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Strength and Durability of Concrete Block by Partial Replacement of Cement with Granite Dust and Fine Aggregate with M-Sand

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Abstract

In this experimental study, granite dust (GD), industrial waste material, is used as a partial replacement of cement in a solid block. Replacement of cement by GD in proportion varying from 0%,5%,10%,20% by weight of cement is done. For each replacement, the compressive strength of the cube after 7, 28, and 60 days is noted. From the compression test conducted, favorable strength is attained at a certain percentage, which has been noted, and by keeping that certain percentage of GD, fine aggregate is partially replaced with manufactured sand (M-sand). Fine aggregate is a significant raw material in construction works that is naturally available. However, due to the over-exposure of river sand, it becomes scarce nowadays. So, an alternative for this is M-sand, which is produced in companies to meet the demand. Replacement of fine aggregate in proportion varying from 0%, 20%, 40%, 60%, 80%, 100% by weight of fine aggregate. For each replacement Workability test such as Slump cone test, compaction factor test, Compressive strength of cube, Compressive strength of concrete block (300mm x 150mm x 200mm), Flexure test, Split tensile strength and Durability tests such as water absorption test, acid test, and the alkaline test is noted after 7,28 and 60 days. From the test result, it is found that the concrete at a level of 10% partial replacement of cement with granite dust and 40% partial replacement of fine aggregate with M-sand gives better workability and high compressive strength.

Keywords - *Granite dust, Fine aggregate, M-sand, Solid block, Durability, Compressive strength.*

I. INTRODUCTION

In almost all construction works, strength and durability are significant factors. For this purpose, Ordinary Portland Cement (OPC) is generally used. In cement, silica (SiO_2) is an important ingredient that gives strength to cement by forming dicalcium silicate (Ca_2SiO_4 or C2S) and tricalcium silicate (Ca_3O_5Si or C3S). As the quantity of SiO_2 increases, the strength of cement will also increase. By taking this into account, cement is partially replaced by GD.[1]

Granite is an igneous rock, formed when a portion of lava remains under the earth and undergoes cooling at slow rate results in the formation of crystalline rock like granite. The main chemical propositions of the granite are SiO_2, Al_2O_3, CaO, MgO, and Fe_2O_3. From the above chemical propositions, SiO_2 is more abundant, which is about 65% to 70%. Therefore by adding it, the quantity of SiO_2 in cement will increase, increasing the strength of cement.[2]

Granite dust is obtained as waste material from the granite polishing industry or cutting industry. Generally, about 2000 tonnes of granite waste is produced in India per week. The huge mass of granite waste from the industries were dumped on open land. The land which becomes a dumping yard for granite dust will lose its productivity, and soil porosity reduces, which further reduces the groundwater recharge. Granite dust has also become a threat to human health. These silica dust particles in GD can cause scarring in the lungs, leading to a lung condition known as silicosis. Due to the above reasons, granite dust disposal becomes a major problem; this gives a new solution for sustainable development by using granite dust in construction works, which can reduce environmental degradation.[3],[4]

River sand is most commonly used as a fine aggregate. However, due to the depletion of the riverbed, the river sand has been highly-priced, and its availability is decreased. To overcome these problems, manufactured sand (M-sand) is used as an alternative or a partial replacement of river sand. The use of M-sand not only reduces the scarcity of river sand but also reduces transportation costs.[5],[6]

The better alternative for river sand is M -sand, produced by equipment in proper proportion and uniform size. It is shaped by Vertical Shaft Impactor (VSI), which gives a smooth surface texture.The cubicle shaped particle provides more strength and greater durability to concrete.[7]

M-sand usage can also reduce the transportation cost cause it can be easily available from nearby industries. Similarly, the usage of GD will also reduce the construction costs cause it is just a waste material from granite industries.

II. MATERIALS USED

The materials used in this experimental study were locally available. The property of these materials was determined as per Indian Standard specifications and recommended code.[8]

1. Cement: Ordinary Portland cement (OPC) of 53-grade RAMCO cement confirming IS:12269-2013 was used throughout the work. The properties of cement are shown in Table1.[9]

Table 1.Properties of M53 grade cement

S.No	Properties of cement	
1	Consistency (%)	29.5
2	Specific gravity	3.15
3	Initial settling time (Minutes)	30
4	Final settling time (Minutes)	600

2. Granite Dust (GD): Waste granite dust Fig 1, which has been locally available, is collected and used in this experimental study. The properties of the GD, which has been found in the laboratory, are shown in Table 2. The chemical composition of GD is shown in Table 3.

