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Study on Mechanical Properties of Concrete Using Marble, Granite, Tandur Stone and Glass Powders as a Partial Replacement for Fine Aggregate

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ABSTRACT

Concrete is a most versatile material used in the construction industry throughout the world for the past one and a half century. The ingredients of concrete traditionally are cement, fine aggregates, course aggregates and required quantity of water. The fine powder / slurry from the flooring stone polishing units (marble, granite, tandur stone and glass powders) is an industrial waste being produced in large quantities and shall be disposed properly without any impact on environment. In one of the studies, marble powder is replaced with constituents of concrete to test the mechanical properties and also its economic value. Er. Raj P. Singh Kushwah, Prof. (Dr.), Ishwar Chand Sharma, Prof (Dr.) PBL Chaurasia (2015) presented in his paper that the marble powder can be utilized in concrete mix as replacement for fine aggregates. Bahar Demirel (2010) presented the use of marble dust in place of fine aggregate in concrete mix and checked the mechanical properties of mix. Similar studies are also done with granite stone and tandur stone powder. Experimental studies are also done on concrete mixes using Granite Powder, Tandur stone Powder and Glass Powder as partial replacement for fine aggregate. It is proposed in the present project work to study the mechanical properties of M30 grade concrete using Marble Powder (MP), Granite Powder (GP), Tandur Stone Powder (TP) and Glass Powder (GS) at 0, 15, 20, 25, & 30 % of replacement for fine aggregate. Tests will be conducted at the age of 7, 28, and 90 days for compressive strength and spilt tensile strength.

Keywords: Tandur Stone Powder, Cement Concrete, Marble Slurry.

1. INTRODUCTION

The ever advancing civilization, modernization, industrialization and technological development in the world, large amounts of natural resources such as stone, sand and water etc., are required for construction purposes. But there are not enough resources for the present. Aggregates both coarse and fine occupy almost 70-75% of the total volume of concrete. Natural aggregates are obtained from natural rocks. To meet the global demand of concrete in the future, it is becoming a more challenging task to find suitable alternatives to natural aggregates for preparing concrete. The different materials that can be used as an alternative for natural fine aggregate include blast furnace slag, manufactured sand, crushed glass, copper slag, recycled aggregates, fly ash etc. Of late, the industrial waste by-products such as Marble Powder, Granit Powder, Tandur stone Powder and Glass Powder are also finding place as constituents of concrete material.

OBJECTIVE

To bring out a comparative study on the influence of replacement of fine aggregate with (i) Marble Waste Powder (MWP) (ii) Granite Powder (iii) Tandur Stone Powder and (iv)Glass Powder separately in various proportion the workability of fresh concrete as well as compressive and spilt tensile strength properties of hardened concrete.

LITERATURE REVIEW

OyekanG.L and Kamiyo O.M (2008)[(2)] studied the performance of hollow concrete 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 sandcrete blocks. It was also,observed that for both mix proportions, 15% granite fines content was the optimum value for improved structural performance.

Er. Raj P. Singh Kushwah, Prof. (Dr.), Ishwar Chand Sharma, Prof (Dr.) PBL Chaurasia (2015) [1] presented in his paper that the marble powder can be utilized in concrete mix by replacing fine aggregates. Different mechanical properties of marble slurry were determined like specific gravity, fineness modulus. It was shown that utilization of marble slurry by replacing it with sand up to 30% which shows equal strength as of conventional concrete i.e. 1:2:4 cement concrete ratio with 0% marble slurry. It concludes that marble slurry can easily be utilized in cement concrete mix.

EXPERIMENTAL PROGRAM

The Mix M30 grade concrete is chosen for this study. Fine Aggregate (FA) is proposed to be replaced by Waste Marble Powder (MP), Granite Powder (GP), Tandur stone Powder (TP), and Glass powder (GP) obtained from Surabhi marble industry Karmanghat Rangareddy district,Patel granite industry in Hayathnagar, Rangareddy district, Tandur stone industry in Hayathnagar, Rangareddy district, Glass industry in Karmanghat, Rangareddy district respectively.

