Utilization of Granite Powder as a Partial Replacement of Fine Aggregate in HPC

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Abstract - **Granite is an igneous rock which is most widely used as building material in different structures. Granite industries generate lot of dirt and desecrate materials. The wastes from the granite polishing units are being disposed to surroundings which cause health vulnerability. This granite powder waste can be used for the preparation of concrete as partial replacement of sand. In order to survey the possibility of utilizing the granite powder as Partial replacement to sand, an experimental examination has been conceded. The aptness of crushed granite fine (CGF) to replace river sand in concrete production for use in rigid pavement was investigated. Compressive test was performed on fresh and hardened concrete. 28 days peak compressive strength value of 40.70N/mm2 was obtained, with the partial replacement of river sand with 15% CGF, as next to value of 35.00N/mm2, obtained with the use of river sand as fine aggregate. Based on cost-effective analysis and results of tests, river sand replaced with 15% CGF is recommended for use in the manufacture of concrete. Conservation of river sand in addition to superior ways of disposing wastes from the mine sites are some of the qualities of using CGF. The percentages of granite powder added by weight to replace sand by weight were 0, 5, 10, 15, 20 and 25. To improve the workability of concrete 1.2% Super plasticizer (by weight of cement) was added. This attempt has been done due to the very expensive hike in the price of fine aggregate and its limited availability due to the curb imposed by the government of Rajasthan. 36 cubes and 18 beams were cast. Compressive strength and flexural strength were determined. The test results indicate that granite as replacement sand with granite powder has valuable effect on the mechanical properties such as compressive strength and flexural strength of concrete.**

keywords - **workability, strength, granite, concrete, replacement, aggregates**

I. Introduction

Concrete is an artificial conglomerate stone made essentially of Portland cement, water, sand and coarse aggregates. The mix of the materials results in a chemical reaction called hydration and an alter in the mixture from plastic to a hard state. It has found use in unusual fields of civil engineering, in highway engineering concrete is used in the construction of slabs used as cc-pavement. The high cost of concrete used in cc-pavement construction stems from the cost of the essential materials. This type of cost can be abridged through the use of locally available substitute material, to the conventional ones usually used in concrete work; of interest to this research is a substitute to sand. The globally consumption of sand as fine aggregate in concrete production is very high, & numerous developing countries have encountered some strain in the supply of natural sand in order to convene the increasing desires of infrastructural development in current years. A condition that is responsible for increase in the price of sand, and the cost of concrete. Higher cost and insufficiency of river sand which is one of the ingredient material used in the production of conventional concrete was reported in India. To overcome the stress and demand for river sand, researchers and practitioners in the construction industries have recognized some alternative namely fly ash, slag, limestone powder, granite powder and siliceous stone powder. In India the use of quarry dust to replace river sand was reported by. The use of rock dust as an alternative to natural sand was also reported by. The use of up to 20% quarry waste fine as a limited replacement for natural sand in the production of concrete, in Malaysia was also reported. Use of crushed granite fines or crushed rock fines as another to sand in concrete production was also reported.

High Performance Concrete (HPC) is the current development in concrete. It has become new popular these days and is being used in so many prestigious projects. Mineral admixtures such as fly ash, as, silica fume etc. are more usually used in the development of HPC mixes. 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 wide use of concrete. 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 forced restrictions on sand removal from the river beds due to unsafe impacts threatening many parts of the state. On the other hand, the granite waste generated by the industry has accumulated over years. Indian granite stone industry at present produces around 17.8 million tons of solid granite waste, out of which 12.2 million tons as discards at the industrial sites, 5.2 million tons in the form of cuttings / trimmings or undersize materials and 0.4 million tons granite slurry at processing and polishing units. The granite waste generated by the industry has accumulated over years. Only unimportant quantities have been utilized and the rest has been discarded unscrupulously resulting in environment problem.

The successful utilization of CGF as fine aggregate would turn this waste material that causes an environmental load due to disposal problem into valuable resources, reduction in the strain on the supply of natural sand, and economy in concrete production. Most of the researchers listed above considered alternative material to sand in the production of concrete for other purposes, not for use in rigid pavement. This project is aimed at determining the suitability of CGF to replace river sand in the production of concrete for use in rigid pavement, using compressive strength and flexural strength tests as basis for assessment.

A partial replacement of cement by mineral admixtures, such as fly ash, slag, silica fume, met kaolin, rice husk ash or fillers such as lime stone powders in concrete mixes would help to overcome these problems and lead to improvement in the durability of concrete.

Based on the above examination, to check the potential of improving the concert of concrete, admixtures were also considered as a partial replacement of cement in this project. However, the selection and amount of mineral and chemical admixtures are an important observation for higher concrete performance. Also, for a better recitation of mixture proportions it is necessary to revise scientifically the properties of proposed concrete. Thus, this assignment was conducted to evaluate the probable use of granite powder as sand substitute together with admixtures as a partial replacement of cement in the production of high performance concrete.