Table 2. Properties of GD

S.No	Properties of GD	
1	Specific gravity	2.65
2	Density (g/cm3)	2.7
3	Porosity (%)	0.5
4	Size	Less than 90µm

Figure 1.Granite Dust

3. Aggregate: Fine aggregate and coarse aggregate for concrete conforming IS:383-2016 are used. Locally available river sand of size ranges from 4.75 mm to 75µ is used as fine aggregate, which is further partially replaced by an M-sand of size ranges from 4.7 mm to 75µ. The properties of Fine aggregate is shown in Table 4. Cursed stone chips, which are locally available of about 6 mm, are used as coarse aggregate throughout the work. The properties of coarse aggregate are shown in Table 5.[10]

Table 3.Chemical Composition of GD

S.No	Chemical Composition	Composition (%)
1	SiO_2 (Silica)	75
2	$Al2O_3$ (Alumina)	12
3	CaO (Lime)	1.0
4	MgO (Magnesia)	1.2
5	TiO_2 (Titania)	1.5
6	Fe_2O_3 (Iron Oxide)	2.5
7	Na_2O (Sodium Oxide)	3.5
8	K_2O (Potassium Oxide)	3.8

Table 4. Properties of Fine aggregate

S.No	Properties	River sand	M-sand
1	Specific gravity	2.65	2.63
2	Density(kg/m3)	1600	1.75
3	Water Absorption (%)	6.52	4.8

Table 5. Properties of coarse aggregate

S.No	Properties of Coarse aggregate	
1	Specific gravity	2.72
2	Density(kg/m3)	1750
3	Water Absorption(%)	5.5

III. MIX PROPORTION

Based on the strength, durability, and workability of the materials used, the mix proportion for the concrete block is shown in Table 6.[11]

The casting of a solid block

In the casting yard, "Ponmani Bricks" in Madurai, the concrete block as shown in Fig 2, of size 300mm x 150mm x 200mm and mix proportion as shown in Table 6, is cast and tested for compression strength in UTM (Universal Testing Machine) as shown in Fig 3. The test results after 7, 28, and 60 days are shown in Table 7, and the density of concrete block for each replacement proportion is shown in Table 8.

Table 7. Compressive Strength Of Solid Block

Mix Designation	7 Days (N/mm2)	28 Days (N/mm2)	60 Days (N/mm2)
CM	5.23	10.13	10.21
GD10	5.25	10.15	10.25
GD10MS20	6.18	10.33	10.49
GD10MS40	6.77	11.50	11.67
GD10MS60	5.63	10.44	10.56
GD10MS80	5.42	10.39	10.35
GD10MS100	5.33	10.17	10.28

Figure 2.Solid Block (300mm x 150mm x 200mm)

Figure 3.Compression Test on Solid Block

Table 6. Mix Proportion

Mix designation	Cement (kg/m^3)	Granite Dust (kg/m^3)	Fine Aggregate (kg/m3)	M sand (kg/m3)	Coarse Aggregate (kg/m3)	Water (kg/m^3)
CM	365	-	815	-	1115	182.5
GD10	328.5	36.5	815	-	1115	182.5
GD10MS20	328.5	36.5	652	163	1115	182.5
GD10MS40	328.5	36.5	489	326	1115	182.5
GD10MS60	328.5	36.5	326	489	1115	182.5
GD10MS80	328.5	36.5	163	652	1115	182.5
GD10MS100	328.5	36.5	-	815	1115	182.5

Table 8. The density of Solid block

Mix designation	Density (kg/m3)
CM	1623
GD10	1625
GD10MS20	1778
GD10MS40	2000
GD10MS60	1956
GD10MS80	1722
GD10MS100	1667

IV. WORKABILITY

Testing of Fresh concrete

To measure fresh concrete's workability, the slump test, as shown in Fig 4, and the compaction factor test was conducted. In the slump test, the frustum cone of top diameter 100mm, bottom diameter 200mm, and height 300 mm was filled with concrete. Then it is removed immediately by raising it slowly in a vertical direction. This allows the concrete to subside, which is called a slump. The slump is measured immediately by determining the height difference between the mold and the highest slump point formed. In the compaction factor test, the concrete mix is filled exactly on the upper hopper, and the trap door is opened, which allows the concrete to fall into the lower hopper. Once the concrete has come to rest, the lower hopper's trap door is opened, which allows the concrete to fall into the cylinder. The weight of the concrete in the cylinder is noted. The cylinder is then refilled with the same concrete sample fully compacted and weighed. The compaction factor is the ratio of partially compacted concrete to the weight of fully compacted concrete. The slump value and the compaction factor for each replacement proportion, 0%,20%,40%,60%,80%,100% of river sand by MS by keeping 10% partial replacement of cement by GD are shown in Table 9.

