Effect of Mortar Thickness on Compressive Strength of Solid Block Masonry Prisms Prototyped Using Granite Dust and M-Sand

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Abstract

An experimental study was conducted to study the effect of mortar thickness on the compressive strength characteristics of masonry prisms with solid blocks prototyped with granite dust (GD) and M-sand (MS). The solid blocks are produced by a constant replacement of cement by 10 % of granite dust and in replacement of fine aggregate by MS in proportions of 0%, 20%, 40%, 60%, 80% and 100%. The mortar grade (cement-sand ratio) used in the study is 1:5.Three types of mortar thickness were used in the study i.e., 10mm, 15mm and 20mm.The compressive strength of the masonry prism has been compared with code provisions i.e., IS1905-1987 and ASTM C 1314.It is observed that the thickness of mortar has marked effect on masonry prism. From the results, it is found that masonry prism of mix designation SGD10M40 with 15 mm mortar thickness achieved maximum compressive strength when compared with control mix (CM).

Keywords *- Granite dust (GD), M-sand (MS), Mortar thickness, Masonry prism, Solid block*

I. INTRODUCTION

Masonry is one of the most ancient construction technologies. Admits of many new technologies in the construction industry, masonry construction finds its relevance still now. This is due to their low cost and the local availability of materials required for masonry. Masonry construction is often used in interior and exterior walls in residential and commercial buildings and residential foundations.

The masonry construction has two different materials: the masonry unit and the mortar phase. The most common masonry walls are clay masonry, stone masonry, brick masonry, cavity wall masonry, grouted masonry and block masonry. The solid block is used as a masonry unit in this study. Solid blocks are also called a concrete masonry unit (CMU). A solid block is often referred to as a precast unit. The two masonry units are joined together by the use of mortar phase. The strength of the masonry wall depends on the compressive strength of the masonry unit as well as the bond strength at the solid block-mortar joint.

The Strength of the masonry prism is the basic parameter in the design of masonry structures. The strength is obtained by conducting experiments with masonry prism. The compressive strength of the solid block masonry prism has been studied by several researchers [1-2]. In their study, it is reported that the solid block masonry prisms are said to have high to medium strength. R. G. Drysdale and A.A.Hamid [3] studied the behavior of concrete masonry units under axial compression and found out that 3 layered masonry prism has better strength properties than 2 layered masonry prism. The study on the effect of mortar with different mix ratios on the compressive strength of concrete masonry prisms was done by Haach et al. [4] with high strength solid blocks. Hopeful Syiemiong and Comingstarful Marthong [5] have done an experimental program in the investigation of the effect of mortar grades on low strength concrete block masonry prism.

In this study, solid blocks were used as masonry unit and mortar of mix design 1:5 is used. The masonry prisms were constructed for three different thickness of mortar, to know the effect of mortar thickness in the compressive strength of masonry prism. In solid blocks, the cement was replaced by GD. GD is a by-product of cutting and grinding processes of granite stone. During the industrial process, the granite grains get mixed with water and become like slurry. The water content in slurry is severely reduced due to factors like evaporation and the waste becomes like a dry powder consisting of non-biodegradable GD. Abukersh and Fairfield studied the effect of using granite as a partial cement replacement on the mechanical properties of concrete. Abukersh and Fairfield [6] studied the effect of using GD on the compressive strength and tensile strength of concrete at different ages. The experimental test results showed that the use of GD at 20% to 50% levels significantly reduces the concrete compressive strength and had little negative effects on concrete tensile strength. Abd Elmoaty and Mohamed Abd Elmoaty [7] studied the effect of using GD on compressive strength of concrete bricks. The test results showed that the use of GD had a positive effect and the optimum GD content was 10%.

In this study, RS is replaced by MS as fine aggregate in different proportions as mentioned in Table 2. The properties of RS match with that of MS. MS is a locally available material and also cheap in cost when compared to MS. Many research works have been carried out by replacing the fine aggregates

by MS [8-9]. This study aims at studying the compressive strength behavior of GD based block masonry prisms under compression and also the effect of different mortar thickness on the compressive strength of such masonry prisms.

II. MATERIALS AND MIX PROPORTION

A. Materials

Cement: The cement used is Ordinary Portland Cement of 53 grade of RAMCO brand.

Fine Aggregate: Locally available river sand as passing 4.75mm sieve and retained on 75-micron sand is used. Manufactured sand (4.75mm to 75-micron) is used as partial replacement to natural sand. River sand and manufactured sand are from zone II.

Coarse Aggregate: Locally available coarse aggregate passing 20mm sieve and retained on 12mm sieve is used.

Granite dust: It is obtained from a granite manufacturer in karuppayurani.

