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Performance evaluation of cement mortars containing marble dust and glass fiber exposed to high temperature by using Taguchi method

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HIGHLIGHTS

- We investigated the performance of the mortar with marble dust and glass fiber exposed to high temperature.
- This article applied the Taguchi method and ANOVA analysis.
- The compressive strength increased with increase of marble dust percentage.
- The most important parameter on the responses was found as temperature degree.

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ABSTRACT

This paper investigated the effects of marble dust and glass fiber on mechanical and physical properties of cement mortars exposed to high temperature as experimentally and statistically. For this purpose, the mixes containing marble dust (0%, 20%, 40% and 50% by volume) and glass fiber (0 kg/m^3, 0.25 kg/m^3, 0.50 kg/m^3, 0.75 kg/m^3) were prepared. The compressive strength and porosity value of the cement mortars were determined after being exposed to high temperatures (400, 600 and 800 °C). In order to reduce the numbers of experiments, an L_{16} (4^3) Taguchi orthogonal array was adopted to the study. Percentage of marble dust, amount of glass fiber and degree of temperature were changed to explore their effects on the compressive strength and porosity values of specimens. Statistically effects of the factors were also determined by using analysis of variance (ANOVA) method. Finally, experimental findings were compared with statistical results and a good agreement between them was achieved.

1. Introduction

Marble has been commonly used as a building material since ancient times. The industry's disposal of the marble powder material, consisting of very fine powders, is one of the environmental problems worldwide today [1]. Marble blocks are cut into smaller blocks in order to give the desired smooth shape. During the cutting process about 25% marble mass is lost in the form of dust. In Turkey marble dust is settled by sedimentation and then dumped away which results in environmental pollution and also causes forming dust in the summer and threatening both agriculture and public health. Therefore, utilization of the marble dust in various sectors that especially the construction, agriculture, glass and paper industries will help to protect the environment [2].

Many researchers recently were interested in studying the possibility of re-use of waste marble dust in useful industries especially with regard to the building and construction materials such as cement, concrete and brick blocks [3].

The technical importance of using waste marble dust in concrete production is expressed by performance improvement of concrete. The economic benefit generally attributes to the reduction of the amount of expensive and or scarce ingredients with cheap materials. Environmentally, when waste marble dusts are recycled, less material is dumped as landfill and more natural resources are saved [4].

The effect of marble dust as sand replacement and cement placement was investigated; many researches indicated positive results and benefits. Waste marble dust can be used as an additive material in production of cement and cost of cement production can be reduced by this way [5]. Corinaldesi et al. [6] investigated mechanical performance of marble dust modified mortar. They showed that 10% substitution of sand by waste marble dust, in the presence of superplasticizing admixtures provided maximum

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compressive strength according to that of the reference mixture after 28 days of curing. Binici et al. [7] showed that the compressive strength of concrete increased with increasing the percentage of marble dust addition. Additionally, they reported that use of marble dust as 15% sand replacement by weight provided the maximum compressive strength up to 360 days of curing. Furthermore, they demonstrated that concrete specimens produced with replacement level of 15% marble dust instead of sand were considerably more resistant to water ingress than those of other concrete specimens and these specimens had the highest sulfate resistance and less reduction in compressive strength after 12 months of exposure. Ergün [8] showed that 5.0% and 7.5% replacement of waste marble dust with cement leads to an increase in the compressive strength of concrete. Demirel [9] showed that the porosity value of concrete decreased and the ultrasonic pulse velocity values increased with the increasing the percentage of marble dust up to 100% as sand replacement. Additionally, Demirel indicated that the filler effect of the marble dust leads to reduction of porosity of concrete.

Generally, in literature waste marble dust has been replaced with either fine aggregate (0–4 mm) or passing 1 mm sieve. But, not a single experimental study on the performance of the cement mortar prepared by replacing very fine sand (passing through 0.25 mm sieve) with waste marble dust. Studies concerning the utilization of marble dust in cement mortar are necessary to fully evaluate the potential using of this waste material.

The main concern with high strength concrete is the increasing brittleness with the increasing strength. To overcome this problem, fiber reinforcement should be used for improving ductility of high strength concrete [10–12]. Short fibers have been known and used for centuries in reinforced brittle materials as cement or masonry bricks. Currently, there are numerous fiber types available for commercial use, the basic types being glass, steel, synthetic materials (polypropylene, carbon, nylon, etc.) and some natural fibers [13].

The main purpose of this study is to investigate the effect of marble dust and glass fiber on the compressive strength and porosity value of the cement mortars exposed to high temperature. The effect of experimental parameters on compressive strength and porosity value was evaluated statistically and the level of significance of the parameters affecting compressive strength and porosity value of the cement mortars was determined by using analysis of variance (ANOVA) method.

