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Compressive Load Capacity of Bakelite Matrix Composite Reinforced with Jordanian Silica Sand and Cement

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ABSTRACT

Jordan is a rich country with natural resources. Silica sand is considered as one of these resources. Composites in which Jordanian silica sand is used as a reinforcement can be manufactured to improve the properties of polymers. In this work, Bakelite was taken as a matrix material. To study how the properties of this new material can be controlled, it was decided to study the variables that may affect these properties. In this study, the effect of the processing parameters such as applied load and cooling rate, and their interaction with the material parameters such as particle size and reinforcement content on the compressive load capacity of the manufactured composite were investigated. It was found that a higher compressive load capacity can be achieved with the increase of the applied load during manufacturing, the increase of the content of the reinforcement, and the increase of the particle size. The effect of the cooling rate depended on the sand content. For example, samples of low sand content (5 and 25%) showed no significant effect. In contrast, samples of high sand content (35 and 50%) showed that the higher the sand content, the lower the strength is.

Keywords: Reinforcement, Bakelite, Cooling Rate, Capacity, Matrix.

INTRODUCTION

Polymer matrix composites (PMCs) are among the best established advanced engineering composite materials. The three classes of polymers, namely thermoplastics, thermosets and rubber, are all employed as matrix materials. As far as mechanical properties were concerned, their stiffness and strength could be dramatically improved by reinforcement [Robinson et al., 2002; Ying Shan et al., 2002; Kuriger et al., 2000; Jalham, 1999; Al-Momany and Jalham, 1999]. An extensive range of processing methods are available for PMCs and vary from simple labor intensive methods to automated processes requiring heavy capital investment and suitable for producing large numbers of components (Brent Strong, 2000; Mathews and Rawling, 1994). A well-established method of manufacturing for a polystyrene matrix reinforced with Jordanian silica sand and cement was reported in (Jalham, 1999). This method was also used to manufacture bakelite matrix reinforced with Jordanian silica sand and cement (Jalham et al., 2010). The percentage of cement was 1/6 of the weight percentage of the silica sand. The reinforcement content (S) and the particle size (Z) were the basic studied parameters while other conditions (such as load and cooling rate) were fixed. It was found that the characteristics of composite materials depend mainly on the type, reinforcement content (*S*), and particle size (*Z*) of the reinforcement. 75% weight percentage of the silica sand and cement was found to be the upper limit of the reinforcement content that improves the properties of composites. Other researchers (Robinson et al, 2002; Ying Shan et al., 2002); also reported that the strength of polymer matrix composites reinforced with silica were superior to their unreinforced polymer matrix. Moreover, Mousa et al. (2001) studied the behavior of styrene/butadiene rubber organoclay nanocomposites and found that the tensile strength was improved by increasing nanosilicate content. The effect of processing parameters such as applied load (*P*) and cooling rate (*C*) and their interacting effects with the particle size and reinforcement content on the compressive load capacity of the manufactured Bakelite composites were not studied

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by Jalham et al. (2010). As an extension for this study, the effect of the processing variables such as the load and cooling rate, and the material variables, e.g., the percentage and size of the reinforcement particles on the compressive load capacity of the Bakelite composite reinforced with Jordanian silica sand and cement are of concern in this work as this product can be used as separation walls or for decorative purposes. It is worth mentioning that the high purity SiO_2 was prepared by using the physical separation method proposed by Jalham and Al-Tahat (2001).

Table 1. Levels of independent variables

Variable	Units	Level			
		1	2	3	4
Processing Variables					
Applied load (*P*)	*kN*	4	5	6	7
Cooling rate(*C*)	*℃ /min*	36	24	18	12
Materials Variables					
Sand percentage (*S*)	*%*	5	25	35	50
Sand Particle Size (*Z*)	*Micron*	60	75	85	-