MIX DESIGNATIONS

It is proposed to replace fine aggregate, Natural River sand, with alternative waste bi-products at 15%,20%,25%, and 30%. The mixes are designated as MP0, MP15, MP20, MP25, MP30,GP0, GP15, GP20, GP25, GP30,TP0, TP15, TP20, TP25, TP30, GS0, GS15, GS20, GS25, and GS30. MP stands for Marble Powder, GP stands for Granite Powder, TP stands for Tandur stone Powder and GS stands for Glass Powder and the number at suffices, i.e.,0,15, 20, 25, and 30 indicates the percentage of waste by-product powders used as fine aggregate.

Concrete cubes of size 150×150×150 mm are proposed for casting at 3 numbers for testing strength at 7 days, 3 numbers for testing strength at 28 days, and 3 numbers for testing strength at 90 days. One more set of 3 numbers for each mix as spare set are also cast for use against any erroneous results. Thus there are 4mixes and 12 cubes for each mix totalling to 48 cubes for each type of powder. Thus the total number of cubes is 192, (4x4x12 =192 cubes).One set of 12 cubes with 100 % natural river sand as fine aggregate whose results are taken as same for MP0, GP0, TP0, and GS0.

MIX DESIGN

Mix Design As Per IS 10262:2009 (M30 Grade)

Stipulation for proportioning

- Grade designation – M30
- Type of cement – PPC (53 grade)
- Max nominal size of aggregate – 20mm

- Maximum cement content – 320kg/m^3(from IS:456-2000 Table no. 5)
- Maximum water cement ratio – 0.45 (from IS:456-2000 Table no. 5)
- Workability – 75to100mm (from IS:456-2000-Cl.7.18)
- Exposure condition – Severe(for reinforced concrete)
- Method of concrete placing – Manual
- Degree of super vision – Good
- Type of aggregate – Angular
- Maximum cement content – 450kg/m^3 (from IS:456- 2000)

Target strength for mix proportioning

$f'_{ck} = f_{ck} + 1.65S$ Where

f'_{ck} = target average compressive strength at 28 days

f_{ck} = characteristics compressive strength at 28 days = 30 N/mm^2

S = Standard Deviation (from table-1 is: 10262:2009 for M30 grade)

= 5 N/mm^2

$f_{ck} = f_{ck} + 1.65S$ = 30+1.65x5= 38.25 N/mm^2

Mix calculation

The mix calculation per unit volume of concrete shall be as follows

- Volume of concrete (a) = 1m^3
- Volume of cement(b) = mass of cement/Specific gravity of cement×1/1000
  = 492.5/3.15 ×1/1000 =0.15 m^3
- Volume of water (c) = mass of water/specific gravity of water × 1/1000
  = 197/1 × 1/1000 = 0.197 m^3
- Volume of FA and CA (d)= [a- (b + c)] = [1-(0.15+0.197)] = 0.653
- Mass of C.A = d× volume of C.A × Sp.gravity of C.A×1000
  = 0.653×0.66×2.67×1000 = 1151 kg
- Mass of F.A = d×volume of F.A × Sp.gravity of F.A ×1000
  = 0.653×0.34×2.56×1000 = 568 kg

Mix proportion for trial number 1

- Weight of cement per cubic meter = 492.5kg
- Weight of water per cubic meter = 197 kg/m^3
- Weight of fine aggregate per cubic meter = 568 kg/m^3
- Weight of coarse aggregate per cubic meter = 1151 kg/m^3
- Water cement ratio = 0.40

