150mm (width) x 150mm (depth) .
- The specimens were tested after deep water curing for 7 days, 14 and 28 days fully immersed in water tank as per IS 516:1959 for method, of tests for strength of concrete.
- At least 3 cube specimen preferably form different batches, are tested at each selected age 7 days, 14 and 28 days respectively.

Flexural Strength

IS 519:1959 describes standard specification for testing concrete with centre point and third point loadings. Centre point loading was adopted and test was carried out for flexural strength.

- The flexural strength test is performed to calculate the tensile load at which the concrete may fail.
- This is an indirect test for assessing tensile strength of concrete specimen.
- The test consists gives tensile strength at failure.
- The Flexural strength of all mixes are measured with beam specimen of size 700mm (length) x 150mm (width) x 150mm (depth).

- The specimens are tested after curing for 28 days fully immersed in water tank as per IS 516:1959 for method of tests for strength of concrete. The central point loading method is used for this testing.

CHAPTER -4

RESULT AND DISCUSSION

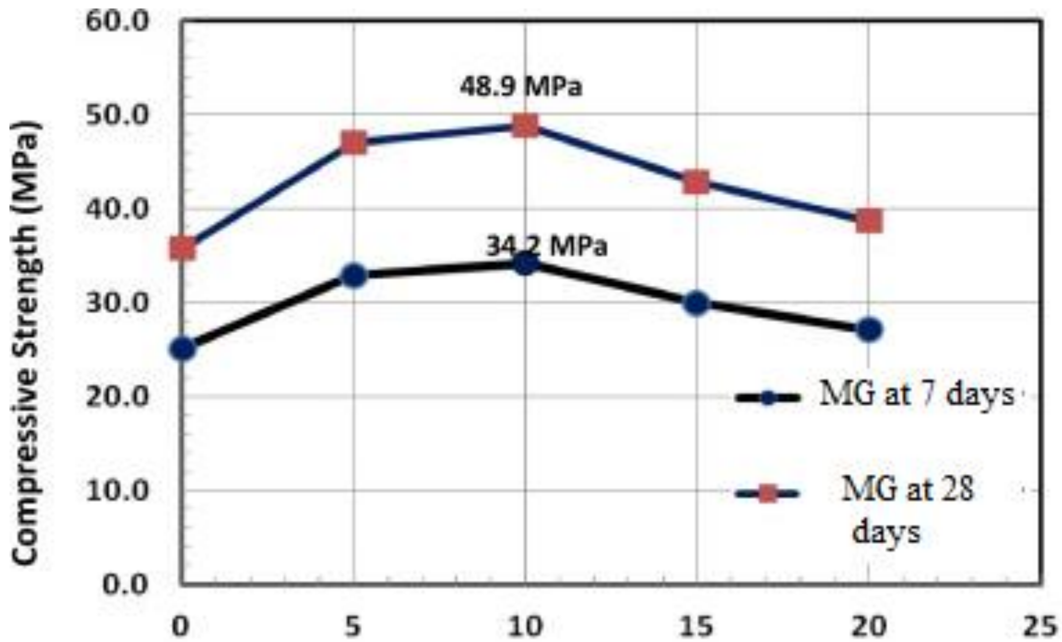
4.1 Compressive strength

The compressive strength of the cubes was determined for control specimens and for specimens with various percentages of granite and marble powder. The average compressive strength of control cubes (Mix MG0) was 35.8 N/mm^2. The cubes with granite and marble powder showed higher compressive strength. The compressive strengths of mix designs MG5, MG10, MG15 and MG20 were 47.1 N/mm^2, 48.9 N/mm^2, 42.9 N/mm^2,38.7 N/mm^2 respectively. The test showed that the optimum percentage of granite and marble powder to achieve the maximum increase in compressive strength was 10%. For 20% partial replacement of sand with granite powder the increase in the compressive strength was relatively small. The values of compressive strengths of cubes made with different percentages of granite powder replacement of sand are given in table and also graphically presented.

Table 4.1 Compressive strengths of cubes with different proportions of MG.