II. LITERATURE REVIEW

In India the marble & granite are the most successful industries. Marble waste when dumped on open ground affects unfavorably the productivity of land as it reduces the porosity and affects ground water revitalize. The marble is widely used in buildings due to its attractiveness, strength & resistance to fire higher than conventional concrete therefore; The results of this study provide a well-built support for the use of quarry rock dust as fine aggregate in concrete manufacturing. Thus, it can be accomplished that the replacement of natural sand with quarry rock dust, as full replacement in concrete is possible.

Kanmalai Williams (2008) examined the performance of concrete made with granite residue as fine aggregate. Sand was replaced with granite residue in steps of 0, 25, 50,75 and 100% cement was replaced with 7.5%Silica fume, 10% fly ash and 10% slag. They further added 1% super plasticizer to improve the workability. The effects of curing temperature at 32º 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 247.35 K Pa after 90 days. In general test performance revealed that granite powder can be utilized as a partial replacement of natural sand in high performance concrete.

Hameed M and Sekar A.S.S (2009) investigated the usage of quarry rock dust and marble sludge powder as probable substitutes for natural sand in concrete. They also carried out durability studies on green concrete and compared with the normal sand concrete. They bring into being that the compressive, split tensile strength and the durability concrete were outstanding when the fine aggregate was replaced with 50% marble sludge powder and 50% Quarry rock dust (Green concrete). The resistance of concrete to sulphate attack was improved very much.

Manasseh Joel (2010) quoted that the use of crushed granite fine to partially replace Makurdi river sand in concrete production will require a higher water to cement ratio, when compared with values obtained with the use of only Makurdi river sand. Peak compressive strength and indirect tensile strength values of 40.70N/mm^2 and 2.30N/mm^2 respectively were obtained when Makurdi river sand was replaced with 20% CGF in concrete production. Peak compressive strength and indirect tensile strength values of 33.07N/mm^2 and 2.04N/mm^2 respectively were obtained when crushed granite fine was replaced with 20% river sand as fine aggregate in the production of concrete. The use of only CGF to completely replace river sand is suggested where CGF is available and commercial analysis is in favor of its usage. Based on findings from the study the partial replacement of Makurdi river sand with 20% CGF is suggested for use in concrete production for use in rigid pavement. Where crushed granite is in large quantity and river sand is limited, the complete replacement river sand with CGF is suggested for use in low to fairly trafficked roads.

Sachin (2010) quoted that use of marble powder and artificial sand as partial replacement for natural sand to conduct their study on mechanical behavior of concrete. Experimental investigation were conducted using natural sand, manufactured sand, marble dust with equal amount of cement, coarse aggregate and water. Sieve analysis was also carried out on fine sand.

Bahar Demirel (2010) investigated the effects of using waste marble dust (WMD) as a fine material on the mechanical properties of the concrete. For this purpose, 4 different series of concrete-mixtures were ready by replacing the fine sand (passing 0.25 mm sieve) with WMD at proportions of 0, 25, 50 and 100% by weight. In order to determine the effect of the WMD on the compressive strength with respect to the curing age, compressive strengths of the samples were recorded at the curing ages of 3, 7, 28 and 90 days. In accumulation, the porosity values, ultrasonic pulse velocity (UPV), dynamic modulus of elasticity and the unit weights of concrete were determined. It was observed that replacement of the fine material passing through a 0.25mm sieve with WMD at particular proportion has displayed an enhancing effect on compressive strength.

T. Felixkala (et al. 2010) had obtained the analysis results that granite powder of marginal quantity as partial sand replacement has positive effect on the mechanical properties such as compressive strength, split tensile strength, modulus of elasticity. They also indicated that the values of both plastic and drying shrinkage of concrete in the granite powder concrete specimens were nominal than those of normal concrete specimens. They inspect the possibility of using granite powder as replacement of sand and partial replacement of cement with fly ash, silica fume, slag and super-plasticizer in concrete. The percentage of granite powder added by weight was 0, 25, 50, 75 and 100 as a replacement of sand used in concrete and cement was replaced with 7.5% silica fume, 10% fly ash, 10% slag and 1% super-plasticizer

Baboo Rai et al (2011) carried out the study on cubes of mortar (1:3) with varying partial replacement of cement with the same amount of WMP and tested at 3 different period of curing. Also cubes of (1:3) mortar with partial replacement of sand with the same amount of WMP Granules were casted and their strength was evaluated after 7, 14, and 28 days in different lots. Their results were judge against with those of standard (1:3) mortar and concrete cubes.

Bouziani Tayeb et al (2011) studied the effect of marble powder content (MP) on the properties self compacting sand concrete (SCSC) at fresh and hardened states. Values of slump flow, the V-funnel flow time and viscosity were found on fresh concrete. At the hardened state, the 28th day compressive strength was found. The achieved test results showed that larger MP content in SCSC (350 kg/m^3) improved the properties at fresh state by decreasing V funnel flow time (from 5s to 1.5s) and increasing the slump flow values (from 28cm to 34cm). With the use of 250 kg/m^3 of MP, the highest initial viscosity was attained while retaining good fluidity at high rotational speeds compared to the MP contents of 150 kg/m^3 and 350 kg/m^3. The 28 days compressive strength decreased with an increase of MP content.