Mix calculations for Cubical and cylindrical Specimens of sizes

Cubical Specimen of size 150x150x150 mm

Cement $1m^3$ = 492.5 kg

3.375×10^{-3} = x

x = 1.66218

For 12 moulds = 1.66218×12 = 19.94kg

Volume of water $1\ m^3$ = $0.197m^3$

3.375×10^{-3} = x

x = 0.0006648

Changed litre (conversion) = 0.664875

For 12 moulds =0.6648×12 = 7.97litre

Mass of C.A $1\ m^3$ = 1151kg

3.375×10^{-3} = x

x = 3.88 kg

For 12 moulds = 3.88×12 = 46.61kg

Mass of F.A $1\ m^3$ = 608kg

3.375×10^{-3} = x

x = 1.917kg

For 12 moulds = 1.917×12 = 23.0kg

Cylindrical moulds

Cement $1m^3$ = 492.5 m^3

5.29×10^{-3} = x

x = 2.605

For 3 moulds : = 2.605×3 = 7.81kg

Volume of water $1\ m^3$ = 0.197 m^3

5.29×10^{-3} = x

x = 0.00104

Changed litre (conversion) = 1.042

For 3 moulds = 1.042×3 = 3.12litre

Mass of C.A $1\ m^3$ = 1151 kg

5.29×10^{-3} = x

x =6.08 kg

For 3 moulds =6.08×3 = 18.26kg

Mass of F.A 1 m^3 =568kg

5.29×10^{-3} =x

X = 3.004kg

For 3 moulds = 3.004×3 = 9.01 kg

Cement: F.A: C.A = 1:1.15:2.33

Concrete cube specimen of 150×150×150mm is cast with the above design mix proportions are tested at 7days. The test results are as follows:

Table No: 1 Combined table of ingredients for Marble powder

S.No.	Marble %	Cement (kg)	Fine Aggregate (kg)		Coarse aggregate (kg)			Water (litres)
			NFA	WMP	20 mm	12mm	6mm	
1.	MP15	28	27.2	4.8	32.5	16.25	16.25	11
2.	MP20	28	25.6	6.4	32.5	16.25	16.25	11
3.	MP25	28	24.0	8.0	32.5	16.25	16.25	11
4.	MP 30	28	22.4	9.6	32.5	16.25	16.25	11

The experimental program is thus established such that required test which finally help in determining the effect of addition of waste marble powder that in different percentages in concrete are assessed reasonable.

Table No: 2 Combined table of ingredients for Granite powder

S.No.	Granite %	Cement (kg)	Fine Aggregate (kg)		Coarse aggregate (kg)			Water (litres)
			NFA	WGP	20 mm	12mm	6mm	
1.	GP15	28	27.2	4.8	32.5	16.25	16.25	11
2.	GP20	28	25.6	6.4	32.5	16.25	16.25	11
3.	GP25	28	24.0	8.0	32.5	16.25	16.25	11
4.	GP 30	28	22.4	9.6	32.5	16.25	16.25	11

Table No: 3 Combined table of ingredients for Tandur stone powder

S.No.	Tandur %	Cement (kg)	Fine Aggregate (kg)		Coarse aggregate (kg)			Water (litres)
			NFA	WTP	20 mm	12mm	6mm	
1.	TP15	28	27.2	4.8	32.5	16.25	16.25	11
2.	TP20	28	25.6	6.4	32.5	16.25	16.25	11

3.	TP25	28	24.0	8.0	32.5	16.25	16.25	11
4.	TP 30	28	22.4	9.6	32.5	16.25	16.25	11

2 EXPERIMENTAL INVESTEGATION

2.1 Slump Test:

Effect of alternative industrial waste bi-product materials on workability of fresh concrete is proposed to be studied by conducting Slump test using standard Slump Cone Apparatus following the procedure as per IS:7320 – 1974.

2.2 Compressive strength test:

Effect of alternative industrial waste bi-product materials on compressive strength of hardened concrete with alternative resources is proposed to be studied at 7 days and 28 days and 90 days by conducting Compression Test using standard Compression Testing Machine Apparatus following the procedure as per IS: 516 – 1959.

2.3 Split Tensile Strength test:

Effect of alternative industrial waste bi-product materials on split tensile strength of hardened concrete with industrial waste bi-product materials is proposed to be studied at 28 days and 90 days by conducting split tensile test using standard Universal Testing Machine (UTM) Apparatus following the procedure as per IS:5816 – 1999.