2. Experimental study

2.1. Materials

Commercial grade ASTM Type I Portland cement, which is produced in Turkey as CEM I Portland cement, was used in the preparation of all cement mortar specimens used in this study.

The marble sludge consisting of Elazig Cherry and Hazar Beige marble dusts was obtained in wet form as an industrial by-product directly from the deposits of marble factories, which forms during the sawing, shaping and polishing processes of the marbles in the Elazig province of Turkey. The marble sludge was dried before the preparation of the cement mortar specimens. The dried material was passed through 0.25 mm sieve and finally the marble dust was obtained to be used in the cement mortar specimens as very fine sand. The chemical properties of the marble dusts and cement used in the experiments are given in Table 1.

High quality river sand was used as aggregate which is widely employed in cement mortars. Maximum grain size of aggregate was 4 mm. The density of the river sand was 2690 kg/m^3. Various proportions (0%, 20%, 40% and 50% by volume) of the fine sand (passing through 0.25 mm sieve) were replaced with waste marble dust. The grain size distributions of very fine sand and waste marble dust are shown in Fig. 1.

The glass fibers were circular straight fibers obtained from Camelsan. The properties of the glass fiber used in this study are given in Table 2.

In the study, modified polycarboxilate based superplasticizer, obtained from SIKA, was used as 1% of cement weight. Regular tap water was used as the mixing water during the preparation of the cement mortar specimens.

2.2. Casting and testing

Sixteen different cement mortar mixes were prepared to be used in the tests for the purpose of evaluating the compressive strength and porosity value of the specimens containing various amounts of glass fiber and marble dust. The mixture designs of the all cement mortar groups are presented in Table 3. A superplasticizer (SP) was used to improve the workability of the mixes.

Mixtures prepared according to Table 3 were cast into steel cube molds ($50 \times 50 \times 50$ mm) to determine the effect of different temperature degrees on compressive strength and porosity value of the mortar specimens. After casting, these specimens were kept in the molds for 24 h at a room temperature of 20 ± 2 °C. After demolding, these specimens were cured in lime saturated water for 28 days.

The specimens were dried in an oven at about 50 °C until a constant mass was achieved at the end of the 28 days. Then, five specimens for each temperature were heated to 400, 600 and 800 °C using a Protherm HLF 150 electrical furnace. The heating rate was set at 2.5 °C/min based on experience from previous researches [14–17]. The mortar specimens were held at these temperatures for one hour to achieve a thermal steady state. Subsequently, the specimens were cooled down inside the furnace and then tests were conducted one day later to determine the compressive strength and porosity values.

The microscopic analyses of the specimens were performed at the Electron Microscopy Laboratory of Firat University using a Jeol JSM7001F scanning electron microscope.

2.3. Design of experiments

Taguchi's method of experimental design provides a simple, efficient, and systematic approach for the optimization of experimental designs for performance quality and cost [18]. To evaluate the each independent factor or their interaction effects on the process characteristics, Taguchi uses standard orthogonal arrays. A loss function is then defined to calculate the deviations between the experimental value and the desired value. This loss function is further transferred into a signal-to-noise (S/N) ratio, η [19]. Usually, there are three S/N ratios available, depending on the type of characteristic; the lower-the better (LB), the higher-the better (HB), and the nominal-the better (NB). The S/N ratios for each type of characteristic can be calculated as follows:

1. Lower is better, choose when goal is to minimize the response. The S/N can be calculated as given in Eq. (1) for smaller the better

$$S/N = -10 * \log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} Y_i^2\right) \quad (1)$$

2. Higher is better: choose when goal is to maximize the response. The S/N is calculated as given in Eq. (2) for larger the better

$$S/N = -10 * \log_{10}\left(\frac{1}{n}\sum_{i=1}^{n} \frac{1}{Y_i^2}\right) \quad (2)$$

Table 1
Chemical property of the cement and marble dusts.

Oxide compounds (mass%)	CEM I 42.5 N	Marble dust (Elazig Cherry)	Marble dust (Hazar Beige)
SiO_2	21.12	28.35	0.18
Al_2O_3	5.62	0.42	0.03
Fe_2O_3	3.24	9.70	0.12
CaO	62.94	40.45	53.24
MgO	2.73	16.25	0.10
Density (g/cm^3)	3.10	2.80	2.72

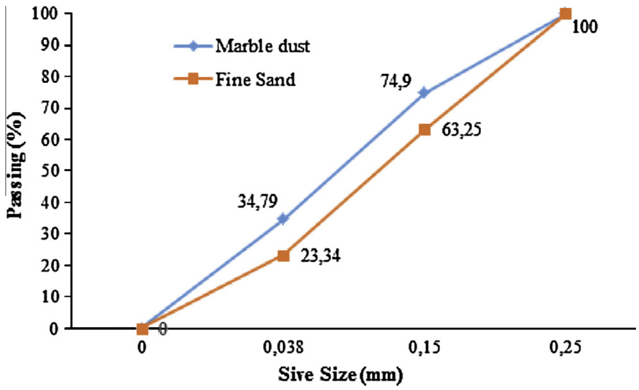

Fig. 1. Grain size distribution of the very fine sand and marble dust.