Table 9. Slump and Compaction Factor value for Fresh concrete

Mix designation	Slump (mm)	Compaction factor
CM	52	0.82
GD10	54	0.83
GD10MS20	58	0.89
GD10MS40	63	0.95
GD10MS60	61	0.93
GD10MS80	56	0.92
GD10MS100	55	0.85

Figure 4 .Slump Cone Test

V. TESTING OF HARDENED CONCRETE

A. Strength of concrete by GD replacement

This experimental study concrete cube of size 150mm x 150mm x 150mm with a proper mix ratio was cast by partial replacement of cement with GD in proportion varying from 0%,5%,10%,15%,20% and were tested for compressive strength confirming IS:516-1959. The test results are shown in Table 10.[12]

Table 10. Compressive Strength of Cube By Partial Replacement Of Cement With GD

Mix Designation	7 Days (N/mm2)	28 Days (N/mm2)	60 Days (N/mm2)
CM	12.26	17.55	17.72
GD5	12.34	17.62	17.85
GD10	12.93	17.93	18.72
GD15	12.57	17.81	18.23
GD20	12.31	17.67	18.05

From the above table, it can be seen that at 10 %, partial replacement of cement by GD gives good results**.** Therefore by taking that certain percent into account, the fine aggregate was further partially replaced by M-sand (MS) to get more strength.

B. Strength of Concrete by GD and MS replacement

In this test, the cube mold of 150mm x 150mm x 150mm is used. The concrete is filled in the mold by layers; each layer is well compacted with a trowel. The specimens were demoulded after 24 hrs and kept in curing. Then the cubes are tested in Compression Testing Machine as shown in Fig 5, after 7, 28, and 60 days. The results are shown in Table 11.

.Table 11.Compressive Strength of Cube by Replacement of GD And MS

Mix Designation	7 Days (N/mm2)	28 Days (N/mm2)	60 Days (N/mm2)
CM	12.47	17.87	17.96
GD10	12.49	17.91	18.01
GD10MS20	12.53	18.27	18.53
GD10MS40	13.21	19.01	19.63
GD10MS60	13.00	18.75	18.80
GD10MS80	12.95	18.50	18.67
GD10MS100	12.82	18.44	18.62

C. Split Tensile Test

The splitting test is well known indirect test used to find the tensile strength of concrete. The test consists of applying compressive line loads along with the opposite generators, concrete cylinder placed with its axial horizontal between the platters as shown in Fig6. The applied line loading forms uniform tensile stress over nearly two-thirds of the loaded diameter. The magnitude of the tensile stress is given by the formula given below

$$T= 2P/ \prod DL$$

Where P - Applied load,
D- Diameter of the cylinder,
L- Length of the cylinder.

The dimension of the standard cylindrical mold has a 150 mm diameter and 300mm length. The specimens were demolded after 24 hrs and put under the curing process. The cubes are tested in Compression Testing Machine after 7, 28, and 60 days. The results are shown in Table 12.

Figure 5.Compression Test on Cube

Table 12. Splitting tensile strength

Mix Designation	7 Days (N/mm2)	28 Days (N/mm2)	60 Days (N/mm2)
CM	1.21	2.39	3.32
GD10	1.28	2.41	3.45
GD10MS20	1.45	2.58	3.49
GD10MS40	1.66	2.93	3.67
GD10MS60	1.58	2.69	3.64
GD10MS80	1.51	2.52	3.58
GD10MS100	1.30	2.46	3.47

Figure 6.Split Tensile Test

D. Flexural Strength Test

This test is carried out to estimate the load at which the concrete members may crack. It also evaluates the tensile strength of concrete indirectly. The standard specimen of 100mm x 100mm x 500mm is used under asymmetrical two-point load. Modulus of rupture (f_r) is determined by the formula given below

$$f_r = FL / bd^2$$

Where F - Force, L - Length, b -Width, d -Thickness
The specimens were demolded after 24 hrs, then cured and tested in UTM with a two-point load after 7, 28, and 60 days. The results are shown in Table 13.