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 end 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 more addition of waste marble powder was found to decrease the compressive strength. The optimal percentage replacement was found to be 10%.

Divakar Y., et al., (2012) Highlighted that the compressive strength has increased by 22% with the use of 35% replacement of fine aggregates with granite fines. With increase of granite fines up to 50% increasing compressive strength will limit to 4% only. The split tensile strength remains identical for 0%, 25% and 35%. For 5% replacement there is an increase of 2.4% of strength and for 15% replacement there is a reduction of tensile Strength by 8%. However we can conclude that with the replacement of 35% granite fines the test results shows no decrease in strength compared with the conventional mix using fully sand as fine aggregates.

S.S Suresh et al (2013) conducted and quoted in the study on concrete using marble dust in varying proportions. Marble sludge powder was obtained in wet form directly taken from deposits of marble industries in Northern India. Wet marble sludge powder was dried out before the sample preparation. Marble dust was sieved from 1mm sieve. The high content of various minerals confirmed that the original stones were Marble and limestone. The dust was also tested to identify the absence of organic matter, thus confirming that it could be used in concrete mixtures and its physical characteristics. Through the help of compressing machine the compressive strength of block were carried out. Ordinary Portland cement (43Grade) with 28% normal consistency with specific surface 2100 cm^2 /g conforming to IS: 8112-1989 was used.

III. EXPERIMENTAL ANALYSIS

A. Materials:

(i) Cement.

The materials of cement was used in an ordinary Portland cement super grade IS: 1489 (43grade) is used. This cement is most commonly used in concrete construction.

(ii) Fine aggregate.

In current study, the high performance concrete mixes were prepared using locally available river sand. The sand used was confining to zone 3. Fineness modulus and specific gravity of the sand were found to be 2.33 and 2.65 respectively.

(iii) Coarse aggregate.

In current study, the high performance concrete mixes were prepared using locally available coarse aggregate. The coarse aggregate used was confining to zone 3. Fineness modulus and specific gravity of the sand were found to be 2.33 and 2.70 respectively.

(iv) Water.

Water is an important ingredient of the concrete as it actually participates in the chemical reaction with cement. In general, water fit for drinking is suitable for mixing concrete. Impurities in the water may affect setting time, strength, shrinkage of concrete or promote corrosion of reinforcement. Locally available drinking water was used in the present work.

(v) Granite Powder.

Granite belongs to igneous rock family. The density of the granite is between 2.65 to 2.75 gm/ 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.

(vi) Admixture.

Super plasticizer was used during investigation to improve the workability of concrete. As per Indian standards, the dosage of super-plasticizer should not exceed 2% by weight of the cement. A higher dosage of super-plasticizer may delay the hardening process. After trials, the optimal dosage of the super-plasticizer was found to be 0.5% to produce slump of 100mm.

B. Standard Consistency Test:

The standard consistency of a cement paste is defined as that consistency which will permit a Vicat's plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 5-7 mm from bottom of the mould. It is used to find out the percentage of water required to produce a cement paste of standard consistency. This is also called normal consistency (CPNC).

Table 1: Consistency Test Results

S. No.	Water Content (% By weight)	Vicat apparatus reading (mm)	Consistency
1.	27	15	30
2.	28	11	
3.	29	8	
4.	30	6	

C. Fineness Test:

The fineness of cement has an important bearing on the rate of hydration, rate of gain of strength, evolution of heat. Finer cement offers greater surface area. Disadvantage of fine grinding is that it is susceptible to air set & early deterioration. Maximum numbers of particles in a sample of cement < 90 microns. The smallest particle should have a size if 1.5 microns. Large particle should have a size of 10 microns. Fineness of cement is tested in two ways.

(i) By sieving. (ii) By determination specific surface by air permeability method.

Table 2: Calculations for Fineness of Cement

S. No	Material	Weight of Material (g)
1	Cement	100
2	Weight of cement left on sieve	**06**

Which is < 10 % hence the cement is acceptable.

E. Initial Setting Time:

The time elapsed between the moments that the water is added to the cement, to the time that the paste starts losing its plasticity. Normally a minimum of 30min has maintained for mixing & handling operations. It should not be less than 30 min.

Table 3: Initial Setting Time of Cement

S. No.	Time(min)	Depth of needle from the top(mm)	Initial Setting Time(min)
1.	0	0	35
2.	5	0	
3.	10	0	
4.	15	1	
5.	20	2	
6.	25	3	
7.	30	4	
8.	35	5	

D. Final Setting Time:

The time elapsed between the moment the water is added to the cement, and the time when the paste has completely lost its plasticity and has attained sufficient firmness to resist certain definite pressure. It should not exceed 10 hours. So that it is avoided from least vulnerable to damages from external activities.