3. Nominal is better: choose when goal is to target the response and it is required to base the S/N on standard deviations only. The S/N is calculated as given in Eq. (3) for smaller the better.

$$S/N = -10 * \log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}(Y_i - Y_0)^2\right) \quad (3)$$

In quality characteristic determination; HB and LB were chosen for compressive strength and the porosity values of the cement mortar specimens, respectively.

In this study, three control factors, i.e., (1) percentage of marble dust used in the cement mortar mix as very fine sand, (2) degree of temperature, (3) amount of glass fiber, which were labeled by A, B and C, respectively, and four control levels for each control factor were considered as shown in Table 4.

When the design type is full factorial, it is necessary to conduct 64 ($4 \times 4 \times 4$) experiments because all the possible combinations should be introduced in the design. To reduce the number of tests, an L_{16} (4^3) orthogonal array that only needs 16 experimental runs was adopted. The orthogonal array and experimental results are given in Table 5.

3. Experimental findings, data analysis and discussion

3.1. Experimental findings

The effects of control factors on responses are plotted in Figs. 2 and 3, respectively. As seen from the figures, the compressive strengths of the cement mortar specimens increased and their porosity values decreased with increasing the percentage of marble dust. On the other hand, contrary of the marble dust effect, the use of glass fiber in cement mortar decrease the compressive strength and increase the porosity values of the specimens.

The reduction in compressive strength of the cement mortars used in the study can be attributed to the poor adhesion between the glass fiber and mortar. The poor adhesion causes voids occurrence in the mortar as can be seen in Fig. 4, therefore compressive strength of the cement mortars containing glass fiber decrease. Due to poor adhesion between the glass fibers and mortar, smooth and clean surfaces without continuous mortar particles are observed.

As can be clearly concluded from Fig. 3, porosity value of the mortar specimens increases with the increasing of glass fiber content. The increase in porosity values suggests that the voids of mortar increases in accordance with the amount of glass fiber. Therefore, this result is consistent with the data obtained through compressive strengths of the cement mortar specimens.

The addition of marble dust as very fine sand into cement mortar containing glass fiber resulted an increase in the compressive strength and a decrease in the porosity value. This result may have one underlying reason; the reason is that the marble dust has a much smaller grain size compared to very fine sand, enabling it to fill in the voids. The fineness of an admixture is highly critical

Table 2
Properties of the glass fiber.

Color	Fiber length (mm)	Fiber diameter (μm)	Density (g/cm^3)	Young's modulus (MPa)	Tensile strength (MPa)
White	6	13	2.68	72000	1700

Table 3
Detail of cement mortar mixes (kg/m^3).

Exp. No	Designation of mixture	Fiber glass	Marble dust	Aggregate (0–0.25)	Aggregate (0.25–4)	Water	Cement	SP
1	FG0-MD0	–	–	407	1253.8	221.4	450	4.45
2	FG0-MD20	–	77.25	325.4	1253.8	221.4	450	4.45
3	FG0-MD40	–	154.5	243.6	1253.8	222.8	450	4.45
4	FG0-MD50	–	193.12	203.6	1253.8	222.8	450	4.45
5	FG0.25-MD0	0.25	–	407	1253.8	221.4	450	4.45
6	FG0.25-MD20	0.25	77.25	325.4	1253.8	221.4	450	4.45
7	FG0.25-MD40	0.25	154.5	243.6	1253.8	222.8	450	4.45
8	FG0.25-MD50	0.25	193.12	203.6	1253.8	222.8	450	4.45
9	FG0.50-MD0	0.50	–	407	1253.8	221.4	450	4.45
10	FG0.50-MD20	0.50	77.25	325.4	1253.8	221.4	450	4.45
11	FG0.50-MD40	0.50	154.5	243.6	1253.8	222.8	450	4.45
12	FG0.50-MD50	0.50	193.12	203.6	1253.8	222.8	450	4.45
13	FG0.75-MD0	0.75	–	407	1253.8	221.4	450	4.45
14	FG0.75-MD20	0.75	77.25	325.4	1253.8	221.4	450	4.45
15	FG0.75-MD40	0.75	154.5	243.6	1253.8	222.8	450	4.45
16	FG0.75-MD50	0.75	193.12	203.6	1253.8	222.8	450	4.45

Table 4
Control factors and their levels.

