# EXPERIMENTAL STUDY OF COMPRESSIVE STRENGTH OF RESIN GROUT WITH MARBLE POWDER

**Noor Ahmed Memon[1], Naseem Usman Keerio[2], Muhammad Aslam Bhutto[3*], Salihuddin Radin Sumadi[4]**

[1]Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science & Technology (QUEST)y, Nawabshah, Pakistan (email: nahmedmemon@gmail.com)

[2]Assistant Professor, Department of Civil Engineering, Quaid-e-Awam University of Engineering, Science & Technology (QUEST)y, Nawabshah, Pakistan (email: engr_nasim@yahoo.com)

[3]School of the Built Environment, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom & Assistant Professor, Department of Civil Engineering, NED University of Engineering & Technology, Karachi, Pakistan (email: mabhuto@hotmail.co.uk)
*corresponding author

[4]Professor, Faculty of Civil Engineering and Director, Construction Technology and Management Centre, University Technology, UTM Skudai, 81310 Johor, Malaysia (salihuddin@utm.my)

**ABSTRACT**
*Grouts are very commonly used in repairing the cracks which are developed in the structural elements. Normally, the grouts are prepared with a combination of the cement as binder and the fine sand as filler. This paper presents the results of an experimental investigation carried out to investigate the effectiveness of using the marble powder as filler over the compressive strength of the cement and polymer grouts. The marble powder is a waste product which can easily be obtained during the cutting process of the marble pieces. In addition, the sand and a mixture of the sand and marble powder have also been used as fillers for comparison of the results. Three proportions of the marble powder in terms of binder to filler ratios of 1:1, 1:1.5, and 1:2 by weight have been used. The test results have revealed that the resin grouts exhibit manifold compressive strength when compared to that of the cement grouts. The increases in the compressive strength of the resin grouts were remarkable when the marble powder only was used as filler and were the highest when the marble powder was used with an equal proportion of the sand.*

**Keywords** *Resin grout, marble powder, sand, filler, compressive strength*

## 1. INTRODUCTION

The search of the advanced materials and the new techniques is one of the active areas of research in all the disciplines of engineering and science. Similarly, extensive efforts have been made in the construction industry to produce high performance materials such as grouts [1-7]. Since the last several decades, cement grout has been considered as an efficient and cheap compound due to its easy application and manufacture from the readily available constituents i.e. cement, fine sand and water [8]. In the manufacture of grout, a large quantity of water is added in order to produce the proper fluidity to be injected in the cracks. This affects the performance of the grout that initially results in the delayed setting time, high rate of shrinkage and porous structure and subsequently results in an inferior durability, sedimentation of sand particles, risk of bleeding, less coherent/adhesive to the old concrete surfaces, etc. [9].

The problems associated with the cement grouts have led to the technique of adding various cementitious materials in single or blended/ multi blended with cement to improve the various properties and performance of concrete, mortar and grout [10-16]. Recently, a substantial application of various types of polymers as a binder has been made in the production of concrete and mortar which is also gaining acceptance in the production of gouts. These polymers may be water based or synthetic/ emulsion type. The polymer grout is a composite in which cement is replaced by the various types of polymers mixed with very fine sand as filler. Since, the specific gravity of sand is high causing its sedimentation which affects the uniformity of the grout produced there by resulting in improper performance. In order to overcome this issue, different materials such as GGBFS, silica fume, fly ash have been tried as filler in the polymer mortars and grouts and it is reported that these materials have shown improved performance of grouts [17-21].

## 2. PRESENT STUDY

The present study comprises an experimental investigation and is aimed at to investigate the effect of using marble powder as the filler on the compressive strength of the cement and polymer (polyester resin) grouts.

### 2.1.Tests

The experiments were carried out in the following three series of tests.

1. In the series I tests, the marble powder and sand were used as fillers in the cement and resin grouts using a binder to filler ratio of a 1:1 by weight and the results are compared to each other.
2. In the series II tests, a combination of equal quantities, i.e. 50-50%, of the marble powder and sand was used as the filler in the cement and resin grouts using a binder to filler ratio of 1:1 by weight. The results are compared to those of the series I tests.
3. In the series III tests, the marble powder, sand and a marble-sand combination were used as fillers in the resin grouts only using the binder to filler ratios of a 1:1.5 and 1:2 and the results are compared to those using the ratio of 1:1.