Table 4: Final Setting Time of Cement

S. No.	Time(min)	Point mark of the needle occurred	Final setting time(min)
1	180	No	260
2	210	No	
3	240	No	
4	250	No	
5	260	Yes	

E. Testing Of Fine Aggregates and Coarse Aggregates

(i) Specific gravity by Pycnometer:

Specific Gravity is defined as the ratio of Weight of Aggregate to the Weight of equal Volume of water. The specific gravity of an aggregate is considered to be a measure of strength or quality of the material. Aggregates having low specific gravity are generally weaker than those with high specific gravity. This property helps in a general identification of aggregates.

Fig. 1 Determination Specific Gravity of Aggregates by Pycnometer

Calculations:

(a) For fine aggregates

Mass of empty Pycnometer M_1 = 500g
Mass of the Pycnometer with dry fine aggregate M_2 = 850 g
Mass of the Pycnometer and fine aggregate and water M_3 = 1720
Mass of Pycnometer filled with water only M_4 = 1500g
The sp. gravity is given by;

$$G = \frac{M_1 - M_2}{M_2 - M_1 - (M_3 - M_4)} = \frac{850 - 500}{850 - 500 - (1720 - 1500)} = 350/130 = 2.65$$

(a) For coarse aggregates

Mass of empty Pycnometer M_1 = 500g
Mass of the Pycnometer with dry coarse aggregate M_2 = 1450 g
Mass of the Pycnometer and coarse aggregate and water M_3 = 2100 g
Mass of Pycnometer filled with water only M_4 =1500g
The sp. gravity is given by;

$$G = \frac{M_1 - M_2}{M_2 - M_1 - (M_3 - M_4)} = \frac{1450 - 500}{1450 - 500 - (2100 - 1500)} = 950/350 = 2.70$$

(ii) Surface Moisture Content and Water Absorption:

The surface moisture in the aggregate, influences the water cement ratio, strength and durability of the mix. To determine the surface moisture of moist or wet aggregate, method is as follows:-

The following apparatus are required:

- A frying pan or metal tray
- Gas stove or an electric hair dryer
- A metal or glass stirring rod
- Scales to measures

Calculations:

(a) For fine aggregate

Weight of moist sample (W) = 500g Surface dry aggregate weight (Wsd) = 499g Bone dry aggregate weight (Wbd) =
Surface moisture = [(W – W_{sd}) / W_{sd}] x 100%
= [(500 – 499) / 500] x 100%
= 0.2% ~ Nil Absorption = [(Wsd – W_{bd}) / W_{bd}] x 100%
= [(499 – 494.05) / 494.05] x 100%
= 1.001% ~ 1%

(b) For coarse aggregate

Weight of moist sample (W) = 2000g Surface dry aggregate weight (W_{sd}) = 1998g Bone dry aggregate weight (W_{bd}) =
Surface moisture = [(W – W_{sd}) / W_{sd}] x 100%
= [(2000 – 1998) / 1998] x 100%
= 0.1% ~ Nil Absorption = [(W_{sd} – W_{bd}) / W_{bd}] x 100%
= [(1998 – 1988) / 1988] x 100%
= 0.5%

(iii) Sieve Analysis of Aggregates:

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. 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 sized particles left over different sieves. The following apparatus is required:

- A set of IS Sieves of sizes – Conforming to IS 460-1962.
- Balance or scale with an accuracy to measure 0.1 percent of the weight of the test sample
- Trays, scoops and miscellaneous accessories

Table 5: Sieve Analysis Result of Aggregates

Weight of sample =10000 gram

Sieve Size (mm)	Wt. Retained (gm)	Wt. Retained (%)	Cum. Wt. Retained (%)	Percentage Passing (%)	Specified Limit for Single Size Aggregate (IS : 383 - 1970)		
					20 mm	12.5 mm	10 mm
80.000	-	-	-	-	-	-	-
40.000	0	0	0	100	100	-	-
20.000	590	590	590	94.10	85-100	100	-
12.500	0	0	0	0	-	85-100	100
10.000	9146	91.46	97.36	2.64	0-20	0-45	85-100

4.750	82	.82	98.18	1.82	0-5	0-10	0-20
2.360	-	-	-	-	-	-	0-5
PAN	182	1.82	100				

Table 6: Sieve Analysis Result of sand

Weight of sample= 1000 gram

Sieve Size (mm)	Wt. Retained (gm)	Wt. Retained (%)	Cum. Wt. Retained (%)	Percentage Passing (%)	Specified Limit (IS : 383 - 1970)
10.000	0	0	0	100	100
4.750	76.2	7.62	7.62	92.38	90-100
2.360	92.9	9.29	16.91	83.09	60-96
1.180	88.5	8.85	25.76	74.24	30-70
0.600	290.8	29.08	54.84	45.16	15-34
0.300	253.2	25.32	80.16	19.84	5-20
0.150	176.0	17.6	97.76	2.24	0-10
PAN	22.4	2.24	100	-	-

Fines. Modulus of sand =**2.83**

(iv) Dry Loose Bulk Density of Aggregate:

The bulk density or unit weight of an aggregate is the mass or weight of the aggregate that required to fill a container of a specified unit volume.