Table 13.Flexural Tensile Strength of concrete

Mix designation	7 Days (N/mm2)	28 Days (N/mm2)	60 Days (N/mm2)
CM	2.9	3.4	4.3
GD10	3.1	3.6	4.9
GD10MS20	3.8	4.1	6.2
GD10MS40	4.0	5.4	6.8
GD10MS60	3.7	5.2	6.5
GD10MS80	3.5	4.8	6.1
GD10MS100	3.3	3.9	5.5

VI. DURABILITY TEST

A. Absorption Test

This test has been done to determine the water tightness of concrete. The water absorption depends on the porosity and permeability of concrete. The average percentage of water absorption of the concrete cube of size 150mm x 150mm x 150 mm after 28 and 60 days are shown in Table 14. [13]

Table.14 Water absorption for concrete cube

Mix Proportion	Average water absorption at 28 days (%)	Average water absorption at 60 day (%)
CM	6.17	7.27
GD10	6.15	7.23
GD10MS20	5.96	6.31
GD10MS40	4.23	5.67
GD10MS60	5.87	5.89
GD10MS80	5.53	6.34
GD10MS100	5.60	6.52

B. Acid Attack Test

This test is carried out to find the resistance of concrete against an aggressive chemical environment. In this test, concrete cubes of size 150mm x 150mm x 150mm with 10 % partial replacement of cement by GD and varying proportion of MS (0%, 20%, 40%, 60%, 80%, 100%) as a replacement of Fine aggregate were cast and demolded after 24 hrs and kept in curing tank. After 7 days of curing, the dry weight is taken and immersed in 5% HCL in 1 liter of water. The pH value of acid media is constantly checked and maintained. The dry weight of the specimen is taken after 7, 28, and 60 days of immersion in acid solution. The percentage of weight loss and Strength reduction in HCL is shown in Table 15 and Table 16. The above procedure is repeated, but in this case, another acid called H_2SO_4 of 5% in 1 liter of water is used. The percentage of weight loss and Strength reduction in the case of H_2SO_4 is shown in Table17 and Table 18. [14]

Table 15. Percent weight loss (5% HCL)

Mix Designation	% weight loss		
	7 days of exposure	28 days of exposure	60 days of exposure
CM	2.49	2.54	3.10
GD10	2.47	2.51	3.07
GD10MS20	2.38	2.43	2.88
GD10MS40	2.12	2.22	2.65
GD10MS60	2.14	2.37	2.67
GD10MS80	2.20	2.42	2.70
GD10MS100	2.25	2.45	2.83

Table 16. Percent Strength loss (5% HCL)

Mix Designation	% Strength loss		
	7 days of exposure	28 days of exposure	60 days of exposure
CM	2.76	7.67	10.90
GD10	2.74	7.63	10.88
GD10MS20	2.67	7.47	10.69
GD10MS40	2.65	7.32	10.45
GD10MS60	2.69	7.35	10.65
GD10MS80	2.71	7.53	10.72
GD10MS100	2.72	7.59	10.81

Table 17. Percent weight loss (5% H_2SO_4)

Mix Designation	% Weight loss		
	7 days of exposure	28 days of exposure	60 days of exposure
CM	1.42	1.96	2.76
GD10	1.39	1.94	2.73
GD10MS20	1.27	1.85	2.65
GD10MS40	1.11	1.83	2.48
GD10MS60	1.23	1.89	2.62
GD10MS80	1.30	1.91	2.67
GD10MS100	1.34	1.93	2.70

Table 18. Percent strength loss (5% H_2SO_4)

Mix Designation	% Strength loss		
	7 days of exposure	28 days of exposure	60 days of exposure
CM	2.09	5.83	7.51
GD10	2.03	5.78	7.48
GD10MS20	1.93	5.69	7.39
GD10MS40	1.87	5.64	7.20
GD10MS60	1.89	5.67	7.35
GD10MS80	1.95	5.72	7.43
GD10MS100	1.99	5.75	7.46

C. Alkaline Attack Test

It is carried out to find the resistance of concrete against the marine environment. In this test, concrete cubes of size 150 mm x 150 mm x 150 mm with 10 % partial replacement of cement by GD and varying proportion of MS (0%, 20%, 40%, 60%, 80%, 100%) as a replacement of Fine aggregate was cast and demolded after 24 hrs and kept in curing tank. After 7 days of curing, the dry weights were taken and immersed in 5% NaOH in 1 liter of water. The pH value of alkaline media is constantly checked and maintained. The dry weight of the specimen is taken after 7, 28, and 60 days of immersion in NaOH solution. The percentage of weight loss and Strength reduction in the case of NaOH are shown in Table 19 and Table 20.

