VOL. 4, NO. 2, APRIL 2009 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

FLEXURAL STRENGTH AND CREEP CHARACTERISTIC OF TILES CONTAINING MARBLE POWDER

R. C. Gupta[1], A. Misra[1] and M. Raisinghani[2]
[1]Department of Structural Engineering, Malaviya National Institute of Technology, Jaipur, India
[2]Vivekananda Institution of Technology, Jaipur, India
E-Mail: m.anurag@mnit.ac.in

ABSTRACT

Marble Powder is a waste product from marble cutting industries. It is produced in huge quantities and is a big environmental and health hazard. Therefore, researchers are focusing on development of technologies for its mass consumption. The present research aims to use marble powder in bulk quantities for manufacture of tiles.

This paper presents results of an investigation on flexural strength and flexural creep characteristics of the flooring tiles containing marble powder. Four different mix proportions (1:5 to 1:8) were chosen for the investigation. The strength testing was carried out as per IS: 1237 and creep specimens were subjected to sustained central line load at 0.75 stress-strength ratio (applied stress: ultimate flexural strength) for a period up to 81 days. The change in deformation was found to become negligible between 45 to 60 days. The results indicated that the tiles satisfying flexural strength requirement as per IS: 1237 can be manufactured having marble powder content up to approximately 87%. These specimens also indicated that the creep deformations are lesser for tiles having greater proportions of marble powder.

Keywords: marble powder, flexural strength, flexural creep, creep deformations.

INTRODUCTION

Marble is one of the stones being most extensively used in construction. The use of marble for construction involves elaborate processing such as cutting, grinding and polishing. These processes produce huge quantity of marble powder slurry. At present, in Rajasthan, these industries produce 5-6 million tones (1) of marble powder slurry per year as waste product. The marble powder slurry is being dumped in open land and there are big heaps and dumps of marble powder lying adjacent to the road at a large number of places. Marble powder slurry has approximately 40% particles below 75 μm diameter of which approximately 30% are having a size less than 25 μm and is a serious environmental pollution hazard(2). After the marble slurry dries, the fine particles of marble powder get entrained in atmosphere due to turbulence from the highway traffic resulting in reduced visibility and creating respiratory problems. In rainy seasons, due to drainage obstruction, the marble slurry makes the road surface slippery, which is dangerous for the traffic. Hence, to minimize the environmental and health problem, there is an urgent need of safe disposal or maximum consumption of marble powder.

There has also been limited research (3), which indicated that it could be utilized for the production of cement. There have been several researches (4,5,6) which indicated successful use of marble powder in production of color washes, tiles, bricks, gypsum based boards, cellular concrete, masonry cement, Portland cement, etc. There has been evidence in the literature (7, 8) that fine / pozzolonic material affect the creep behavior of concrete. The study conducted on mortar specimens also indicates similar behavior (9, 10). Therefore, an investigation was planned to study the effect of marble powder on flexural strength and creep behavior of concrete tiles containing marble powder.

EXPERIMENTAL PROGRAMME

Materials

The properties of concrete are affected by the properties of its constituent materials. The following materials were used in the investigation.
Ordinary Portland cement with trade name 'VIKRAM' 43-Grade has been used in this investigation.
The physical and chemical properties of marble powder samples collected from field (Agarwal Merbles, V. K. I. Area, Jaipur) were evaluated. The results obtained for physical and chemical properties are given in Table-1 variation of properties of marble powder from different sources found by other authors (11) are also shown in Table-1.

Table-1. Physical and chemical properties of marble slurry.

Properties	**Value** (By author)	**Values** (11) (CBRI)
Physical Properties		
Specific gravity	2.67	2.5-2.8
Water content	49.40 %	0.0 – 50.0 %
Liquid limit	18.05 %	12.0 – 21.0 %
Plastic limit	N.P.	Generally N.P.
Shrinkage limit	23.00 %	15.0 – 33.0 %
Particle size (% passing)		
150 μm	80.0 %	-
75 μm	40.0 %	-
25 μm	30.0 %	-

Chemical analysis		
SiO_2	2.76 %	2.0 – 20.0 %
Fe_2O_3	0.40 %	0.3 – 3.5 %
Al_2O_3	0.98 %	0.8 – 6.0 %
CaO	34.90 %	20.0 – 45.0 %
MgO	18.96 %	0.2 – 20.0 %
L.O.I.	41.92 %	15.0 – 45.0 %
Others	0.08 %	-

Mix proportions and specimens

After preparing a number of trial mixes, four mix proportions were selected for flexural strength and creep behavior of tiles. The details of mix are given in Table-2.

Table-2. Mix proportions of control tile specimens.

Sample ID No.	Mix Proportions		Water/ Cement ratio
	Cement	Marble powder	
S1	1.00	5.00	0.710
S2	1.00	6.00	0.710
S3	1.00	7.00	0.733
S4	1.00	8.00	0.833

For flexural strength (7 days and 28 days) and flexural creep testing 72 specimens (18 for each mix) of size 250 mm x 250 mm x 25 mm were prepared. For mixes S3 and S4 the tiles could not be prepared with 0.71 water/cement ratio. Hence water/cement ratio was increased to get the workable mixes. These specimens were prepared by applying a pressure of 6.25 MPa. After the application of required pressure, specimens were taken out from the moulds. The specimens were left for 24 hours in the air and then cured in water for 28 days.