Bulk Density = $^{Mass}/_{volume}$

This method of test covers the procedure for determining unit weight or dry loose bulk density of aggregates.

Table 7: Cylindrical Metal Capacity as per size of Aggregate

Max size of Aggregate	Nominal Capacity in (liter)
475 mm and under	3
Over 4.75 mm to 40 mm	15
Over 40 mm	30

Calculations:

Weight of empty container		= M1
Weight of container with sample		= M3
Weight of sample (Loose)	W (gm)	= M3-M1
Volume of the container	V (cc)	= (π/4) x d2 x h
Dry Loose Bulk density	γ (gm/cc)	= W/V

Table 8: Bulk density Results

Description	Test		
	1	2	3
Weight of empty container M1 (gm)	10000	10000	10000
Weight of container with sample M3 (gm)	31780	31910	31880
Weight of sample (loose) W=M3-M1 (gm)	21780	21910	21880
Volume of container V = (π/4)x d^2 x h (cc)	15000	15000	15000
Dry Loose Bulk density γ = W/V (gm/cc)	1.45	1.46	1.46
Average Dry loose bulk density (gm/cc)		1.46	

Result ok as per IS 2386 (part 3)

G. CASTING OF CUBES AND BEAMS:-

The concrete cubes were casted for the determination of compressive strength of concrete and beams were also casted for the determination of flexural strength of the concrete. Casting was carried out in 6 phase as follows:

Table 9: Proportion of Granite in Concrete

S. No.	Phase	Percent Replacement of fine aggregate by granite
1.	A	0
2.	B	5
3.	C	10
4.	D	15
5.	E	20
6.	F	25

In every phase 6 cubes (150mm x 150mm x 150mm) and 3 beams (100mm x 100mm x 500mm) were casted. Three cubes for 7 days compressive strength and three cubes for 28 days compressive strength. Three beams were tested after 28 days.

H. *PRODUCTION OF CONCRETE:-*

(i) Raw Materials

- ***Phase A:***

  Raw materials used for the production of concrete were as followings:
  - Ambuja cement (OPC 43 Grade) as a binder
  - Sand were used as fine aggregate
  - Coarse aggregates was of 20mm size
  - Water (W/C Ratio = 0.42 as per Mix Design)
  - Super-plasticizer Carboxylated Acrylic Ester (CAE) was used as chemical Admixture (4 kg/m3 as per mix design)

  These raw materials were mixed in the ratio of 1.0: 2.04: 3.54
- **Phase B**

  In this phase the fine aggregate were replaced by 5% with granite.
- **Phase C**

  In this phase the fine aggregate were replaced by 10% with granite.
- **Phase D**

  In this phase the fine aggregate were replaced by 15% with granite.
- **Phase E**

  In this phase the fine aggregate were replaced by 20% with granite.
- **Phase F**

  In this phase the fine aggregate were replaced by 25% with granite.

(ii) Batching

Weight batching was preferred. The cement, sand or fine aggregate, coarse aggregate, water and granite were taken in desired proportion by weight.

(iii) Mixing

As the quantity of the concrete was small, Pan mixing was preferred.

Fig.2 Mixing Of Concrete in Concrete Lab

(iv) Placing in moulds

After mixing the concrete uniformly, it is then filled in moulds (Six cubes and three beams).The moulds before placing the concrete mix, were oiled uniformly and bolts were tightened properly.

Fig.3 Placing Of Concrete Mix in the Moulds in Concrete Lab

(v) Compaction

Compaction of the concrete cubes was carried with the help of the table vibrator. The concrete cubes were filled in three layers and compacted.

Fig.4 Compaction of Concrete Cube by Tamping In Concrete Lab

The compaction of concrete beams was also carried out with the help of tamping road. After the compaction of cube and beam moulds, these are placed for 24 hrs at the room temperature so the cubes and beams get sufficient hardened and do not breaks while de-moulding these.

Fig. 5 Compaction of Concrete Beam in Concrete Lab

(vi) Casting of Beams:

Beam mould of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm).Tamping bar (40 cm long, weighing 2 kg and tamping section having size of 25 mm x25 mm

Fig.6 Finishing of Concrete Beam in Concrete Lab

(vii) De-moulding

After the cubes and beams get sufficient hardened or at the end of 24 hrs the beams and cubes were demoulded.

Fig 7. De-moulding of Cubes

(viii) Curing

The de-moulded cubes & beams were placed in a water tank for curing.

Fig. 8 Compaction of Concrete Cube By Tamping In Concrete Lab

I. TESTING OF HARDENED CONCRETE CUBES AND BEAMS:

After the completion of curing of the concrete cubes and beams, the 28 days compressive strength and flexural strength is to be determined.