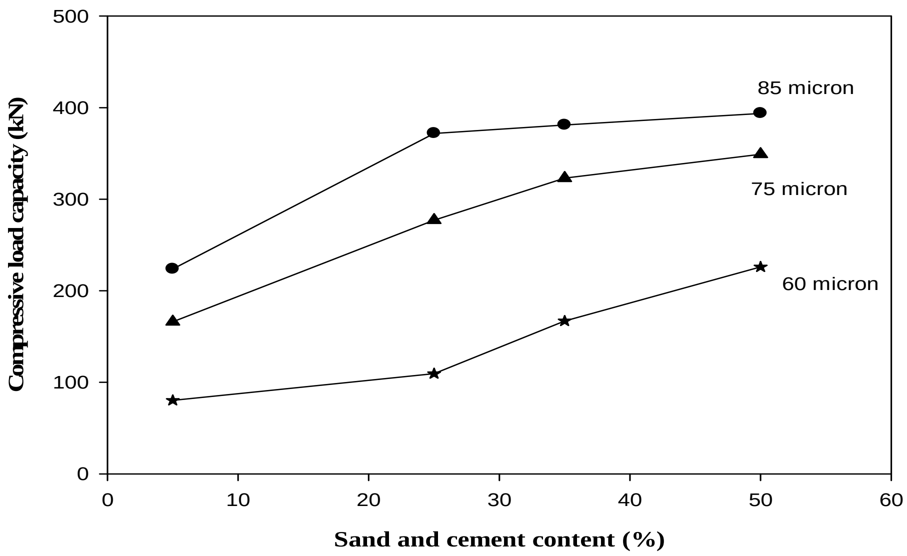

Figure 1. The influence of sand and cement content (%) on the compressive load capacity of the composite used in this study for the cooling rate of 12 °C/min.

Methodology

Based on the research work, which was conducted by Jalham [2003], the variables were determined to be four: the applied load, cooling rate, the percent, and size of the reinforcement particles. To study the effect of each variable on the compressive load capacity, four levels of each variable were considered. But three levels were studied for particle sizes (Table 1) of silica sand, which was limited because of the available sieves in our laboratory. Three samples for each level were manufactured, because of the limited supply of the bakelite raw material. The manufacturing and deformation of the sample was conducted according to the proposed methodology suggested by Jalham (1999) using a computerized universal testing machine (UTM) to determine the maximum load capacity of the samples. The samples were prepared in the form of cylinders of a diameter of 30 mm and a height of 30 mm. The upper limit of the reinforcement was taken to be 50 weight percent of silica sand and cement as this percentage is safe based on what had been reported by (Jalham, 1999) and (Jalham et al., 2010). The processing parameters were limited by the available equipment in the laboratory. The previously mentioned limitations cannot be considered as an obstacles for conducting this work because enough levels of the variables, that may show an acceptable trend of the results, can be studied.

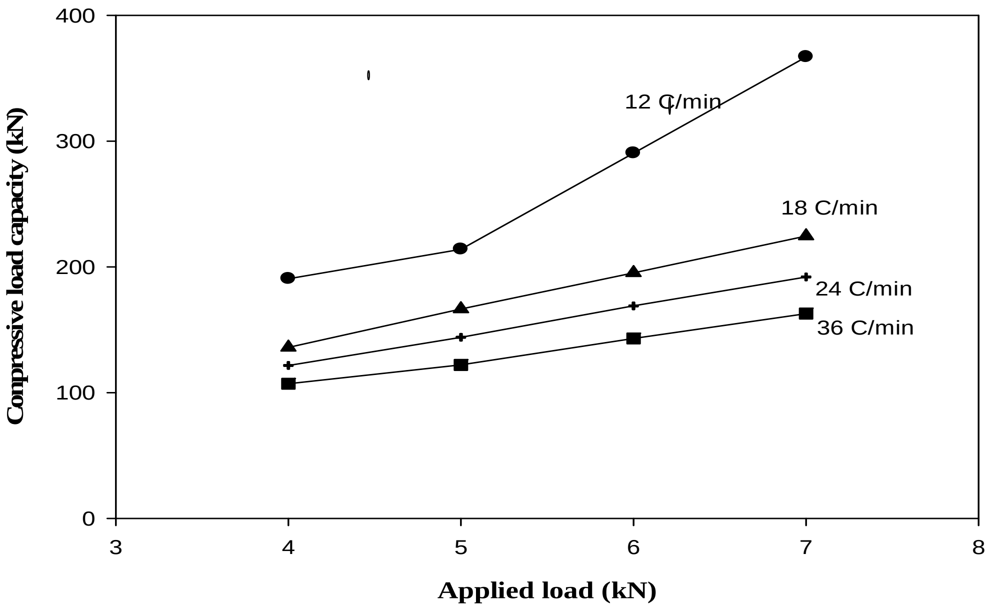

Figure 2. The influence of applied load on the compressive load capacity of the composite used in this study for particle size of 85 micron