Mix design	**% of granite powder**	**Compressive strength (N/mm^2) at 7 days**	**Compressive strength (N/mm^2) at 28 days**	**% Increase in strength at 7 days**	**% Increase in strength at 28 days**
MG0	0	25.1	35.8	–	–
MG5	5	32.9	47.1	31.1	31.4
MG10	**10**	**34.2**	**48.9**	**36.3**	**36.6**
MG15	15	30.0	42.9	19.5	19.8

Mix design	% of granite powder	Compressive strength (N/mm^2) at 7 days	Compressive strength (N/mm^2) at 28 days	% Increase in strength at 7 days	% Increase in strength at 28 days
MG20	20	27.1	38.7	8.00	8.10



% of marble and granite powder (MG)

Fig.10 students performing Compressive strength test

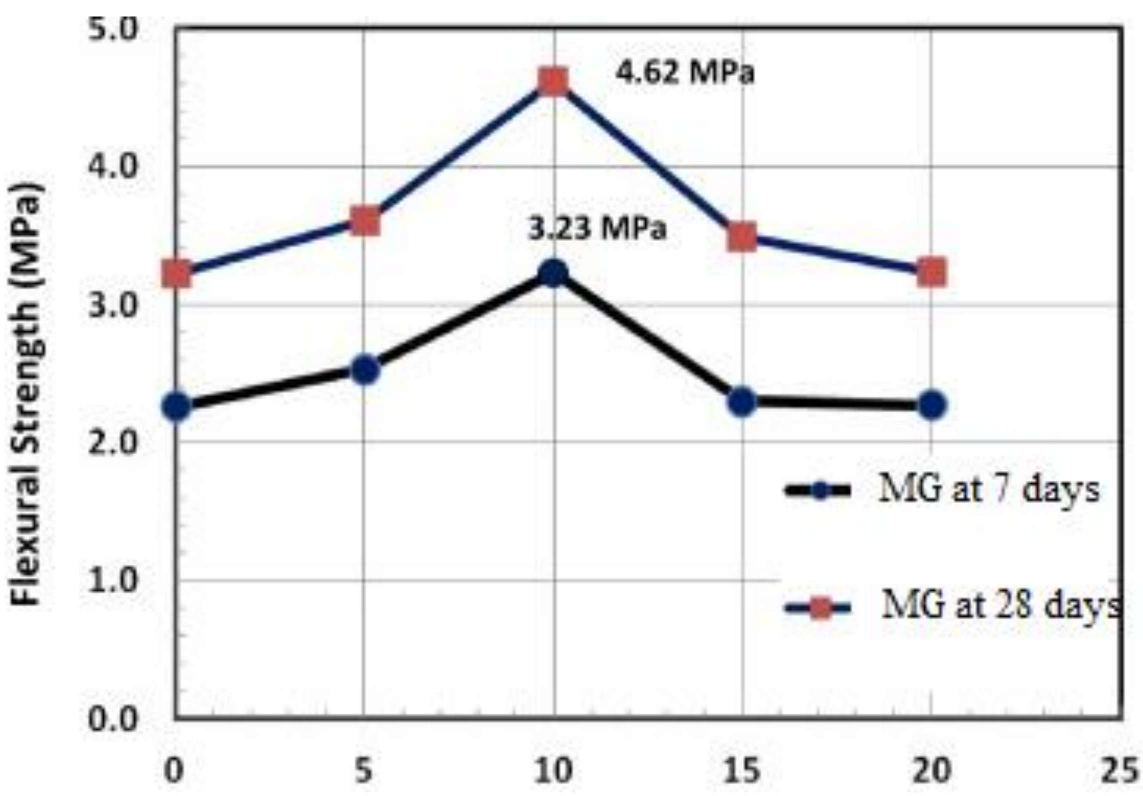
4.2 Flexural strength

The flexural strength of the beams was determined for the control beams as well as the beams with various percentages of granite powder. The flexural strength of control beams at 28 days (Mix MG0) was 3.23 N/mm^2 (469 psi). The beams with granite powder showed higher flexural strength. The flexural strengths of mix designs MG5 (5%), MG10 (10%), MG15 (15%) and MG20 (20%) were 3.61 N/mm^2, 4.62 N/mm^2, 3.49 N/mm^2, 3.42 N/mm^2 respectively. The tests showed that the optimum percentage of granite powder to achieve the maximum increase in flexural strength was 10%. For 20% partial replacement of sand with granite powder the increase in the flexural strength was relatively small. The values of flexural strengths of beams made with different percentages of granite powder of sand are given in table and also presented graphically.

Table 4.2 Flexural strength of beams with different proportions of marble and granite powder.