B. Mix Proportion

Based on the physical properties of the material the mix proportion for the mortar of mix ratio 1:5 and water-cement (w/c) ratio 0.5 is given in Table 1. The mix proportion for the solid block with w/c ratio 0.5 is given in Table 2.

Table 1 Mix proportion of mortar

Mix	Cement (kg)	Fine Aggregate (kg)
CM	385	2100

Table 2 Mix proportion of solid blocks

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)
SCM	370	-	820	-	1120	185
SGD10	370	37	820	-	1120	185
SGD10MS20	333	37	353	164	1120	185
SGD10MS40	333	37	492	328	1120	185
SGD10MS60	333	37	328	492	1120	185
SGD10MS80	333	37	164	656	1120	185
SGD10MS100	333	37	-	820	1120	185

III. EXPERIMENTAL PROCEDURE

A. Casting of Solid Blocks

The solid blocks for this research were manufactured in Ponmani Bricks, Madurai. The casting of solid blocks includes 3 steps: mixing, molding and curing. The raw materials are measured as per requirement are transferred into the stationary mixer as a dry mix and then required water is added to the mix to blend the mix. After mixing of materials, the wet mix is transferred to the mould machine. The size of the mould used is 300mm x 150mm x 200mm (length x width x height).The mould machine has 10 moulds. The solid blocks were cast for different mix designations. A total of 340 solid blocks were cast. For each mix designation 40 moulds were cast. The mould is filled with the concrete mix and then compacted by the upper mould with vibrations. After compaction, the mould is pushed out from the block as shown in Fig 1. The blocks are kept for wet curing for a period of 2 weeks and then kept to dry for 1 day. The solid block has a weight of 25kg.

Fig. 1 Manufacture of Solid block

B. Compressive strength of Mortar cube

The mortar cube of size 70.6mm x 70.6mm x 70.6 mm is used to determine the compressive strength of mortar. The mix ratio of mortar is 1:5 and mix proportion corresponding to Table 1. The compressive strength of the mortar cube is determined by the use of the Universal Testing Machine (UTM).

C. Construction of Masonry Prism

To accomplish the objective, the masonry prisms were constructed using solid blocks as shown in Fig. 2. The masonry prisms were constructed as per the guidelines of ASTM E 519 [10]. Masonry prisms were also constructed with mortars of different thickness to known the effect of mortar thicknesses on the strength of prism. Mortars of thickness 10mm, 15mm and 20mm are adopted in this study. Four masonry

prisms were constructed for each mortar thickness and each mix proportion. Therefore, a total of 84 masonry prisms were constructed for this study. The dimensions of the constructed masonry prism specimens are tabulated in Table 3. The masonry prisms were capped with gypsum as per provisions in ASTM C 1552 [11] to ensure the uniform transfer of forces by UTM to the contact surface of the prisms.

Table 3 Dimension of masonry prism

Mortar Thickness	Length (mm)	Thickness (mm)	Height (mm)
10 mm	300	150	620
15 mm	300	150	630
20 mm	300	150	640

Fig. 2 Solid Block Masonry prism

D. Compressive Strength of masonry prism

After 24 hours, the masonry prisms were then tested under a 2000 KN capacity UTM. The masonry prisms were tested in UTM by subjecting it to uni-axial compression load. The specimens were loaded beyond maximum load until major cracks had been observed and stopped before the complete collapse of the test specimens. Totally 84 masonry prism specimens corresponding to four specimens each in 21 groups were tested. The tests were conducted as per provisions of ASTM C 1314 and IS: 1905-1987. The Correction Factors (CF) to the compressive strength obtained as per the code provisions are ASTM C 1314 and IS: 1905-1987 shown in Table 4.

Table 4 Correction Factor Values

Height to Thickness ratio	CF as per code provision	
	IS:1905-1987	ASTM C1314
4.1	1.15	1.56
4.2	1.16	1.57
4.3	1.17	1.58

IV. RESULTS AND DISCUSSION

The results of the test conducted on the mortar cube and masonry prism are tabulated in Table 5, Table 6, Table 7 and Table 8. Table 5 gives the compressive strength of mortar cubes for 7 days, 28 days and 90 days. Table 6, Table 7 and Table 8 gives the 7 days and 28 days compressive strength of the masonry prism for different Mix designations for mortar thickness of 10mm, 15mm and 20mm respectively.