Designation	Control factor	Level 1	Level 2	Level 3	Level 4
A	Percentage of marble dust (%)	0	20	40	50
B	High temperature degree (°C)	20	400	600	800
C	Amount of glass fiber (kg/m^3)	0	0.25	0.50	0.75

Table 5
L_{16} orthogonal array and experimental results.

No	A	B	C	Experimental results	
	Marble dust (%)	Temperature (°C)	Fiber glass (kg/m^3)	Compressive strength (MPa)	Porosity (%)
1	1	1	1	84.7	17.1
2	1	2	2	65.27	17.8
3	1	3	3	46.71	25.13
4	1	4	4	18.06	28.08
5	2	1	2	85.41	17.17
6	2	2	1	69.38	17.48
7	2	3	4	44.87	24.71
8	2	4	3	23.33	26.89
9	3	1	3	88.18	17.23
10	3	2	4	66.1	17.78
11	3	3	1	55.18	21.69
12	3	4	2	28.11	26.44
13	4	1	4	88.65	17.24
14	4	2	3	70.45	17.58
15	4	3	2	56.81	22.77
16	4	4	1	32.92	25.35

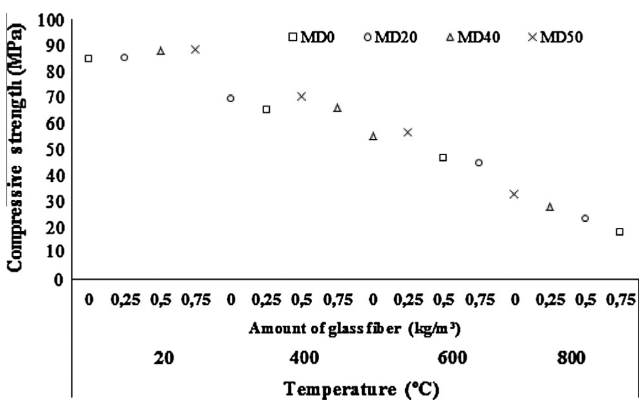

Fig. 2. Change in compressive strength values of the specimens exposed to high temperature.

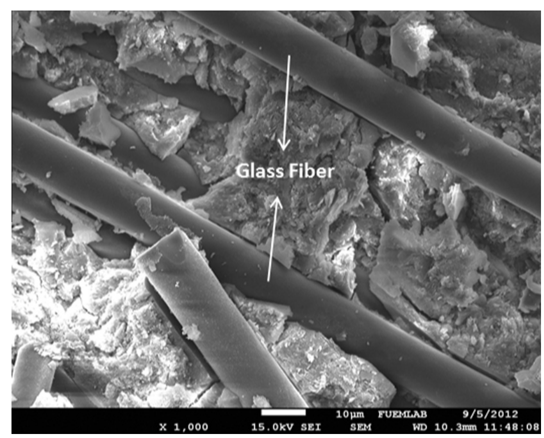

Fig. 4. SEM Image of the glass fiber reinforced cement mortar.

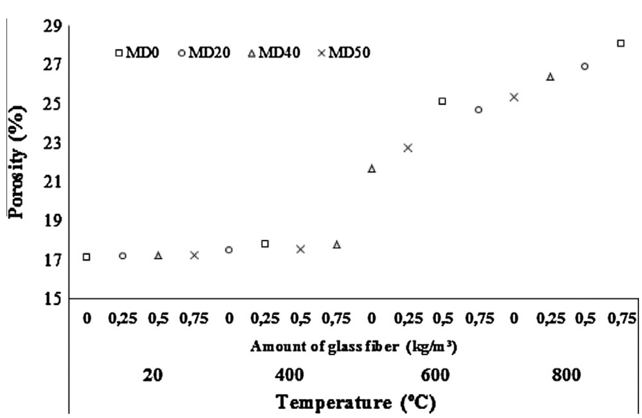

Fig. 3. Change in porosity values of the specimens exposed to high temperature.

for the modification of aggregate/cement paste interface zone, which is the weakest link of a concrete's structure [20].

It can be seen clearly from Fig. 1 that average particle size of the fine sand is very large compared to marble dust, thus its filler effect may not be sufficient as marble dust. It can be concluded that compressive strength of the mortars without marble dust relatively low, because filler effect of fine sand is not as good as those of marble dust. The marble dust particles, however, may act as ideal micro-filler in the interfaces between aggregate and cement paste or pores in the bulk paste. Therefore, a high level of compressive strength is achieved in mortars containing both marble dust and glass fiber compared to that of the only glass fiber reinforced mortars. Moreover, the addition of marble dust into the mortars with glass fiber has led to a decrease in porosity values. These observations are in good agreement with earlier findings [9,21,22].