Mix design	**% of granite powder**	**Flexural strength (N/mm^2) at 7 days**	**Flexural strength (N/mm^2) at 28 days**	**% Increase in strength at 7 days**	**% Increase in strength at 28 days**
MG0	0	2.26	3.23	–	–
MG5	5	2.53	3.61	11.9	11.8
MG10	10	3.23	4.62	42.9	43.0
MG15	15	2.30	3.49	1.77	8.0

Mix design	% of granite powder	Flexural strength (N/mm^2) at 7 days	Flexural strength (N/mm^2) at 28 days	% Increase in strength at 7 days	% Increase in strength at 28 days
MG20	20	2.27	3.24	1.01	0.3



% of marble and granite powder

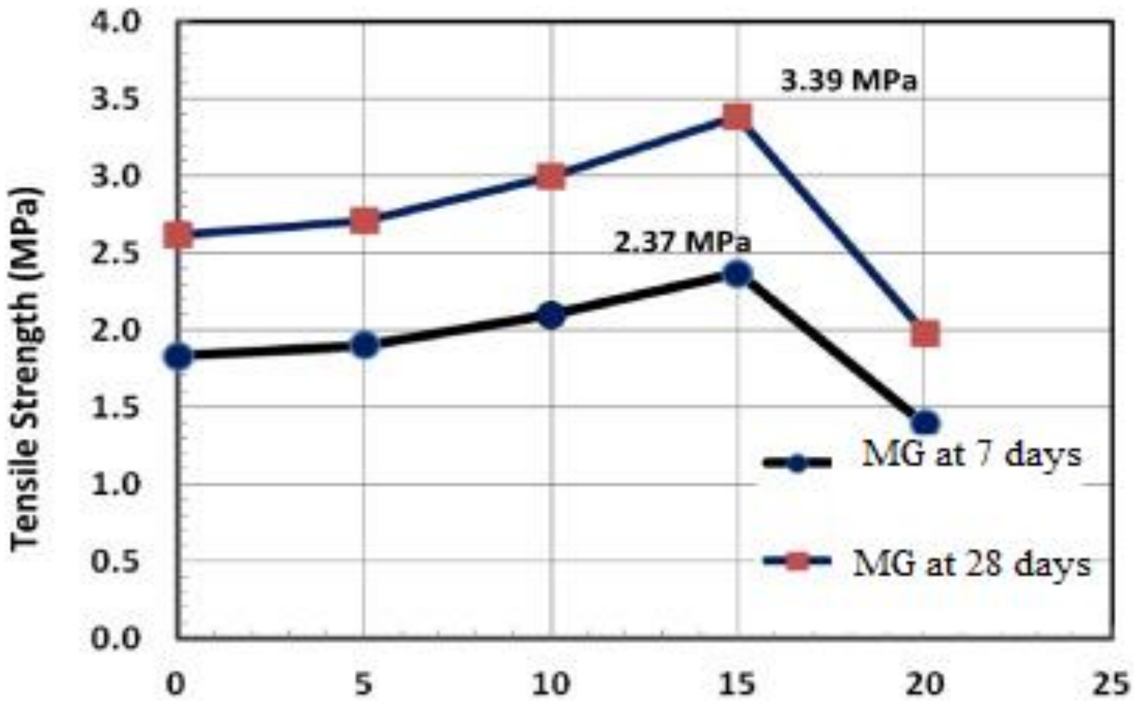
Fig.11 flexural strength test

4.3 Split tensile strength

The tensile strength of concrete was determined indirectly using the split-cylinder strength test. The indirect test is widely accepted test method to determine the tensile strength of concrete given the difficulty and variability associated with the direct tensile tests. The split-cylinder tensile strength was determined by testing twenty 150 mm × 300 mm (6 in × 12 in) cylinders. Ten cylinders were tested at 7 days and ten cylinders were tested at 28 days. The split-cylinder tensile strength was determined using Eq. (1) :(1)ft=2PπLD where P is the cylinder failure load, L is the cylinder length equal to 300 mm, and D is the cylinder diameter equal to 150 mm. The split tensile strength of the cylinders was determined for the control cylinders as well as the cylinders with various percentages of granite and marble powder. The split tensile strength of the control cylinders at 28 days (Mix MG0) was 2.62 N/mm^2. The cylinders with granite powder showed higher flexural strength compared to control mixes. The split tensile strength of mix designs MG5 (5% GP), MG10 (10% GP), MG15 (15%) and MG20 (20%) were 2.71 N/mm^2, 3.0 N/mm^2, 2.39 N/mm^2, 1.98 N/mm^2 respectively. The tests showed that the optimum percentage of granite powder to achieve the maximum increase in split tensile strength was 15% compared to an optimum value of 10% for compression and flexural strengths. For 20% partial replacement of sand with granite powder, the split tensile strength was lower than the control cylinders. This observation was different than those of compression and flexural strength. For compression and flexural strength, the 20% replacement of granite powder showed a modest increase rather than a decrease in strength. The values of split tensile strength of cylinders made with different percentages of granite powder of sand are shown in Table and also presented graphically.