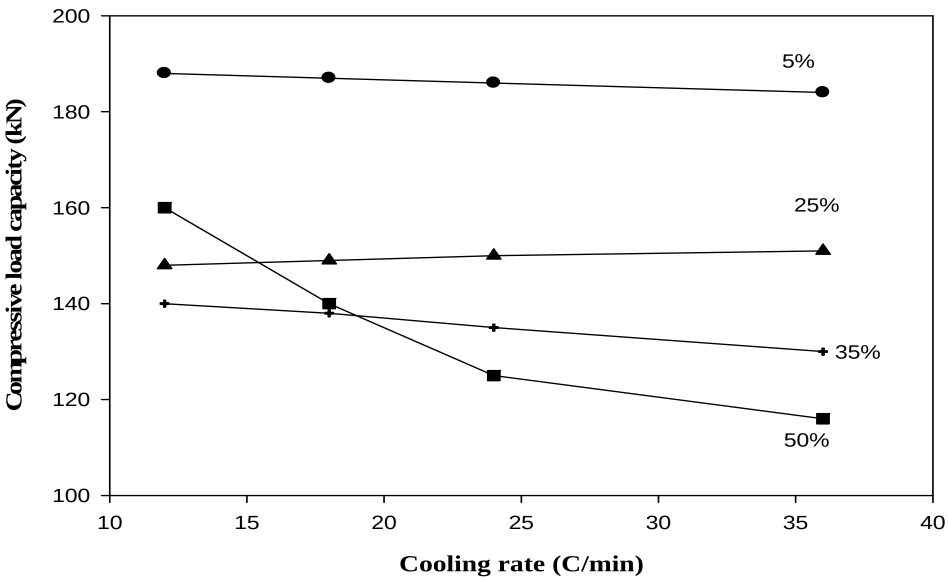

Figure 3. The influence of cooling rate on the compressive load capacity of the composite used in this study

Results and Discussion

The maximum compressive load was taken as the control parameter for the strength comparison of the composite material samples. The effect of the parameters and their interaction can be seen in Figures 1, 2, 3, 4.

It is clear from Figure 1 that the influence of reinforcement (silica and cement) content and particle size and their interaction on the compressive load capacity of the manufactured composite material shows a systematic pattern. The higher the percentage of the reinforcement (silica and cement) content, the higher the compressive load capacity of the material for the same particle size and the higher the particle size, the higher the compressive load capacity of the composite for the same content of the reinforcement (silica and cement). This is due to the increase in the space occupied by the hard particles of silica sand and the increase in the strength of the bonding among the constituents as a results of the increase in the amount of the cement, which plays an important role in binding. A good agreement with the results in the works (Jalham, 2003, Robinson et al., 2002; Ying Shan et al., 2002; Kuriger et al., 2000; Jalham, 1999; Al-Momany and Jalham, 1999) can be observed.