### 2.2. Materials used

The following materials have been used in the preparation of the grouts.

1. Hill sand dried in air in accordance with the ASTM C778 specifications [22] and marble powder passing from #100 sieve were used as fillers. Marble powder is basically a waste product and is obtained during the cutting process of the marble pieces. It is easily available from the marble cutting shops in the local market.

2. Iso-phthalic unsaturated polyester (IUP) resin commonly known as polyester resin has been used as the binder in the resin grout (RG) during the present study. **Figure 1** shows the polymer chain or chemical composition of the IUP resin. A chemical compound called methyl ethyl ketone per oxide (MEKP) has been used as hardener. A hardener is a curing agent added to the resins for their hardening/ solidification [23]. The quantity of hardener to be used with the resin was adjusted in order to achieve the standard gel time (working time period) of 30±5 minutes in accordance with the ASTM D2471 [24]. MEKP is a mixture of various isomers and contains the bivalent O–O linkage. Its reaction with the resins results in the solidification of resins even at normal room temperature. The chemical composition of the hardener (MEKP) is depicted in **Figure 2**.

3. In the cement grout, ordinary Portland (OPC) Type-I with a water-cement ratio of 0.6 has been used.

### 2.3.Test specimens and preparation

A total of thirty-six specimens, three of each case, were tested. The test specimens were standard square cubes of 50x50x50 mm. Two types of grouts, namely cement (CG) and resin grouts (RG), were used. In the resign grouts, the polyester resin was used. The resin and filler were mixed thoroughly in a neat, clean and dry container for 5 to 7 minutes. The cube specimens were cast by pouring the prepared grout in the cube moulds. An apparent solidification of the resin grouts was witnessed within four hours of their molding. However, the specimens were demoulded after 24 hours after casting. The specimens were kept under room temperature of about $30\pm5^{0}$ C. Figure 3 shows a few specimens exposed in to room temperature after casting. The cement grout specimens were cured in water. All specimens were tested after a curing of 28 days.

### 2.4. Testing procedure

All the specimens were tested in a universal testing machine (UTM) as shown in Figure 4. A constant rate of loading at 1 kN/sec was maintained. The tests were performed in compliance of the specifications of ASTM C 942 [25] and ASTM C109/C [26].

## 3. TEST RESULTS

Table **1** to
Table **3** give comparison of the compressive strengths of the cement and resin grouts obtained from the series I, II and III tests respectively. Figure 5 shows the compressive strengths of CG and RG grouts versus the proportion of the marble powder.

## 4. DISCUSSION OF TEST RESULTS

The results of the series I, II and III tests show that:

### 4.1. Results of series I tests

- The compressive strength of the cement grout (CG) specimens using sand or marble powder as the filler was approximately the same.
- The compressive strength of the resin grout (RG) specimens using the marble filler was increased by 1.81 times compared to those using the sand filler.
- The compressive strengths of the RG specimens using either the sand or marble filler were greater than those of the CG specimens. The increase in the strength was 1.94 times in case of the sand filler, while that in case of the marble filler was 3.70 times.

### 4.2. Results of series II tests

- The CG specimens using sand, marble powder or a mixture of the equal quantities of the sand and marble as the filler have the identical compressive strengths.
- For the RG specimens using a mixture of the sand and marble filler, the compressive strengths of the specimens were increased by 2.41 and 1.33 times, respectively, compared to those using the sand and marble fillers.
- For the specimens having a mixture of the sand and marble filler, the compressive strengths of specimens using the resin grout was approximately 4.42 times greater than those using the cement grouts.

### 4.3. Results of series III tests

- The compressive strength of RG specimens using the sand and marble filler was reduced to approximately 20% and 50%, respectively, by doubling the quantity of the filler, i.e. from 1:1 to 1:2 ratio.
- The compressive strength of RG specimens using the sand-marble filler was reduced to approximately 9% and 20% by increasing the quantity of the filler by 1.5 and 2.0 times respectively.
- In case of the RG specimens having binder to filler ratios of 1:1, 1:1.5 and 1:2, the increase in the compressive strengths of specimens using the sand-marble filler was approximately the same, i.e. 2.40 times, compared to those using the sand filler respectively.
- Among all the tested specimens, the highest increase in the compressive strength of specimen was obtained when the polyester resin was used as the binder and a mixture of the sand and marble powder as the filler.