Table 5 Compressive strength of cement mortars at different curing ages

Mix designation	CM
7 days (N/mm^2)	8.6
28 days (N/mm^2)	13.5

Table 6 Compressive Strength of Masonry Prism of Mortar thickness 10 mm

Mix	Compressive strength of prisms (Mpa)			
	7 days		28 days	
	Initial Crack	Final Crack	Initial Crack	Final Crack
SCM	5.51	7.24	8.31	10.43
SGD10	5.95	7.46	8.95	10.85
SGD10MS20	6.28	7.82	9.53	11.52
SGD10MS40	6.64	8.46	9.81	12.46
SGD10MS60	6.11	7.72	9.24	11.32
SGD10MS80	5.74	7.54	8.76	10.92
SGD10MS100	5.62	7.29	8.45	10.78

Table 7 Compressive Strength of Masonry Prism of Mortar thickness 15 mm

Mix	Compressive strength of prisms (Mpa)			
	7 days		28 days	
	Initial Crack	Final Crack	Initial Crack	Final Crack
SCM	5.72	7.35	8.42	10.65
SGD10	6.16	7.67	9.06	10.92
SGD10MS20	6.51	8.01	9.64	11.65
SGD10MS40	6.85	8.58	9.92	12.74
SGD10MS60	6.34	7.93	9.36	11.44
SGD10MS80	5.96	7.61	8.84	11.12
SGD10MS100	5.81	7.48	8.57	10.89

From Table 6, The compressive strength of masonry prism of mix SGD10 shows 2.9% and 3.8% increase in compressive strength when compared to the control mix for 7 days and 28 days respectively. This shows GD increases the compressive strength of the masonry prism. This can also be seen in Table 7 and Table 8.

Table 8 Compressive Strength of Masonry Prism of Mortar thickness 20 mm

Mix	Compressive strength of prisms (Mpa)			
	7 days		28 days	
	Initial Crack	Final Crack	Initial Crack	Final Crack
SCM	5.38	7.03	8.25	10.35
SGD10	5.82	7.21	8.56	10.58
SGD10MS20	6.18	7.72	9.25	11.26
SGD10MS40	6.44	8.15	9.48	12.28
SGD10MS60	6.02	7.53	8.92	11.14
SGD10MS80	5.64	7.26	8.54	10.73
SGD10MS100	5.42	7.11	8.35	10.61

In Table 6, the maximum compressive strength is obtained for Mix ID SGD10MS40, it shows 14.4% and 16.3% increase in strength when compared to the control mix for 7 days and 28 days respectively. And at 60% replacement of RS by MS the compressive strength decreases. So 40% replacement of MS is the optimum percentage for replacement of Fine aggregate by MS.

Fig. 3 and Fig. 4 shows us the graph of compressive strength of masonry prism for 10mm, 15mm and 20mm for 7 days and 28 days respectively. In referring to Fig 3 it is found that concrete mix SGD10MS40 of 15mm mortar thickness has the highest compressive strength for 7 days and 28 days masonry prism. The strength masonry prism with 15 mortar thickness is higher than the strength of masonry prism with 20mm mortar thickness. The result shows that the compressive strength of the masonry prisms increases when the height is increased from 620mm to 630mm and decreases when the height is increased from 630mm to 640mm. As the height of prisms increases the compressive strength will decrease. It means that the mortar binding capacity decreases when the thickness increases.

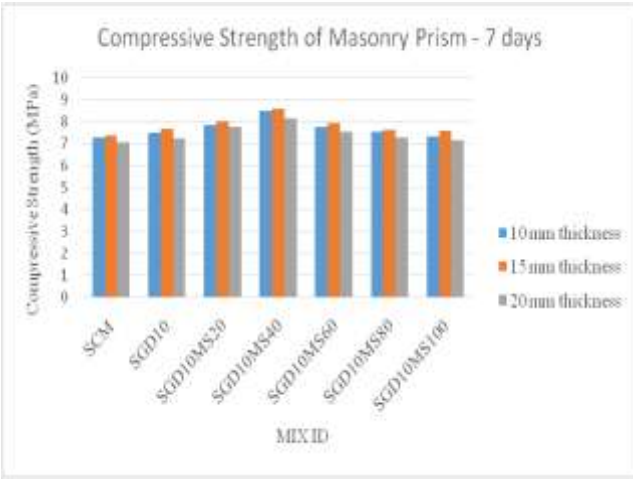

Fig. 3 Graph showing 7 days Compressive Strength of Masonry Prism of different Mortar Thickness

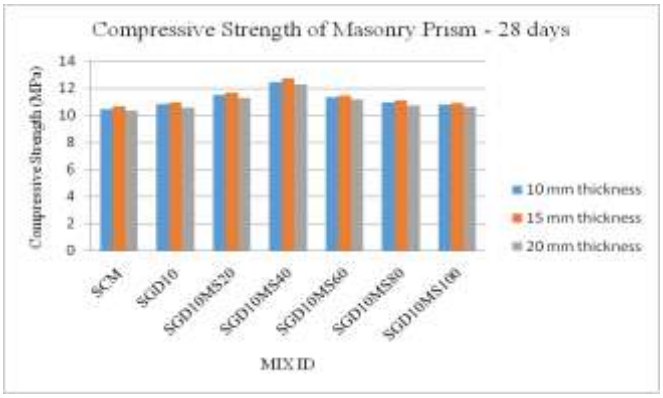

Fig.4 Graph showing 28days Compressive Strength of Masonry Prism of different Mortar Thickness

From Fig 4, the compression strength of SGD10MS40 of 15 mm thickness mortar increases by 21.9% when compared to the masonry prism of the same mix proportion with 10mm thickness. This shows that the mortar thickness influences the compressive strength of masonry prism.