(i) Compressive Strength:-

Out of many test applied to the concrete, this is the most important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not. Compressive strength of concrete depends on many factors such as water-cement ratio, cement strength, quality of concrete material, and quality control during production of concrete etc. Test for compressive strength is carried out either on cube or cylinder. Various standard codes recommend concrete cylinder or concrete cube as the standard specimen for the test. The acceptance criteria of quality of concrete are laid down in IS: 456-2000. The criteria are mandatory and various provisions of the code have to be complied before the quality of concrete is accepted. In all the cases, the 28-days compressive strength shall alone be the criterion for acceptance or rejection of the concrete.

Table 10: Testing of cubes casted in phase A
(Testing of Ordinary concrete cubes)

Time (days)	Maximum Load Applied (N)	Area of Specimen(mm^2)	Compressive Strength(N/mm^2)	Avg. Compressive Strength(N/mm^2)
7 days Compressive strength	500	22500	22.22	**22.44**
	510	22500	22.66	
	505	22500	22.44	

28 days Compressive strength	800	22500	35.55	35.70
	810	22500	36.00	
	800	22500	35.55	

Table 11: Testing of cubes casted in phase B (F.A. replaced by 5 % with granite)

Time (days)	Maximum Load Applied (N)	Area of Specimen(mm^2)	Compressive Strength(N/mm^2)	Avg. Compressive Strength(N/mm^2)
7 days Compressive strength	520	22500	23.11	23.33
	530	22500	23.55	
	525	22500	23.33	
28 days Compressive strength	830	22500	36.88	36.88
	835	22500	37.11	
	825	22500	36.66	

Table 12: Testing of cubes casted in phase C (F.A Replaced by 10 % with granite)

Time (days)	Maximum Load Applied (N)	Area of Specimen(mm^2)	Compressive Strength(N/mm^2)	Avg. Compressive Strength(N/mm^2)
7 days Compressive strength	560	22500	24.88	24.80
	555	22500	24.66	
	560	22500	24.88	
28 days Compressive strength	870	22500	38.66	38.73
	875	22500	38.88	
	870	22500	38.66	

Table 13: Testing of cubes casted in phase D (F.A Replaced by 15 % with granite)

Time (days)	Maximum Load Applied (N)	Area of Specimen(mm^2)	Compressive Strength(N/mm^2)	Avg. Compressive Strength(N/mm^2)
7 days Compressive strength	580	22500	25.77	25.92
	585	22500	26.00	
	585	22500	26.00	
28 days Compressive strength	900	22500	40.00	40.22
	910	22500	40.44	
	905	22500	40.22	

Table 14: Testing of cubes casted in phase E (F.A Replaced by 20 % with granite)

Time (days)	Maximum Load Applied (N)	Area of Specimen(mm^2)	Compressive Strength(N/mm^2)	Avg. Compressive Strength(N/mm^2)
7 days Compressive strength	565	22500	25.11	25.03
	560	22500	24.88	
	565	22500	25.11	
28 days Compressive strength	880	22500	39.11	39.03
	875	22500	38.88	
	880	22500	39.11	

Table 15: Testing of cubes casted in phase F (F.A replaced by 25 % with granite)

Time (days)	Maximum Load Applied (N)	Area of Specimen(mm^2)	Compressive Strength(N/mm^2)	Avg. Compressive Strength(N/mm^2)
7 days Compressive strength	510	22500	22.66	23.03
	520	22500	23.11	
	525	22500	23.33	
28 days Compressive strength	840	22500	37.33	37.10
	835	22500	37.11	
	830	22500	36.88	

(i) Flexural Strength:-

Flexural strength of concrete is determined as per IS: 456: 1956. Beam mould of size 15 x 15x 70 cm (when size of aggregate is less than 38 mm) or of size 10 x 10 x 50 cm (when size of aggregate is less than 19 mm). Tamping bar (40cm long, weighing 2 kg and tamping section having size 25 mm x 25 mm.

Table 16: Testing of beams casted in phase A

S.No.	Max. Load (P) kN	Flexural strength f_{cr}(N/mm^2) = PL/bd^2	Avg. Flexural strength (N/mm^2)	Compressive strength (N/mm^2) $f_{cr} = 0.7\sqrt{f_{ck}}$	Avg. Compressive strength (N/mm^2)
1.	9.0	4.5	4.42	41.32	**39.83**
2.	9.0	4.5		41.32	
3.	8.5	4.25		36.86	

Table 17: Testing of beams casted in phase B (F.A. replaced by 5 % with granite)

S.No	Max. Load (P) kN	Flexural strength f_{cr}(N/mm^2) = PL/bd^2	Avg. Flexural strength (N/mm^2)	Compressive strength (N/mm^2) $f_{cr} = 0.7\sqrt{f_{ck}}$	Avg. Compressive strength (N/mm^2)
1.	9.0	4.5	4.58	41.32	**42.89**
2.	9.5	4.75		46.04	
3.	9.0	4.5		41.32	

Table 18: Testing of beams casted in phase C (F.A. replaced by 10 % with granite)

S.No.	Max. Load (P) kN	Flexural strength f_{cr}(N/mm^2) = PL/bd^2	Avg. Flexural strength (N/mm^2)	Compressive strength (N/mm^2) $f_{cr} = 0.7\sqrt{f_{ck}}$	Avg. Compressive strength (N/mm^2)
1.	9.5	4.75	4.75	46.04	**46.04**
2.	9.5	4.75		46.04	
3.	9.5	4.75		46.04	