Table 4.3 Split tensile strength of cylinders with different proportions of marble and granite powder.

Mix design	% of granite powder	Split tensile strength (N/mm^2) at 7 days	Split tensile strength (N/mm^2) at 28 days	% Increase in strength at 7 days	% Increase in strength at 28 days
MG0	0	1.83	2.62	–	–
MG5	5	1.90	2.71	3.82	3.44
MG10	10	2.10	3.00	14.76	14.5
MG15	15	2.37	3.39	29.51	29.4
MG20	20	1.39	1.98	− 24.1	− 24.4



% of marble and granite powder

4.4 Summary of test results of granite and marble powder specimens

The concrete mix with granite and marble powder in concrete showed good workability and had slump values similar to those of normal concrete mixes. The ingredients were easy to mix, pour, transport, finish and demold. The compressive strength of concrete increased with the addition of granite and marble powder as partial replacement of sand. This results in more surface area that allows more Using 10% granite and marble powder in concrete gave the best result (highest increase in compressive strength) compared to other ratios. The increase in this case was 36%. The same observation for the compression strength was observed for the flexural strength. With 10% MG replacement, the increase in flexural strength was about 43%. For the split-cylinder tensile strength, the optimum value of the percentage of (MG) in concrete was 15% compared to 10% for flexural and compressive strength. The increase in tensile strength for 15% and 10% of (MG) was approximately 30% and 15% respectively. For 20% (MG) in concrete the split tensile strength was lower than that of the control mix.

4.5 Discussion of results

The experimental investigation carried out in this study showed that partial replacement of sand in concrete with granite and marble powder enhances its compressive strength, flexural strength, and tensile strength. The particle size is very important for the physical and chemical contributions of granite powder in concrete. Because the particle size of granite powder is smaller than sand, they were able to fill the voids between sand particles similar to the way sand particles fill the void between coarser aggregates thus resulting in less voids and higher density and strength. In addition, because the particle size is smaller than sand, the surface area will be larger. Because of higher surface area of granite powder compared to sand, the concrete is expected to have higher strength due to more bonded areas with hydrating cement. Although the granite powder generally has less silicon oxide content compared to sand and that not all granite powder may react chemically with cement, the filler effect will bring improvements in the concrete. In the case of the marble powder, the increase in strength may be attributed to the modest increase in fineness of particles especially in the smaller diameter particles. The test results showed that the best gain in compressive strength and flexural strength was with 10% granite and marble powder ratio. Beyond 10%, the increase was less. It seems beyond this percentage, the filling effect of granite powder is not optimized. Typically an optimal size distribution in concrete will give higher density and fewer voids. If the particle size distribution is not optimal, the concrete will have more voids leading to lower strength. It seems that as the surface area increases, more hydrating cement is needed to bond these areas. If the water-cement ratio and added admixtures are not enough to hydrate enough cement, then the increased surface area of granite powder would not all be bonded and therefore less strength was observed with increased ratios of granite and marble powder. Similar results were also observed by other researchers.

CHAPTER – 5

Conclusions

Based on the results of this study, the following conclusions can be drawn:

1. The concrete mix made using granite powder (GP) and marble powder (MP) as partial replacement of sand showed good workability and fluidity similar to normal concrete mixes.

2. The compressive strength of concrete increased with the addition of granite and marble powder as partial replacement of sand. Using 10% in concrete gave the best result (highest increase in compressive strength) compared to other ratios.

3. Similar to the observations in the compressive strength, the flexural strength of concrete increased with the addition of powder (MG) as partial replacement of sand. The maximum increase was observed for 10% ratio.

4. For the split-cylinder tensile strength, the optimum value of the percentage of (MG) in concrete was 15% compared to 10% for flexural and compressive strength. The increase in tensile strength for 15% and 10% of (MG) was approximately 30% and 15% respectively. For 20% (GP) in concrete the split tensile strength was actually lower than that of the control mix.

5. This study was limited to the evaluation of the mechanical properties of concrete with granite powder and marble powder as well its workability and fluidity. The longer-term performance of concrete with granite powder and marble powder was not part of this study. Durability is important for the proper use of this material in structural as well as non-structural applications and will be investigated in a future study.

6. This study as well studies in other countries have shown the viability of producing concrete with granite powder and marble powder byproducts. This will encourage producers and environmental groups to continue collecting and storing these hazardous airborne fines. Life-cycle cost analysis for the use of these materials compared to current concrete material also needs to be addressed in future research.

Fig.12 concrete cubes in different stages

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