Fig No:1 Moulds samples for test preparation

3. CASTING SCHEDULE

For casting the cubes and cylinder specimens, standard cast iron metal moulds of size 150x150 cubes, 150x300mm cylinder moulds are used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before the concrete is poured into the moulds. Thoroughly mixed concrete is filled into the mould in three layers of equal heights followed by tamping. Then the mould is placed on the table vibrator for a small period. Excess concrete is removed with trowel and top surface is finished to smooth level. Moulds were provided with base plates, having smooth surface to support. Care was taken to ensure that there were no leakages.

Table No: 4 Cubes and Cylinders Casting Schedule for MP, GP & TP Mix

Grade	Mix Designation	Date of Casting	No of Cubes	No. Of Cylinders	Testing for7days	Testing for28days	Testing for 90 days
M30	1 0%	05/02/2016	12	3	12/02/2016	03/03/2016	05/05/2016
M30	15%	10/02/2016	12	3	16/02/2016	08/02/2016	10/05/2016
M30	20%	11/02/2016	12	3	17/02/2016	09/03/2016	11/05/2016
M30	25%	06/02/2016	12	3	12/02/2016	04/03/2016	06/05/2016
M30	30%	13/02/2016	12	3	19/02/2016	11/02/2016	13/05/2016

(a) Testing specimen under CTM

(b) Cube specimens

(c) Universal Testing Machine

(d) Tested specimen

Fig No. 2 Tests on Hardened Concrete

4. RESULTS & DISCUSSION

The concrete with waste marble powder is workable only when necessary plasticizers are used. Concrete with waste marble powder can be considered for mass concrete works like roads, retaining walls, bridge piers etc. The slump increases with increase in percentage of Granite Waste Powder (GWP).The reason for increase in slump is due to fewer fines in the Granite powder. The slump decreases with increase in percentage of Tandur Waste Powder (TWP). The reason for decrease in slump is due to less fineness modulus. The Slump increases with increase in percentage of Glass Waste Powder (GWP).The reason for increase in slump is due to less fines and glass particles being spherical in nature, add for good workability. Either the rate of decrease in workability with increase in % of MP and GP or the rate of increase in workability with increase in % of GP is almost uniform. Whereas in respect of GS, the variation of workability with increase in % of GS is not uniform. The increase in % of GP and GS is adding for good workability.

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Compressive Strength Results

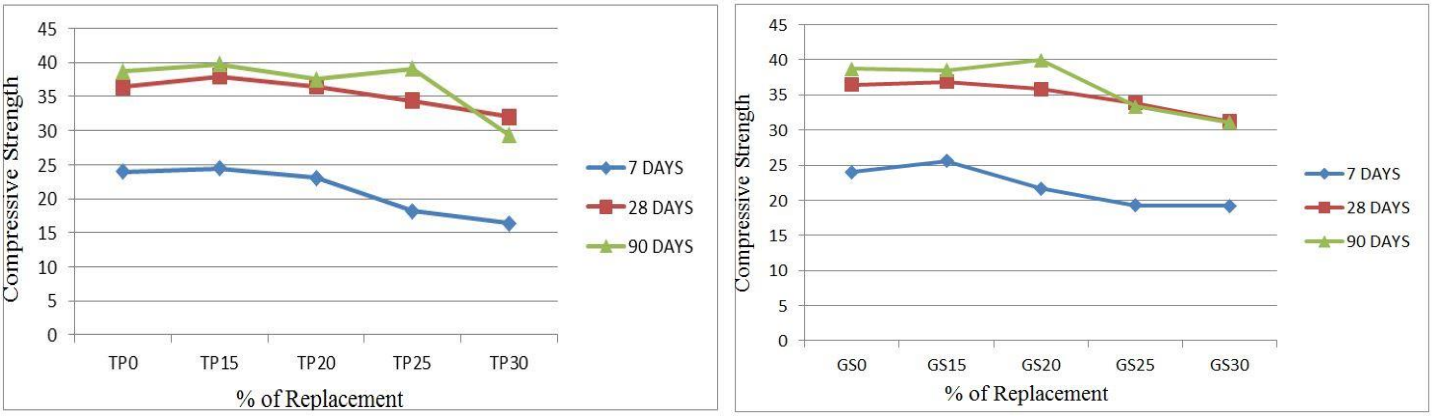
The Compressive Strength Results of various materials being used in this experimental study are being tested.