Table 19: Testing of beams casted in phase D (F.A. replaced by 15 % with granite)

S.No	Max. Load (P) kN	Flexural strength f_{cr}(N/mm^2) = PL/bd^2	Avg. Flexural strength (N/mm^2)	Compressive strength (N/mm^2) $f_{cr} = 0.7\sqrt{f_{ck}}$	Avg. Compressive strength (N/mm^2)
1.	10	5.0	5.08	51.02	**52.76**
2.	10.5	5.25		56.25	
3.	10.0	5.0		51.02	

Table 20: Testing of beams casted in phase E (F.A. replaced by 20 % with granite)

S.No.	Max. Load (P) kN	Flexural strength fcr(N/mm2) = PL/bd2	Avg. Flexural strength (N/mm2)	Compressive strength (N/mm2) $fcr = 0.7\sqrt{fck}$	Avg. Compressive strength (N/mm2)
1.	10	5.0	4.91	51.02	**49.36**
2.	10	5.0		51.02	
3.	9.5	4.75		46.04	

Table 21: Testing of beams casted in phase F (F.A. replaced by 25 % with granite)

S.No.	Max. Load (P) kN	Flexural strength f_{cr}(N/mm^2) = PL/bd^2	Avg. Flexural strength (N/mm^2)	Compressive strength (N/mm^2) $f_{cr} = 0.7\sqrt{f_{ck}}$	Avg. Compressive strength (N/mm^2)
1.	9.5	4.75	4.66	46.04	**44.46**
2.	9	4.5		41.32	
3.	9.5	4.75		46.04	

J. ACCELERATED CURING TEST OF CONCRETE (ACT):

Normally, the strength of concrete is found out after 7 days and 28 days. For some construction activities, it may be too late and need to know the strength earlier.

Table 22: ACT Results

S. No	Description	weight of cube (gm)	Load (KN)	Strength (N/mm2)	Average Strength (Ra)	R28=8.09+1.64 Ra Final strength
1	**Phase A**	8277	390	17.33	**17.18**	**36.2652**
2		8290	395	17.56		
3		8300	375	16.67		
4	**Phase B**	8286	400	17.78	**17.79**	**37.2656**
5		8257	395	17.56		
6		8237	406	18.04		
7	**Phase C**	8336	415	18.44	**18.37**	**38.2168**
8		8325	413	18.36		
9		8257	412	18.31		
10	**Phase D**	8368	422	18.76	**18.82**	**38.9548**
11		8354	425	18.89		
12		8270	424	18.84		
13	**Phase E**	8250	410	18.22	**18.08**	**37.7412**
14		8360	407	18.09		
15		8352	404	17.96		
16	**Phase F**	8348	390	17.33	**17.37**	**36.5768**
17		8400	395	17.56		
18		8290	388	17.24		

Final strength is Equivalent to 28 days strength.

K. REBOUND HAMMER TEST

Determined as per I.S 13311: Part- 2. Rebound Hammer test is a Non-destructive testing method of concrete which provide a convenient and rapid indication of the compressive strength of the concrete. The rebound hammer is also called as Schmidt hammer that consist of a spring controlled mass that slides on a plunger within a tubular housing. When the plunger of rebound hammer is pressed against the surface of concrete, a spring controlled mass with a constant energy is made to hit concrete surface to rebound back. This measured value is designated as Rebound Number (rebound index). A concrete with low strength and low stiffness will absorb more energy to yield in a lower rebound value.

(i) Correlation between compressive strength of concrete and rebound number:

The most suitable method of obtaining the correlation between compressive strength of concrete and rebound number is to test the concrete cubes using compression testing machine as well as using rebound hammer simultaneously. First the rebound number of concrete cube is taken and then the compressive strength is tested on compression testing machine. The fixed load required is of the order of 7 N/ mm2 when the impact energy of the hammer is about 2.2 Nm.The load should be increased for calibrating rebound hammers of greater impact energy and decreased for calibrating rebound hammers of lesser impact energy. The test specimens should be as large a mass as possible in order to minimize the size effect on the test result of a full scale structure. 150mm cube specimens are preferred for calibrating rebound hammers of lower impact energy (2.2Nm), whereas for rebound hammers of higher impact energy, for example 30 Nm, the test cubes should not be smaller than 150 mm.

