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Evaluation of Bending Resistance of Gypsum Composite with Perforated Non-Woven Fabric using Response Surface Methodology

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ABSTRACT: Gypsum is one of the most useful building materials in building industry due to its unique properties. But it is weak against bending and tensional forces acting on it. Therefore in this kind of building material to overcome the structure weight and also improving mechanical properties, textiles can be used as reinforcing member due to their tensional property and low weight. In this research, perforated non-woven fabric and its waste affection on bending resistance of gypsum composite has been evaluated. Response surface method has been used to analyze bending property of gypsum composite as dependent variable. Non-woven fabric weight, the number of holes and this kind of fabric waste has been selected as independent variables. As a result of this study bending resistance predictive model of gypsum composite is provided and this model has a high coefficient of determination. Also according to the results of this study, it was determined that using textile materials in the form of fabric waste will follow more considerably effect on improving bending property of gypsum composite than the perforated fabric.

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1- Introduction

Building Materials are reinforced by textiles with the goals such as reducing the damages caused by the earthquake and more resistant against compressive, tensile and bending forces acting on building materials. Over the last decade natural and artificial fibers in typical, micron and nanometer sizes are used to make building materials reinforced [1-4]. Tensile and bending resistance of gypsum composite that was reinforced with glass fibers type E, had increased significantly [5]. By using polypropylene and poly-paraphenylene terephthalamide with the volume fraction greater than 15% distributed for random in gypsum composite, an improvement in tensile resistance could be observed than the reference specimen [6].

In the current study, we tried to evaluate the influence of the weight, the number of the perforations and the waste of non-woven fabrics on bending resistance on gypsum composite. In addition, a model for bending behavior of gypsum composite with perforated non-woven fabric using response surface methodology was provided, as well.

2- Methodology

In the current study, response surface method (RSM) was used as experimental design method. The analysis was done using Design-Expert software. Spunbond non-woven polyester fabrics in 4 weights, commercial gypsum Semnan-Mazandaran and the harp number 50 and distilled water are used. Fiber distribution in three types of fabrics were observed by Dino-Lite digital microscope. The observation showed high density of fibers for 50 g/m2 fabric, low density for 30 g/m^2 fabric and average density of fibers for 40 g/m2 fabric.

Table 1 shows the factors of experimental design and the number of its levels.

Table 1. Variables used in the central composite design and their levels

Variable	Levels			
	Code	-1	0	+1
Number of perforations	A	30	36	42
Fabric weight(g/m^2)	B	30	40	50

After shaping six reference specimens with distilled water and gypsum, six specimens were made of each three weight fabrics and three groups of number of perforations. Prepared fabrics with the dimension of 40×160 mm^2 were placed 5 mm above the bottom of the bending mold and 5 mm below the surface of the mold. To forming gypsum composite with fabric waste, waste with dimension of (20-50)×(1-2) mm^2 were prepared and mixed with the mortar of gypsum and water and then poured into mold. The specimens were exposed in 23°C and 60% relative humidityy of ambient air

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and then 21 days in oven at 45°C [7].

3- Results and Discussion

The results of average bending resistance of gypsum composite for all of 54 specimens are shown in Table 2.

Table 2. The average results of gypsum composites for bending test

Fabric weight	No. of perforations	Bending resistance MPa	CV%
30	30	0.143	4.32
	36	0.139	5.44
	42	0.135	3.74
40	30	0.152	3.13
	36	0.157	2.06
	42	0.161	3.19
50	30	0.130	1.97
	36	0.131	1.90
	42	0.134	1.91
With fabric waste		0.175	4.54
Reference specimens		0.119	0.51

Using Design-Expert software statistical analysis of the data is performed. Table 3 shows suggested model of ANOVA table that is significant (α=0.05).

Table 3: The results of ANOVA for response surface quadratic model for bending resistance

source	Sum of squares	df	Mean square	F value	p-value
Model	42.23	5	8.45	24.37	0.0003 significant
A	0.11	1	0.11	0.32	0.0587
B	2.10	1	2.10	6.06	0.0433
AB	0.77	1	0.77	2.23	0.1786
A^2	0.002	1	0.002	0.007	0.9371
B^2	33.33	1	33.33	96.19	<0.0001
Residual	2.43	7	0.35		
Lack of Fit	0.96	3	0.32	0.88	0.5238 Not significant
Pure Error	1.46	4	0.37		
Total	44.65	12			

Index statistical data standard deviation, variations coefficient and R-squared coefficient were determined 0.59, 2.45 and 94.5%, respectively. The final equation in terms of coded factors for bending resistance of gypsum composite (R1) is:

$$R1= -18.86-0.21A+2.45B+7.33AB-8.04A^2-0.03B^2 \quad (1)$$

The response surface plot observed in Figure 1 shows the combined effect of input factors, number of perforations and fabric weight (g/m^2) on response factors.

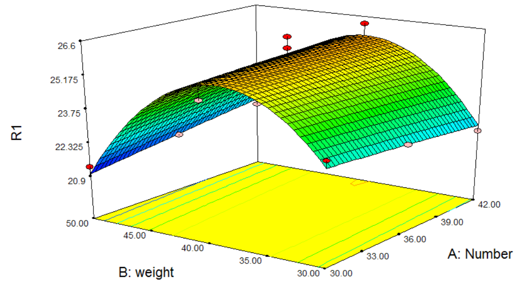

Figure 1. Response surface plots for bending resistance of gypsum composite

According to the results, gypsum composite with the fabric weight of 40 g/m^2 has the most resistance against bending force than the reference specimens (increased by 31.06%). Microscopic photos showed high fiber density in fabric weight of 50 g/m^2 whereas in fabric weight of 30 g/m^2 it was low. Fabric weight of 40 g/m^2 has good cohesion among gypsum ingredient due to its average fiber density and satisfying permeate of gypsum in the fabric. Moreover this type of fabric has acceptable resistance, as well. But cohesion factor between the fabric and the gypsum plays more important role than the fabric resistant in bending resistant of the composite.

Additionally, the effect of three different treatments including the gypsum composite with fabric waste, the fabric weight of 40 g/m^2 with 42 perforations and the reference specimens on bending resistance of gypsum composite were tested using one way ANOVA by SPSS software. The results of the Duncan's test for bending resistance of gypsum composite are summarized in Table 4. Figure 2 shows a broken bending specimen under bending force.

Table 4. Duncan's test on bending resistance data

Group	N	Subset for alpha= 0.05		
		1	2	3
reference specimen	6	0.119		
with fabric layers	6		0.161	
with fabric waste	6			0.175
Sig.		1.000	1.000	1.000

According to the analysis of results of the test, using fabric waste improved bending resistance of the gypsum composite by 46.19% than the reference specimens. The reason why this kind of fabric waste could increase bending resistance more than the fabric layer is that the fabric waste is scattered in three dimensions among the gypsum mortar and they could damp bending force better than the fabric layer.

Figure 2. The reinforced samples after the bending test

4- Conclusions

In the current study, the influence of some factors such as the weight of non-woven fabrics, the number of perforations and waste on bending resistance of gypsum composites is deliberated. The way of response surface methodology was used and gave desirable results on estimating bending resistance of composite.

All of gypsum composites bending resistance which those contain fabric layers in, increased satisfactorily than the reference specimens.

Gypsum with gypsum cohesion played more important role in the amount of reinforcing.

Bending resistant of the gypsum composite which those contain fabric waste in, improved significantly than the reference specimens.

Fabric existence in gypsum composite causes refraining from shooting gypsum smithereens after breaking under bending force and it would reduce the loss of earthquake incidence.

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