Table 19. Percent weight loss (5% NaOH)

Mix Designation	% Weight loss		
	7 days of exposure	28 days of exposure	60 days of exposure
CM	1.38	1.80	2.32
GD10	1.36	1.78	2.30
GD10MS20	1.11	1.62	2.05
GD10MS40	0.98	1.56	1.97
GD10MS60	1.05	1.59	1.99
GD10MS80	1.17	1.67	2.17
GD10MS100	1.21	1.72	2.23

Table 20. Percent weight loss (5% NaOH)

Mix Designation	% Strength loss		
	7 days of exposure	28 days of exposure	60 days of exposure
CM	1.82	2.67	3.54
GD10	1.79	2.64	3.51
GD10MS20	1.63	2.43	3.39
GD10MS40	1.51	2.32	3.32
GD10MS60	1.54	2.35	3.35
GD10MS80	1.67	2.49	3.43
GD10MS100	1.72	2.53	3.48

VII. RESULT AND DISCUSSION

The graphical representation of the compressive strength of the cube (150mm x 150mm x150mm) of the proper mix ratio with a partial replacement of cement by GD is shown in Figure 1.

Figure7 shows that at 10%, partial replacement of cement by GD gives good results**.** Therefore by taking

that certain percent, the fine aggregate was further partially replaced by MS to attain more strength.

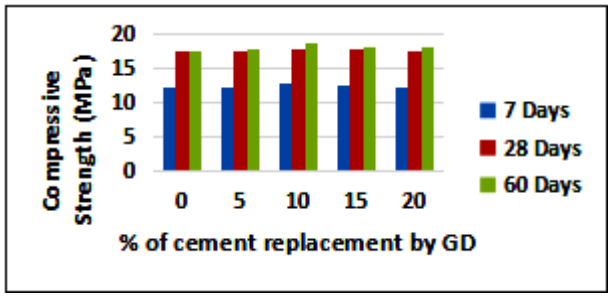

Figure 7. Compressive Strength Of Cube By Partial Replacement Of Cement With GD

The graphical representation of compression strength of cube with 10% partial replacement of cement by GD and 0%,20%,40%,60%,80%,100% of replacement of fine aggregate by MS is shown in Figure 8.

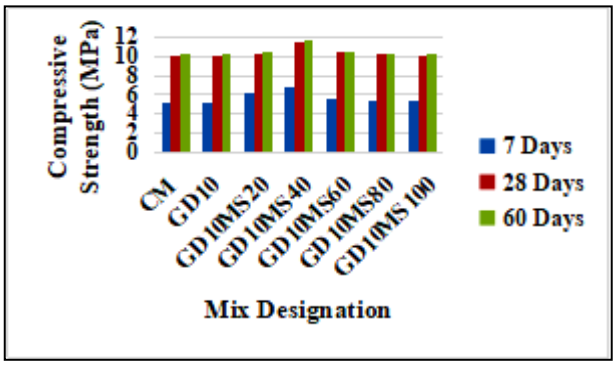

Figure 8.Compression Strength of Cube by Replacement of GD And MS

From Figure 8, it can be seen that the strength attained is more at 40 % replacement of MS. For further investigation, Solid blocks of size 300mm x 150mm x 200mm is cast with the same mix ratio and replacement proportion and tested; the graphical representation of determining compression values was and shown in Figure 9.

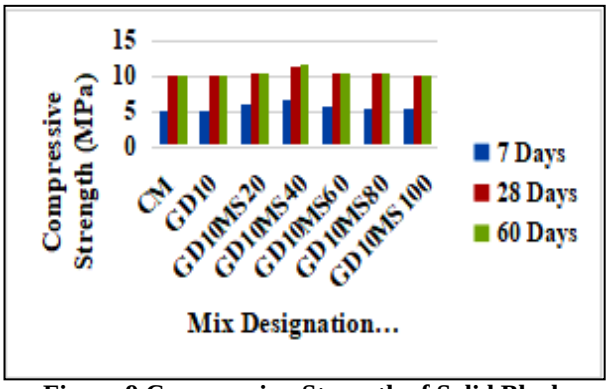

Figure 9.Compression Strength of Solid Block

From the above Fig 9, it can be seen that in the case of the solid block also attained strength is more at 40 % replacement of MS than other percents of replacement of MS.