## 5. CONCLUSIONS

An experimental study has been carried out to investigate the effectiveness of using the marble powder as filler upon the compressive strength of the cement and polymer (polyester resin) grouts. The tests of square cube specimens were carried out to determine the compressive strength. The sand, marble powder and a mixture of equal quantities of the sand and marble powder (50% each) were used as fillers, while the polyester resin and cement were used as binders. Three different binder to filler ratios of 1:1, 1:1.5 and 1:2 were used in the grout specimens. The test results of specimens have shown that:

1. The compressive strengths of the resin grout (RG) specimens using the sand, marble powder or a mixture of the sand and marble powder (50% each) as fillers were increased significantly compared to those of the cement grout (CG) specimens using the same fillers. The increase in the strength was the highest, 4.42 times, in case of the sand-marble filler, while the increases were 1.94 and 3.70 for the sand and marble fillers respectively. This shows that the polyester resin is more effective and efficient binding material to be used in the grout in place of the cement.

2. Among the three fillers, the mixture of the sand and marble (50% each) was found to be the most effective filler. The compressive strengths of RG specimens using the sand-marble filler were increased by 2.41 and 1.33 times, respectively, compared to those using the sand and marble fillers.

3. The use of sand, marble or sand-marble filler has, however, an insignificant effect, up to 10%, upon the compressive strength of the CG specimens.

4. As expected, the binder to filler ratio has significant effect upon the compressive strength of grout specimens. The compressive strength of specimens was decreased with the increase in the proportion of the filler. However, the increase in the compressive strengths of the RG specimens having binder to filler ratios of 1:1, 1:1.5 and 1:2 and using the sand-marble filler was approximately the same, i.e. 2.40 times, when compared to those of the respective specimens using the sand filler.

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## LIST OF TABLES



## LIST OF FIGURES

Figure 3 Test specimens after casting being cured at room temperature
Figure 4 Testing of specimens in universal testing machine (UTM)
Figure 5 Compressive strength of CG and RG versus proportion of marble powder

**Table 1 Average compressive strengths of CG and RG specimens (series I tests)**

| **Binding material/ binder** | **Filler** | **Average Compressive strength (MPa)** | **Ratio of compressive strengths** | |
|---|---|---|---|---|
| | | | **Marble/ sand** | **Resin/ cement** |
| Cement | Sand | 25.4 | --- | --- |
| Cement | Marble | 24.1 | 0.95 | --- |
| Resin | Sand | 49.2 | --- | 1.94 |
| Resin | Marble | 89.1 | 1.81 | 3.70 |

**Table 2 Average compressive strengths of CG and RG specimens (series II tests)**

| **Binding material/ binder** | **Average Compressive strength (MPa) Filler** | | | **Ratio of compressive strengths** | | |
|---|---|---|---|---|---|---|
| | **Sand** | **Marble** | **SM -Sand (50%) Marble (50%)** | **SM/ sand** | **SM/ marble** | **SM- Resin /cement** |
| Cement | 25.4 | 24.1 | 26.8 | 1.06 | 1.11 | --- |
| Resin | 49.2 | 89.1 | 118.7 | 2.41 | 1.33 | 4.42 |

**Table 3 Average compressive strengths of RG specimens (series III tests)**

| **Resin grout (Binder: filler)** | **Average Compressive strength (MPa) Filler** | | | **Ratio of compressive strengths** | | | |
|---|---|---|---|---|---|---|---|
| | **Sand** | **Marble** | **SM -Sand (50%) Marble (50%)** | **Marble /sand** | **SM/ sand** | **SM/ marble** | **SM/ SM(1:1)** |
| 1:1 | 49.2 | 89.1 | 118.7 | 1.81 | 2.41 | 1.33 | --- |
| 1:1.5 | 45.5 | 59.0 | 109.2 | 1.30 | 2.40 | 1.85 | 0.92 |
| 1:2 | 40.4 | 47.4 | 98.2 | 1.17 | 2.43 | 2.07 | 0.83 |