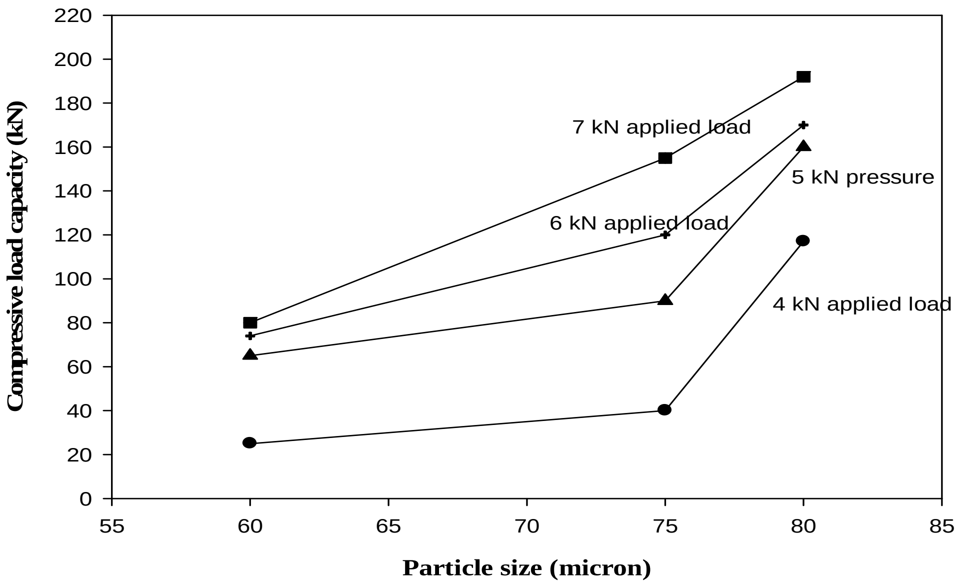

Figure 4. The influence of particle size on the compressive load capacity of the composite used in this study

The relationship between the applied load and the compressive load capacity as well as the cooling rate and the compressive load capacity and their interaction are presented in Figure 2. It can be concluded that the higher the applied load during the process of manufacturing, the higher the compressive load capacity of the composite is. This can be explained in that the higher the applied load during manufacturing of the product, the higher the density and the better the bonding of the reinforcement with the matrix is. On the other hand, this figure shows that the higher the cooling rate, the lower the compressive load capacity of the product is. This is due to the fact that polymeric material, which is the matrix in this case, and the reinforcement which is ceramics in this study are characterized by their bad heat conductivity. In this case the outer surface of the manufactured composite solidifies first and much time is needed for conduction to the other parts of the specimen which plays a very important role in creating internal thermal stresses.

Figure 3 shows the interaction among the results. The effect of the cooling rate depended on the sand content. For samples of low sand content (5 and 25%), there was no effect although for the high sand content (35 and 50%), the higher the sand content, the lower the strength is. This may be due to the low percentage of the reinforcement, which is 5% and to some extent is near to the pure polymer in composition. But for the composite that has a 50% content of the reinforcement the higher the cooling rate, the lower the compressive load capacity is because there was not enough time for bonding as the polymer cools quickly.

Particle size has also influenced the compressive load capacity of the composite material. This can be observed in Figure 4. It can be concluded that the higher the particle size, the higher the compressive load capacity is for the same applied load which is in a good agreement with the results presented in the work of Jalham (1999) and Jalham (2003). And also the higher the applied load, the higher the compressive load capacity for the same particle size.

Conclusions

It can be concluded that for the bakelite matrix composite material used in this study:

1- The higher the applied load during manufacturing, the higher the compressive load capacity is.

2- The effect of the cooling rate depended on the sand content. For samples of low sand content (5 and 25%), there was no effect although for the high sand content (35 and 50%), the higher the sand content, the lower the strength is.

3- The higher the particle size, the higher the compressive load capacity is.

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قدرة الباكلايت المعزز بالرمل الأردني والإسمنت على تحمل أحمال الضغط

عصام جلهم وعباس الرفاعي*

ملخص

الأردن غني بالموارد الطبيعية، ويعد الرمل أحد هذه الموارد. ومع ان هنالك إمكانية لتصنيع مواد مركبة من البلكلايت المعزز بالرمل الأردني، إلا ان هنالك حاجة لدراسة ظروف التصنيع لمعرفة تأثير عوامل التصنيع على الصفات الميكانيكية لهذا المركب. وفي هذه البحث تم دراسة تأثير كل من معدل التبريد، الضغط، نسبة الرمل، وحجم حبيبات الرمل على الصفات الميكانيكية لهذا المركب. وأظهرت النتائج ان قوة المادة المركبة تزداد بزيادة نسبة الرمل او زيادة حجم الحبيبات او بزيادة الضغط أثناء عملية التصنيع. اما بالنسبة لمعدل التبريد، فانه لا يوجد تأثير له إذا كانت نسبة الرمل قليلة (5% و25%) واما بالنسبة لنسب الرمل الكبيرة (35% و50%) فان قوة التحمل تقل كلما زادت نسبة الرمل.

الكلمات الدالة: الباكلايت، معدل التبريد، القدرة.

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