When exposed to high temperature, the chemical composition and physical structure of the concrete change considerably. Dehydration, including the release of chemically bound water from calcium silicate hydrate, becomes significant above 110 °C. The dehydration of the matrix and the thermal expansion of the aggregate give rise to internal stresses, and beginning at 300 °C, micro-cracks begin to pierce through the material [14,23]. $Ca(OH)_2$, one of the most important compounds in cement paste, dissociates at around 530 °C, resulting in the shrinkage of concrete [14,24,25].

As seen from Fig. 2, the compressive strength decreased slightly up to heating at 600 °C and then sharp reduction occurred beyond that point due to the loss of crystal water, leading to the reduction of the $Ca(OH)_2$ content and changing the morphology and formation of micro-cracks. Fig. 5 shows SEM micrographs illustrating the microstructure characteristics of control mortar specimens at 20, 400, 600 and 800 °C, respectively.

It can be seen from Fig. 5 that the micro-cracks in microstructure of the mortar specimens started to appear at around 400 °C and continued to grow until final rise in temperature at 800 °C. The reduction in compressive strength of mortar specimens may be due to the formation of micro-cracks that lead to weakening interfacial transition zone and bonding between the aggregate

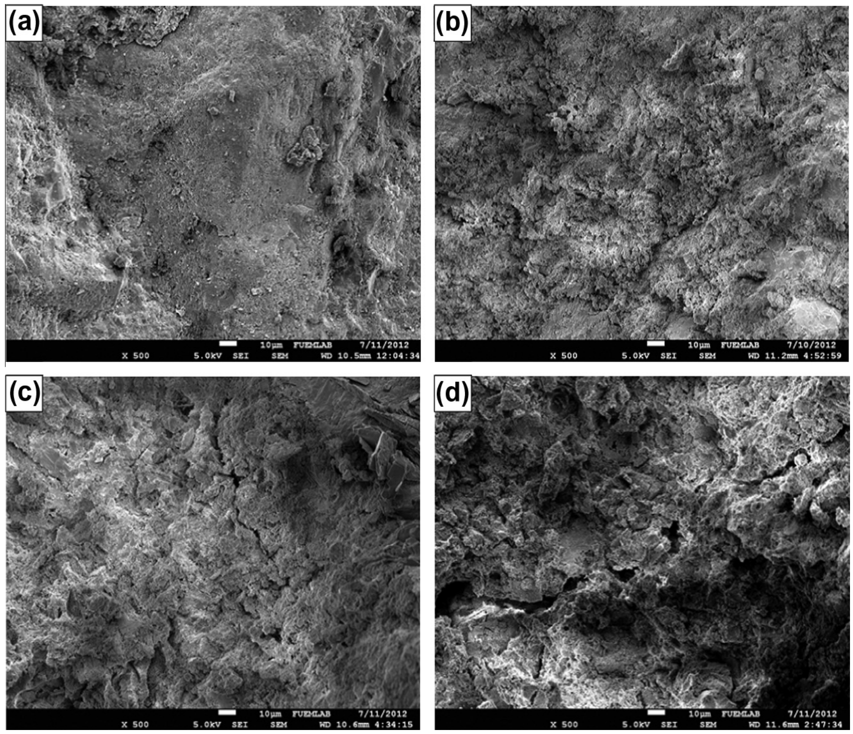

Fig. 5. SEM micrographs of FG0-MD0 specimens exposed to (a) 20 °C, (b) 400 °C, (c) 600 °C, and (d) 800 °C.