The maximum compressive strength of the masonry prism as calculated as per the code provisions and they are tabulated in Table 9, Table 10 and Table 11 for mortar thickness of 10mm, 15 mm and 20 mm respectively. The maximum compressive strength is calculated to find the actual compressive strength of the masonry prism. The maximum compressive strength is calculated by multiplying the correction factors shown in Table 4 with the compressive strength values in Table 6, Table 7 and Table 8.

Table9 Maximum Compressive Strength of Masonry Prism of Mortar thickness 10 mm

Mix ID	Maximum compressive strength of prisms (Mpa) as per Code Provision	
	IS:1905-1987	ASTM C1314
SCM	12.00	16.28
SGD10	12.48	16.93
SGD10MS20	13.25	17.98
SGD10MS40	14.33	19.44
SGD10MS60	13.02	17.66
SGD10MS80	12.56	17.04
SGD10MS100	12.40	16.820

Table10 Maximum Compressive Strength of Masonry Prism of Mortar thickness 15 mm

Mix ID	Maximum compressive strength of prisms (Mpa) as per Code Provision	
	IS:1905-1987	ASTM C1314
SCM	12.36	16.73
SGD10	12.67	17.15
SGD10MS20	13.52	18.30
SGD10MS40	14.78	20.01
SGD10MS60	13.28	17.97
SGD10MS80	12.90	17.46
SGD10MS100	12.64	17.10

Table11 Maximum Compressive Strength of Masonry Prism of Mortar thickness 20 mm

Mix ID	Maximum compressive strength of prisms (Mpa) as per Code Provision	
	IS:1905-1987	ASTM C1314
SCM	12.11	16.36
SGD10	12.38	16.72
SGD10MS20	13.18	17.8
SGD10MS40	14.37	19.41
SGD10MS60	13.04	17.61
SGD10MS80	12.56	16.96
SGD10MS100	12.42	16.77

The height to thickness ration has an effect on the compressive strength of masonry prism. The results show that the compressive strength of masonry prism increases by 13.1%, 13.8% and 16.4% after applying the CF as per IS:1905-1987 for mortar thickness 10mm, 15mm and 20mm respectively. Similarly, the compressive strength of masonry prism increases by 35.9%, 36.3% and 36.7% after applying the CF as per ASTM C 1314 for mortar thickness 10mm, 15mm and 20mm respectively. The maximum compressive strength of the masonry prism as per code provisions increases as the height to thickness ratio of the masonry prism increases.

V. CONCLUSION

From the above experimental investigation, the following conclusions have been arrived.

1. From the compression test results, it is found that the masonry prism with 10% replacement of cement by GD shows a higher compressive strength than the masonry prism with a reference control mix for both 7 days and 28 days. This shows that the replacement of 10% of cement by GD has a positive effect on the compressive strength of masonry prism.
2. Replacement of 40% RS by MS with 10% of GD as replacement of cement yielded good compressive strength for masonry prism of mix proportion in Table 2 and w/c ratio 0.5 whatever the thickness of mortar is.
3. The compressive strength of masonry prism for the thickness of 15 mm is greater than that of masonry prism of 10 mm and 20 mm thickness for 7 days and 28 days.
4. Analyzing the result it is concluded that the mortar thickness has an effect on the strength of masonry prism.
5. The result shows that as the height of masonry prism increases the compressive strength decreases whatever the mix proportion is.
6. From the experimental analysis, it is concluded that Masonry prism of 15 mm mortar thickness SGD10MS40 mix, which is 10% replacement of Cement by GD and 40% replacement of RS by MS, is found to be the most preferable one when compared with other mixes of masonry prism by analyzing its Compressive strength.
7. The compressive strength of masonry prism depends on the individual compressive strength of solid block and mortar.
8. The mortar thickness also influences the compressive strength of the masonry prism.
9. The compressive strength of the masonry prism also depends on the height of masonry prism because first, the masonry goes through the pure compression and afterward it goes through bending along with compression.
10. The maximum compression strength of the masonry prism as per ASTM C 1314and IS: 1905-1987 depends on the height to thickness ratio of the masonry prism.
11. The maximum compression strength of the masonry prism increases as the height to thickness ratio increases.

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