Table No: 5 Compressive Strength results strength of Tandur stone Powder Mix (TP) and Glass Powder Mix (GS) concrete at 7, 28 & 90 days

Mix Designations	Date of casting	Date of testing in 7 days	Date of testing in 28 days	Date of testing in 90 days	Compressive strength in 7 days (N/mm²)	Compressive strength in 28 days (N/mm²)	Compressive strength in 90 days (N/mm²)
TP0	5/2/2016	12/2/2016	3/3/2016	5/05/2016	24.00	36.43	38.73
TP15	10/2/2016	15/2/2016	7/3/2016	10/5/2016	24.44	37.99	39.77
TP20	11/2/2016	18/2/2016	10/3/2016	11/5/2016	23.10	36.51	37.55
TP25	6/02/2016	12/2.2016	3/3/2016	6/05/2016	18.21	34.36	39.10
TP30	13/2/2016	22/2/2016	14/3/2016	13/5/2016	16.44	31.99	29.32

S.No	Mix Designations	Date of casting	Date of testing in 7 days	Date of testing in 28 days	Date of testing in 90 days	Compressive strength in 7 days (N/mm²)	Compressive strength in 28 days (N/mm²)	Compressive strength in 90 days (N/mm²)
1.	GS0	5/2/2016	12/2/2016	3/3/2016	5/05/2016	24.00	36.43	38.73
2.	GS15	10/2/2016	15/2/2016	7/3/2016	10/5/2016	25.63	36.89	38.51
3.	GS20	13/2/2016	18/2/2016	10/3/2016	13/5/2016	24.70	35.86	39.99
4.	GS25	8/02/2016	12/2.2016	3/3/2016	8/05/2016	19.26	33.36	33.33
5.	GS30	16/2/2016	22/2/2016	14/3/2016	16/5/2016	19.23	31.26	31.10

Fig No:3 Comparison of compressive strength of Tandur stone Powder Mix (TP) and Glass Powder Mix (GS) concrete at 7, 28 & 90 days



(i) It can be observed from the above test results that the compressive strength of the Marble Powder Mix concrete is uniformly decreasing from 24 N/mm^2 for MP0 to 19.2 N/mm^2 for MP30 at 7 days. While that at 28 days is decreasing from 36.42 N/mm^2 for MP0 to 27.30N/mm^2 for MP 30 at 28 days. However the compressive strength results at 90 days show a different pattern of variation but all the results for 4 different Mixes show lesser values than MP0. It can be observed the decrease in compressive strength with increase in percentage of marble powder. Marble Powder also did not add the secondary pozzolanic action at later days, i.e., after 28 days because of less silica content. The addition of Marble by replacing natural sand fine aggregate is not showing encouraging results. However the marble powder can be used as a partial replacement for natural sand up to about 20 % since the test results are close to the target strength. Thus the disposal/waste management of MP as an industrial waste powder can be properly ensured by using in concrete works and to which extent the natural sand can be conserved.

(ii) The compressive strength for other proportions, i.e., GP20, GP25, and GP30 shows a uniform reduction. The test results at 90 days reveal that strength uniformly decreased with increase in % of GP. From the above results it

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may be observed that granite powder and natural sand being more or less similar in physical properties, there is not much variation in the compressive strength results. All the results at 28 days for all GP mixes satisfy the target strength. The marginal decrease in variation of strength with increase in percentage of GP may be due to some percentage of very fine particles of granite powder. Granite powder can also be safely and judiciously used in place of sand even up to 30% of GP. The marginal decrease in variation of strength with increase in percentage of GP may be due to some percentage of very fine particles of granite powder. Granite powder can also be safely and judiciously used in place of sand even up to 30% of GP.