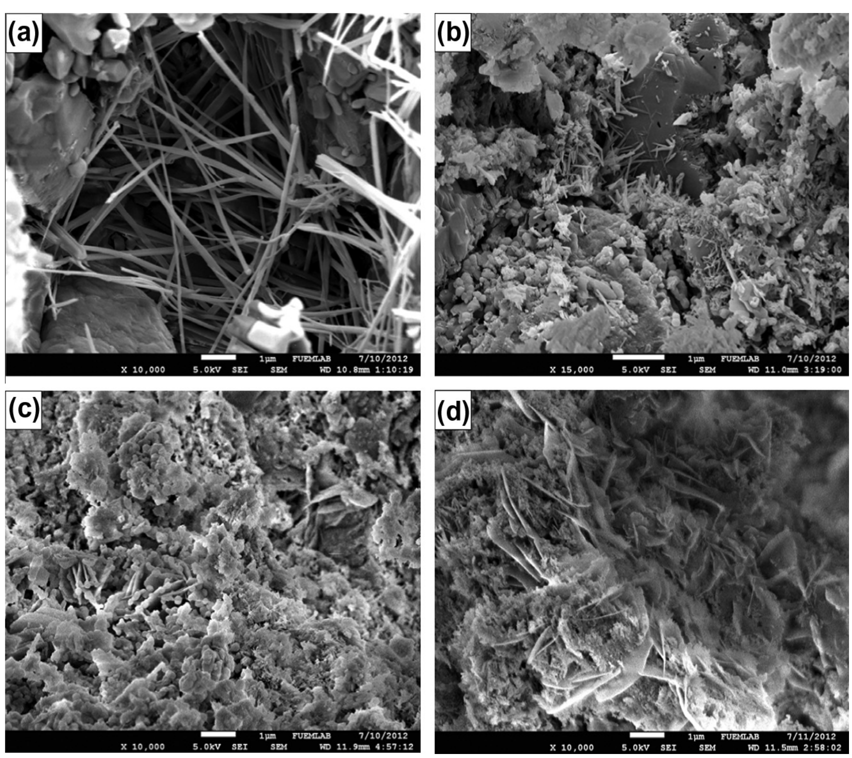

Fig. 6. SEM micrographs of the mortar specimens exposed to (a) 20 °C, (b) 400 °C, (c) 600 °C, and (d) 800 °C.

and cement paste. As seen from Fig. 5, SEM investigation of the mortar specimens revealed massive changes in the morphology of the specimens exposed to 600 and 800 °C. This finding is probably due to the predominance of micro-cracks, the increase porosity of the mortar due to the voids, the deformation of $Ca(OH)_2$ crystals, and finally disrupted CSH phase boundaries. Therefore, the loss of strength observed at higher temperatures may be attributed to the loss of bound water, increased the porosity of the specimens. Similar observations could be found in the open literature [14,26,27].

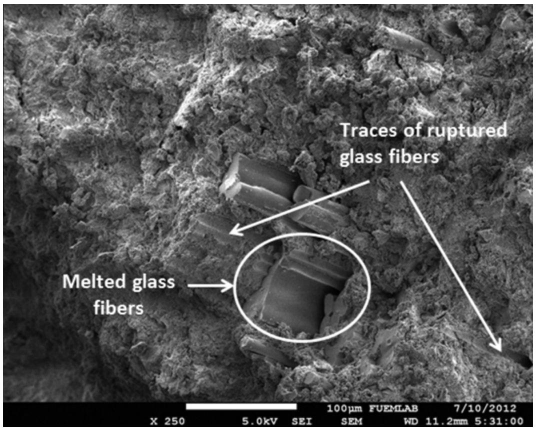

Fig. 7. SEM micrographs of the cement mortar containing glass fiber exposed to 800 °C.

Microstructural changes of the CSH gels in the mortar specimens with increasing temperature degree are shown in Fig. 6.

As can be clearly seen from Fig. 2, the compressive strengths of the all mortar specimens decreased after exposed to the high degree of temperature. Although the mortar specimens containing glass fiber generally had less compressive strength than the control specimen, the strength loss percentages in these specimens were less than the control specimen after high temperatures.

The glass fibers in the mortar specimens began to melt and rupture after the 600 °C. The deformed fibers and traces of ruptured fibers in the cement mortars due to the high temperature are shown in Fig. 7.

Addition of marble dust as fine sand into the cement mortars with and without glass fiber leads to the reduction of the voids and modification of aggregate/cement paste and/or fiber/mortar interface zones. Therefore, addition of marble dust into the mortar specimens increased the resistance to high temperature.

3.2. Data analysis of the S/N ratios

Table 6 shows the corresponding *S/N* ratios for compressive strength and porosity values of the cement mortars obtained by using Eqs. (2) and (1), respectively. The mean *S/N* ratio for each level of the other factors was calculated in a similar manner and the results are shown in Tables 7 and 8. Additionally, the total mean *S/N* ratio is computed by averaging the total *S/N* ratios. Based on the data presented in Tables 7 and 8, the optimal performance for compressive strength and porosity values of the cement mortars was obtained at 50% marble dust (Level 4), 20 °C temperature (Level 1), and 0 kg/m^3 glass fiber (Level 1) settings. Figs. 8 and 9 present plots of the *S/N* ratio for the three control parameters A, B, and C studied at four levels for the compressive strengths and porosity values. The *S/N* ratio corresponds to the smaller variance of the output characteristics around the desired value.

Table 7
Response table mean signal-to-noise (*S/N*) ratio for compressive strength factor and significant interaction.

Symbol	Control factor	Level 1	Level 2	Level 3	Level 4
Mean S/N ratio					
A	Percentage of marble dust (%)	33.34	33.96	34.78	35.34[a]
B	High temperature degree (°C)	38.76[a]	36.62	34.09	27.95
C	Amount of glass fiber (kg/m^3)	35.14[a]	34.75	34.15	33.38

Total mean *S/N* ratio: 34.355.
[a] Optimum level.