Similarly, durability tests on the concrete cube were carried out to find its resistance against an aggressive environment. In this paper, to find durability, an acid test (HCL, H_2SO_4) and alkaline test (NaOH) has been done. The % weight (Wt) loss and % strength loss at 60 days of concrete exposure to these chemicals are shown in Figure 10 and Figure 11.

From Figure 10, it is assumed that the percent weight loss is lesser in 40% MS replacement (GD10MS40) than other replacement percents of MS. Similarly, from Figure 11, it can be seen that the strength loss is low in 40% MS replacement when compared to other proportions.

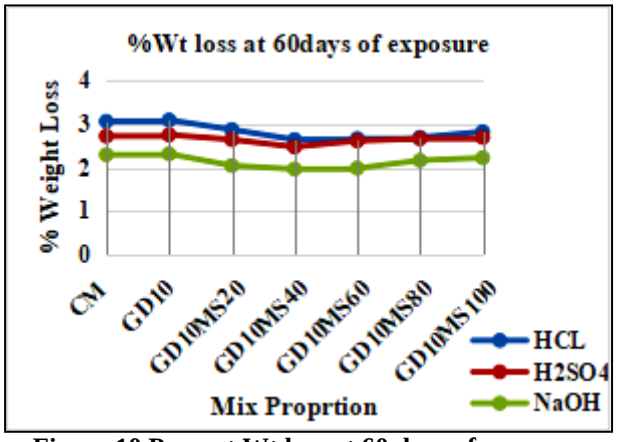

Figure 10.Percent Wt loss at 60 days of exposure

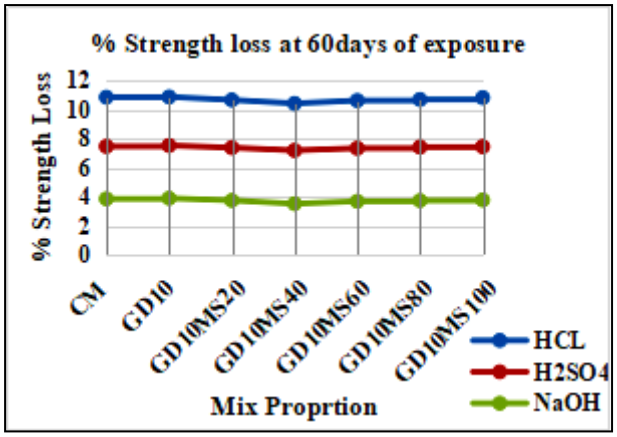

Figure 11. Percent Strength loss at 60 days of exposure

. VIII. CONCLUSION

Compressive strength, Flexural strength, and Splitting tensile strength of conventional concrete cube at 60 days is 17.96 MPa,4.3 MPa, and 3.32 MPa.

1. In the partial replacement of cement by GD in proportion varying from 5%,10%,15%, and 20% by the weight of cement. In this, the 10 % replacement of GD gives favorable strength, and further increasing of GD percent in concrete will increases the silica content but at the same time increases the settling time.

2. Therefore, by keeping that 10 % replacement of GD, to achieve even more strength, the fine aggregate is partially replaced by MS in proportion varying from 20%,40%,60%,80%, and 100% by weight of fine aggregate. In this at 40% replacement of MS gives favorable results and on further increasing of MS percent due to its micro-fine particle, the workability and strength of concrete reduce.

3. Therefore, from the above discussion, the strength is attained more at 10% replacement of cement by GD and 40% replacement of fine aggregate by MS (GD10MS40).

4. The compressive strength, Flexural strength, and Split tensile strength for a concrete cube of proportion GD10MS40 at 60 days is 19.63 MPa, 6.8 MPa, and 3.67 MPa, which is more than the control mix and other proportions; therefore, the structure may attain more strength.

5. From Table 14 to 20, it can be seen that the mix proportion GD10MS40 is more durable than the control mix (CM) and other mix proportions.

6. environmental pollution can also be minimized by using GD, one of the landfill and health problems.

7. River sand depletion will also get reduced using M-sand as a partial replacement of fine aggregate.

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