Test procedure

Compact setups were fabricated in the laboratory to perform flexural creep test on tiles as shown in Figure-1. The setup was calibrated using a digital load cell. Before carrying out creep test strength tests, flexural strength was also evaluated as par IS: 1237[12]. After curing the specimens were dried in air for 7 days and the creep test was performed till the change in deflection become negligible [13].

Figure-1. Tile testing apparatus.

The tiles of 250 mm x 250 mm x 25 mm size were tested for flexural creep with two opposite edges simply supported and the other two free. These tiles were made to rest on 12 mm diameter high carbon steel bars placed at 200 mm c/c. These tiles were subjected to a central line load through 12 mm diameter high carbon steel bars parallel to the simply supported edges. The loading arrangement is shown in Figure-1. Prior to applying the loads, the tiles were properly leveled and centered. Plaster of Paris was used for transferring uniform pressure at mid span as well as at supports (Figure-2). The loads were applied gradually and the deflection readings were taken immediately after application of load. Using dial gauges of 0.01 mm accuracy the deflection readings were recorded at an intervals of 24 hours. The development of micro-cracks at the time of application of load and also with time were observed with the help of magnifying mirror and noted carefully. All the tests were performed at room temperature. To account for shrinkage, variation of temperature and humidity, one of the tiles under test was kept free from load and the changes in dial gauge reading were recorded with time. It was found to be negligible and has not been considered.

VOL. 4, NO. 2, APRIL 2009 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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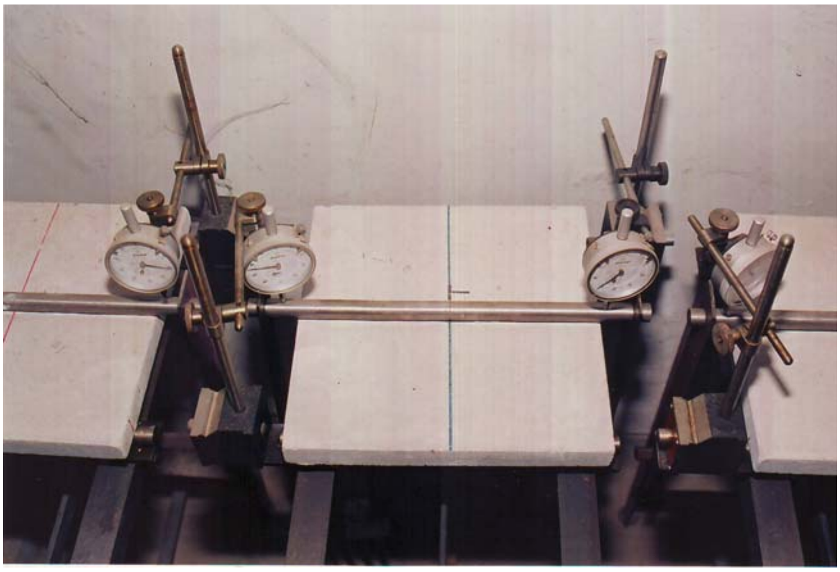

Figure-2. Simply supported tile specimen under centre line load.

RESULTS AND DISCUSSIONS

Flexural strength

The flexural strength of tile specimens after 7 and 28 days for four mixes are given in Figure-3. The results indicate that the flexural strength decreases as the cement content decreases in the mix. The tiles prepared with mix proportions 1:7 (1 cement: 7 marble powder) satisfied the flexural strength criteria for flooring tiles as per IS: 1237. Whereas, the tiles prepared with 1:8 (1cement: 8 marble powder) mix proportion failed to satisfy the above requirement. It suggests that the flooring tiles containing approximately 87% marble powder satisfy the flexural strength criteria.

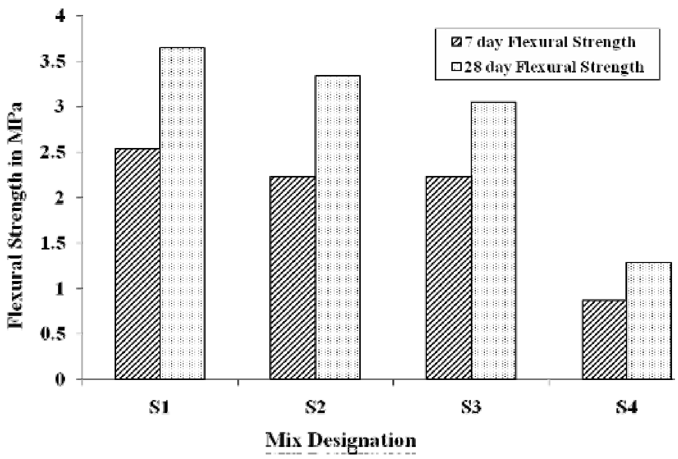

Figure-3. Flexural strength of tile specimens.