3.3. Analysis of variance (ANOVA)

The analysis of variance (ANOVA) is the statistical treatment most commonly applied to the results of the experiment to determine the percent contribution of each factor and factor interactions. ANOVA employs sums of squares which are mathematical abstracts that are used to separate the overall variance in the response into variances due to the processing parameters and measurement errors [28]. In this study, ANOVA analysis and *F*-tests were carried out to determine statistically significant process parameters and percent contribution of these parameters on the compressive strengths and porosity values of cement mortar produced with marble dust and glass fiber. MINITAB software was used for calculation. ANOVA results are tabulated in Tables 9 and 10 for compressive strength and porosity values, respectively. The last column of these tables indicates the statistically effect of each factor on responses. The *F*-test was performed according to confidence level 95% ($\alpha = 0.05$ in this study). At this level, all control factors are suitable since calculated *F*-ratios are greater than the tabulated *F*-ratio (4.76) value. As shown from the ANOVA tables, when the ANOVA results are scrutinized, the most effective

Table 6
L_{16} orthogonal array and corresponding *S/N* ratios for compressive strength and porosity value.

No	A Marble dust (%)	B Temperature (°C)	C Fiber glass (kg/m^3)	*S/N* ratio for compressive strength	*S/N* ratio for porosity
1	1	1	1	38.54	−24.64
2	1	2	2	36.00	−25.13
3	1	3	3	32.87	−27.85
4	1	4	4	25.97	−29.02
5	2	1	2	38.76	−24.73
6	2	2	1	37.01	−24.72
7	2	3	4	32.72	−27.77
8	2	4	3	27.36	−28.78
9	3	1	3	38.98	−24.68
10	3	2	4	36.07	−25.00
11	3	3	1	35.30	−26.94
12	3	4	2	28.77	−28.77
13	4	1	4	38.77	−24.76
14	4	2	3	37.40	−24.91
15	4	3	2	35.46	−27.17
16	4	4	1	29.72	−28.02

Table 8
Response table mean signal-to-noise (*S*/*N*) ratio for porosity factor and significant interaction.

Symbol	Control factor	Level 1	Level 2	Level 3	Level 4
Mean S/N ratio					
A	Percentage of marble dust (%)	−26.66	−26.50	−26.22	−26.21[a]
B	High temperature degree (°C)	−24.70[a]	−24.94	−27.43	−28.52
C	Amount of glass fiber (kg/m^3)	−26.08[a]	−26.32	−26.56	−26.64

Total mean *S*/*N* ratio: −26.399.
[a] Optimum level.

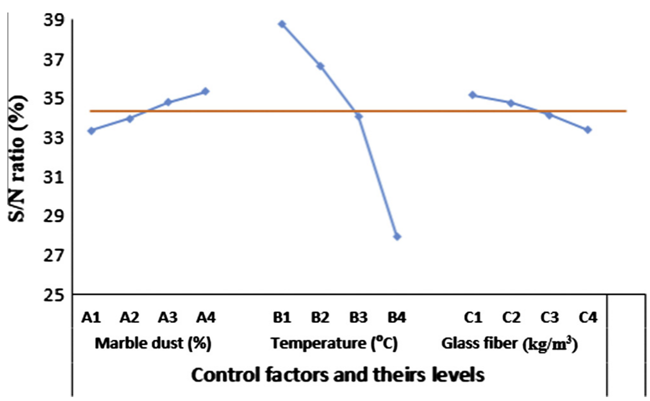

Fig. 8. *S*/*N* ratios of the compressive strengths.

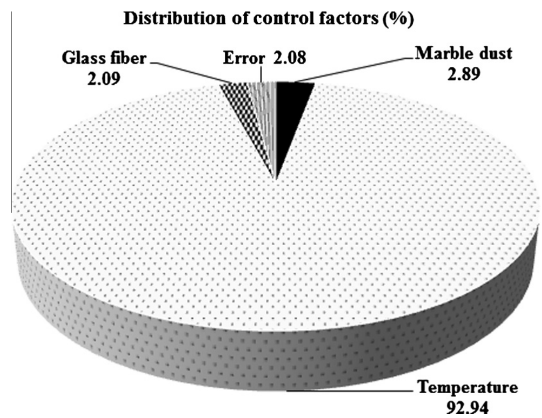

Fig. 10. Effect of control factors on the compressive strength.

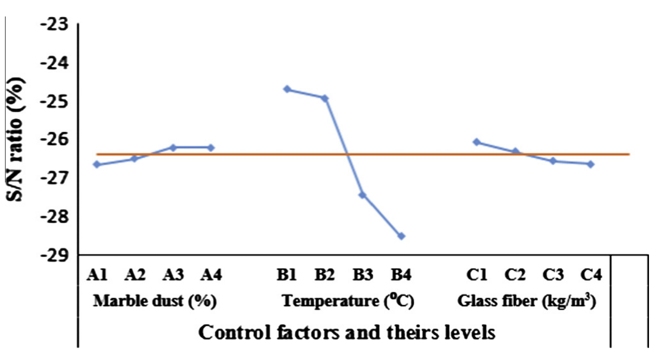

Fig. 9. *S*/*N* ratios of the porosity values.