Table 23: Rebound Hammer Result

S.No.	ID MARK	OBS. R VALUE				AVE. R VALUE	DIRECTION	CONVERSION FACTOR	COMP. Str. N/mm^2
1	Phase A-1	35	39	39	35				
2	Phase A-2	35	39	38	35	37	0	.952	**35.224**
3	Phase A-3	38	35	38	38				
4	Phase B-1	38	35	38	38				
5	Phase B-2	35	38	39	35	37	0	.977	**36.149**
6	Phase B-3	39	35	39	35				
7	Phase C-1	35	39	39	35				
8	Phase C-2	39	39	38	35	37.5	0	.990	**37.125**
9	Phase C-3	39	35	39	38				
10	Phase D-1	40	39	39	37				
11	Phase D-2	39	37	38	37	38	0	1.012	**38.456**
12	Phase D-3	37	38	39	36				
13	Phase E-1	37	38	39	39				
14	Phase E-2	40	36	36	40	38.5	0	.987	**37.995**
15	Phase E-3	40	40	38	39				
16	Phase F-1	35	39	38	39				
17	Phase F-2	39	35	35	39	37.5	0	1.011	**37.912**
18	Phase F-3	38	36	39	38				

Table-24 below shows the quality of concrete for respective average rebound number.

Average Rebound Number	Quality of Concrete
>40	Very good hard layer
30-40	Good layer
20-30	Fair
<20	Poor concrete
0	Delaminated

As such the estimation of strength of concrete by rebound hammer method cannot be held to be very accurate and probable accuracy of prediction of concrete strength in a structure is ± 25 percent.

K. ULTRASONIC PULSE VELOCITY TEST (UPV)

This testing is used to determine the integrity of structural concrete by measuring the speed and attenuation of an ultrasonic wave passing along a specific test path in the element being tested. In Ultrasonic pulse velocity method, ultrasonic pulse is generated by an electro-acoustical transducer. When the pulse is induced into the concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves is developed, which includes longitudinal (compressive), transverse (shear) and surface (Raleigh) waves. The receiving transducer detects the onset of the longitudinal waves, which is the fastest. Because the velocity of the pulses is almost independent of the material through which they pass, and depends only upon its elastic properties, In case of poor quality of concrete, lower velocities are obtained.

Table 25: UPV Result

S.No	Id Mark	Type of Transmission	Dist. B/W Transducer	Avg. Time(μs)	Velocity KM /SEC	Quality Of Concrete
1	Phase A-1	Direct				
2	Phase A-2	Direct	.150	37.5	**4.0**	Good
3	Phase A-3	Direct				
4	Phase B-1	Direct				
5	Phase B-2	Direct	.150	35.7	**4.2**	Good
6	Phase B-3	Direct				
7	Phase C-1	Direct				
8	Phase C-2	Direct	.150	34.9	**4.3**	Good
9	Phase C-3	Direct				
10	Phase D-1	Direct				
11	Phase D-2	Direct	.150	31.9	**4.7**	Excellent
12	Phase D-3	Direct				
13	Phase E-1	Direct				
14	Phase E-2	Direct	.150	39.5	**4.5**	Good
15	Phase E-3	Direct				

16	**Phase F-1**	Direct	.150	38.5	**4.2**	**Good**
17	**Phase F-2**	Direct				
18	**Phase F-3**	Direct				

Table 26: Velocity criteria for concrete quality grading

S.No.	Pulse Velocity (km/sec)	Concrete quality Grading
1	Above 4.4	**Excellent**
2	3.7 to 4.4	**Good**
3	3.00 to 3.75	**Doubtful**
4	Below 3.0	**Poor**

In case of Doubtful Quality in may be necessary to carry out further test.

L. COST ANALYSIS

The quantity of the constituent material per cubic meter of concrete as determined from mix design and cost of replacing fine aggregate with Granite powder is as presented in Tables 26 and 27 respectively. Table 27 compares the cost of producing concrete of the same grade with different materials.

Table 27: Summary of mix design

Material	Quantities (kg /m^3)
Cement	353
Fine aggregate	721.80
Coarse aggregate	1252.19
Water	148

Table 28: Cost of replacing fine aggregate with different percentages of granite powder in the production of a cubic meter of concrete

A	B	C	D	E	F	G
0	100	0.2723	0	245.07	0	245.07
5	95	0.2587	0.0136	232.82	2.04	236.90
10	90	0.2451	0.0272	220.56	4.08	224.64
15	85	0.2315	0.0408	208.31	6.12	214.43
20	80	0.2178	0.0544	196.06	8.16	204.22
25	75	0.2042	0.0680	183.80	10.2	194.00

A = Percentage of granite powder
B = Percentage of fine aggregate
C = Volume of fine aggregate in 1 m^3
D = Volume of Granite Powder in 1 m^3
E = Cost of fine aggregate per cubic meter of concrete (Rs.900 per cubic meter)
F = Cost of granite powder per cubic meter of concrete (Rs.150 per cubic meter)
G = Total cost of Granite and fine aggregate per cubic meter

IV. CONCLUSION

- The following conclusions can be drawn from the study;
- Replacement of fine aggregate with granite powder is found to improve the strength of concrete.
- The optimal dosage of replacement is found to be15%.
- Utilization of granite powder will avoid the disposal problems and related environmental issues.
- Utilization of granite powder will reduce the usage of river sand and conserve natural resources.
- Peak compressive strength and flexural strength values of 40.22 N/mm2 and 5.33N/mm2 respectively were obtained when fine aggregate was replaced with 15% granite powder in concrete production.

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