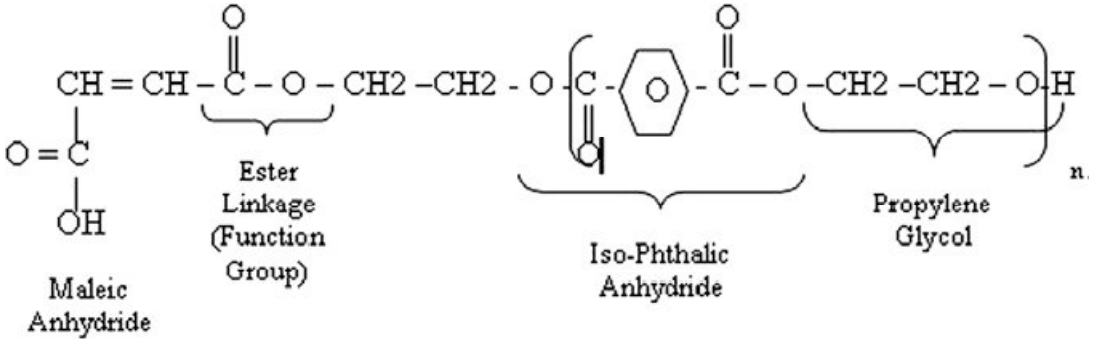


Figure 1 Chemical composition of iso-phthalic unsaturated polyester (IUP) resin [17]

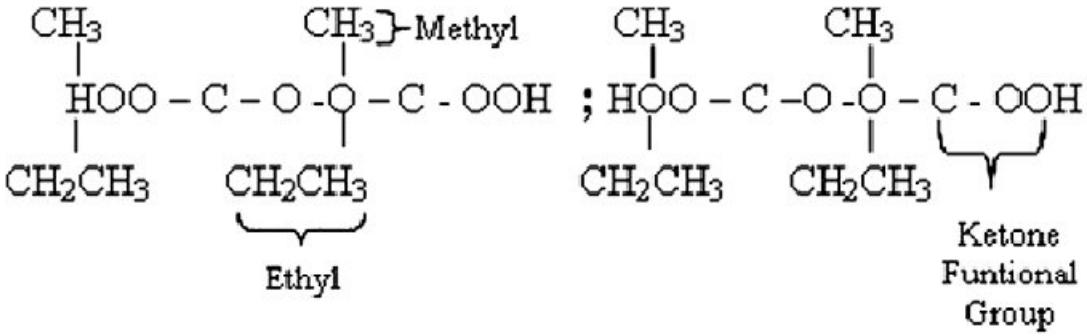


Figure 2 Chemical composition of methyl ethyl ketone per oxide (MEKP) hardener [17]

Figure 3 Test specimens after casting being cured at room temperature

Figure 4 Testing of specimens in universal testing machine (UTM)

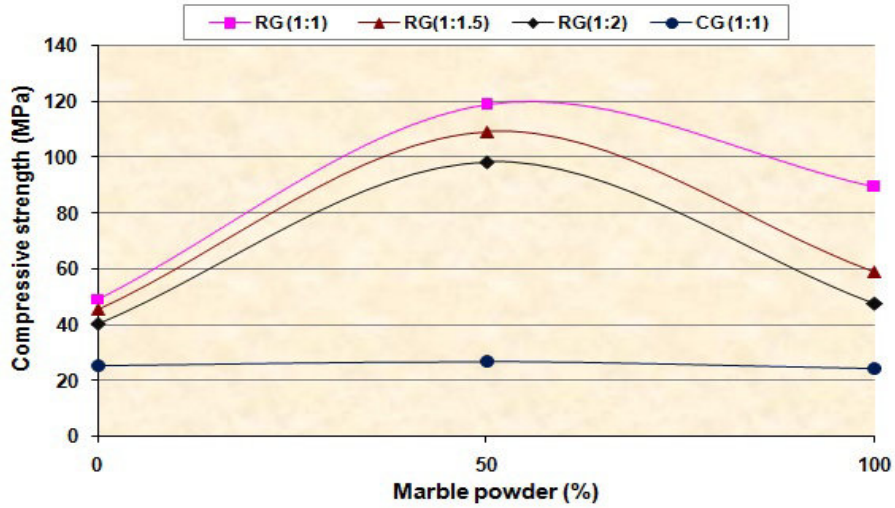


Figure 5 Compressive strength of CG and RG versus proportion of marble powder