Creep test

Based on the flexural strength test, the mixes which satisfied the flexural strength requirement (specimens S1, S2 and S3) were chosen for flexural creep test. The specimens were tested as mentioned in section 2.3. The flexural creep test results of 18 tiles (average of six test results) are summarized in Table-3. The typical flexural creep curves of these three mixes are shown in Figures 4, 5 and 6.

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Table-3. Flexural creep test results for tiles size of tile specimens: 250mm x 250mm distance between roller supports: 200mm.

Speci-men ID No.	**Wet transverse strength** (MPa)	**Stress - Strength** ratio	**Time of loading** (days)	**Instan-taneous deflection** (mm)	**Creep deflection** (mm)	**Total deflection** (mm)	**Instan-taneous recovery** (mm)	**Creep recovery** (mm)	**Residual deforma-ion** (mm)
S1	3.700	0.750	65	0.145	0.080	0.225	0.152	0.018	0.055
S2	3.480	0.750	45	0.155	0.055	0.210	0.142	0.018	0.050
S3	3.050	0.750	81	0.110	0.045	0.155	0.125	0.005	0.025

The results show that for the same stress strength ratio, mixes having greater quantity of marble powder showed lesser instantaneous deflection and creep deflection and showed a lower residual deformation. The creep test results are suggestive of better performance of tiles with higher marble powder content for same stress strength ratio.

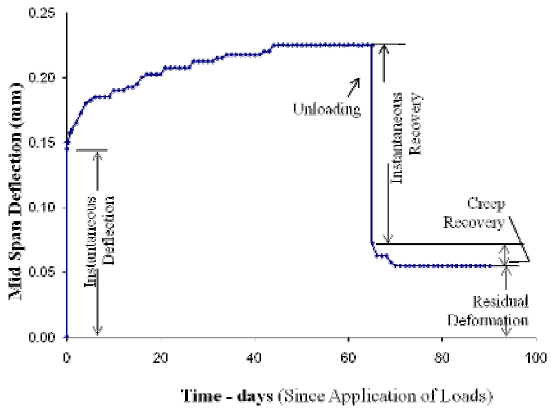

Figure-4. Flexural creep and creep recovery of tile (Mix S1) for stress strength ratio 0.75.

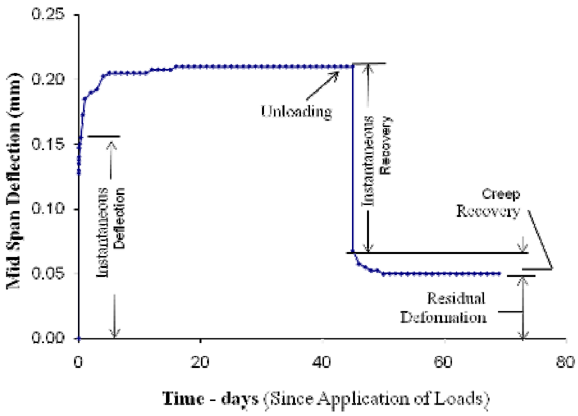

Figure-5. Flexural creep and creep recovery of tile (Mix S2) for stress strength ratio 0.75.

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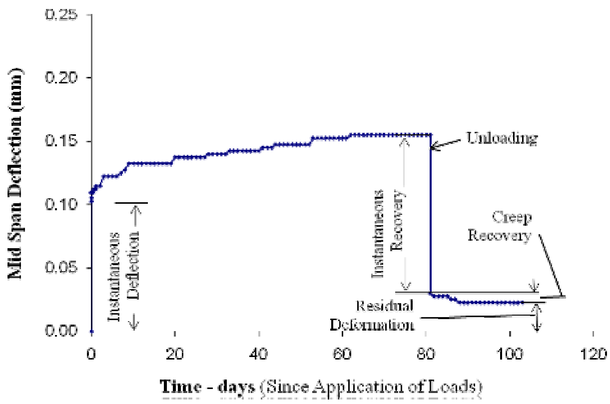

Figure-6. Flexural creep and creep recovery of tile (Mix S3) for stress strength ratio 0.75.

CONCLUSIONS

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

- Tiles having mix proportion of 1:7 (1cement: 7 marble powder) could be prepared to satisfy the flexural strength requirement of flooring tiles;
- The creep specimens attained steady state under flexural creep in 45 to 60 days, for 0.75 stress-strength ratio; and
- The creep deflections were substantially smaller then the instantaneous deflections. However, the magnitude of the instantaneous deflections, creep deflection and residual deformations were very-very small and are suggestive of good performance of tiles under sustained loads.

ACKNOWLEDGEMENTS

The authors acknowledge with thanks the laboratory support extended by M/s Mayur Tiles, Sitapura, Jaipur and Malaviya National Institute of Technology, Jaipur. Financial support for the project, provided by Ministry of Human Resources Development, New Delhi, is great fully acknowledged.

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