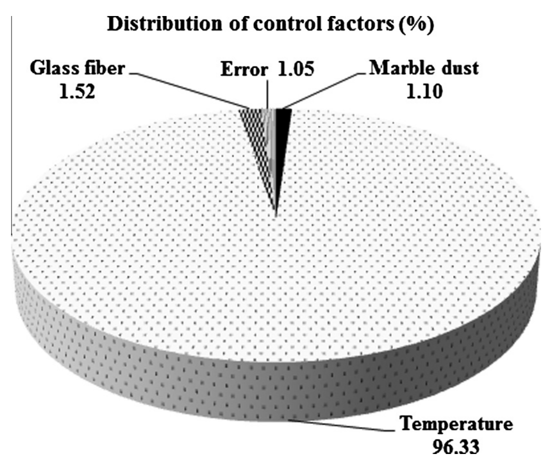

Fig. 11. Effect of control factors on the porosity value.

Table 9
Analyses of variance (ANOVA) for compressive strength.

	Degrees of freedom	Sum of square	Variance	*F*	Contribution of factors (%)
Marble dust	3	9.29	3.10	7.95	2.89
Temperature	3	262.36	87.45	224.56	92.94
Glass fiber	3	7.04	2.35	6.02	2.09
Error	6	2.34	0.39	–	2.08
Total	15	281.03	–	–	100

factor is temperature degree on the compressive strength and porosity. Additionally, the glass fiber is more effective factor according to the marble dust used in the compressive strength specimens. On the other hand, contrary of the compressive strength specimens, marble dust is more affective factor according to the glass fiber used in the porosity test specimens. The percent contribution factors on responses are given in Figs. 10 and 11. As seen from Figs. 10 and 11, experimental errors are very low levels

Table 10
Analyses of variance (ANOVA) for porosity value.

	Degrees of freedom	Sum of square	Variance	*F*	Contribution of factors (%)
Marble dust	3	0.57	0.19	6.24	1.10
Temperature	3	42.32	14.11	461.88	96.33
Glass fiber	3	0.76	0.25	8.30	1.52
Error	6	0.18	0.03	–	1.05
Total	15	43.83	–	–	100

for compressive strength (2.08%) and porosity value (1.05%). It can be seen from these figures that the temperature degree is the most effective factor on the compressive strength (92.94%) and porosity (96.33%) compared to the marble dust and glass fiber used in the specimens.

4. Conclusions

The following conclusions can be drawn based on the experimental and statistical studies presented in this paper.

- The experimental results indicated that the compressive strength of the mortar specimens increased as a result of the fact that certain ratios of marble dust were added to mortars instead of very fine sand, and at the same time it lead to an decrease in porosity values. This is due to the marble dust particles may act as ideal micro-filler in the interfaces between aggregate and cement paste and pores in the bulk paste.
- When glass fibers were added to the mortar specimens, the compressive strength decreased and porosity value increased. This result can be attributed to the poor adhesion between the glass fibers and mortar.
- The porosity value of the mortar specimen increased when it was exposed to the high temperature. This finding is due to the release of bound water from the cement paste and occurrence of air voids in the mortar. The highest porosity value occurred in specimens containing glass fiber (0.75 kg/m^3) and without marble dust that were subjected to 800 °C.
- The drastic increasing in porosity values between 400 and 800 °C indicated that the physical state of the mortar specimens deteriorated rapidly beyond 400 °C.
- The reduction in the compressive strength of the mortar was more pronounced especially specimens exposed to temperatures higher than 400 °C. This result is due to the water loss of crystallization resulting in a reduction of the $Ca(OH)_2$ content, in addition to the changes in the morphology and the formation of microcracks.
- Decomposition of $Ca(OH)_2$ and C–S–H gels, especially at 800 °C, resulted in the total deterioration of mortar. This finding is one of the results decreasing compressive strength and increasing the porosity value.
- The test results indicated that high temperature resistance of the mortar specimens containing glass fiber increased depending on the increase in the amounts of glass fiber.
- Addition of marble dust into the cement mortars with and without glass fiber increased the resistance to high temperature. This finding can be attributed to the marble dust particles leads to the reduction of the voids and modification of aggregate/cement paste and/or fiber/mortar interface zones.
- According to the *S*/*N* ratio results, the optimum compressive strength and porosity value were achieved at A4B1C1 parameter settings.
- Based on the ANOVA results, the most efficient parameter was found the temperature degree on the both compressive strength (92.94%) and porosity value (96.33%) of the cement mortar specimens. Marble dust (2.89%) and glass fiber (1.52%) were found the second ranking factors on compressive strength and porosity values, respectively. These factors do not seem to have much of an influence on the responses.

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