(iii) It can be observed from the above test results that the TP15 & TP20 mixes showing marginal increase in compressive strength at 28days, i.e., 36.43 N/mm^2 for TP0 and 37.99 N/mm^2 (4.3% increase) for TP15 and 36.51 N/mm^2 for TP20 (0.2% increase). The target strength is reached for all the TP mixes. The compressive strength results in respect of TP mixes also show a decrease in trend with increase in percentage of TP. The compressive strength of TP15 &TP25 shows a marginal increase over TP0 at 90 days. The early strength at 7days is decreasing drastically with increase in % of TP. It may be observed above the industrial waste bi-product of TP can also be used as a replacement for natural sand even up to 25%.

Split Tensile Tests Results

Split tensile strength of MP Mixes is seen decreasing uniformly with increase in percentage of MP. The split tensile strength pattern of GP Mixes is seen marginally increasing with increase in % of GP. The split tensile strength pattern of TP Mixes shows more or less uniform results except for TP Mixes which is showing a higher value of 3.2N/mm^2.The Split tensile strength pattern of GS Mixes is also more or less uniform results with a marginal increase in split tensile strength with increase in % of GS.

It can be observed that the replacement of natural sand with any of the above said four industrial bi-products wastes i.e. MP, GP, TP & GS up to a percentage of 30 doesn't have notable impact on the split tensile strength of the different mixes.

Table No: 6 Split tensile strength of Granite Powder(GP) Mix for 28 days

S.No	Mix Designations	Date of casting	Date of testing in 28 days	Split tensile strength for 28 daysin N/mm^2
1.	GP0	5/2/2016	3/3/2016	2.51
2.	GP15	10/2/2016	7/3/2016	2.54
3.	GP20	11/2/2016	10/3/2016	3.07
4.	GP25	6/2/2016	3/3/2016	3.10
5.	GP30	13/2/2016	14/3/2016	3.13

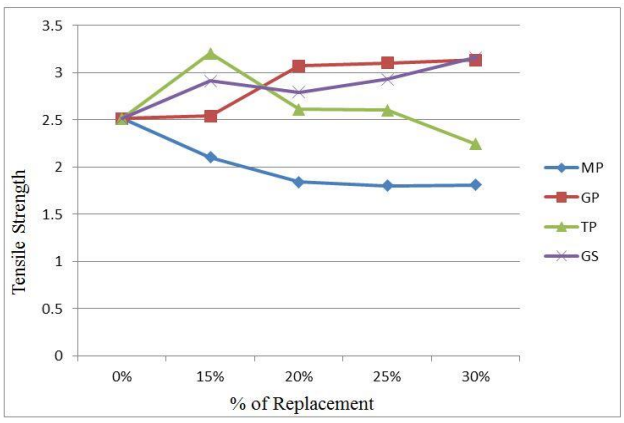

Fig No: 4 Split tensile strength of MP, GP, TP & GS for 28 days

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5. CONCLUSIONS

In addition of Marble powder & Tandur powder as part replacement is decreasing the workability and hence plasticizers are required to improve the workability. Workability in respect of GP and TP Mixes is seen increasing with increase in percentage replacement. Thus, addition of MP, GP, TP and GS is not having notable impact on workability of concrete. In fact, GP and GS Mixes show an increase in workability which is an advantage. Addition of MP, GP, TP and GS as a replacement for natural sand in certain percentages also don't have notable effect on compressive strength up to 20% in respect of MP, 30% in respect of GP, 20% in respect of TP and 30% in respect of GS without forgoing the target compressive strength. The addition of MP, GP, TP and GS as a replacement for sand up to 30% do not show notable impact even on the split tensile strength. Thus it can be concluded that the natural sand can be replaced up to 20% in respect of MP, 30% in respect of GP & GS and up to 20% in respect of TP.

Thus the industrial waste by-products like WMP, WGP, WTP and WGS can be disposed safely and environment friendly by using them in construction industry as a replacement up to certain percentages as specified above in the concrete, at least in the mass concrete works like roads, bridge piers, retaining walls etc. there by not only conserving natural resources i.e., river sand but also provides an acceptable solution for eco-friendly disposal of the said industrial waste material.

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