Effect of the Binder on Compressive Strength and Bending Strength for Composite Bodies Sintered in Different Degrees

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Abstract: This research includes the formation of composite bodies. Polyvinyl butyral, Phathlic acid ester and paraffin wax pastillated are mixed in different ratios. This mixture added to Dwekela kaolin to forming 4 groups of samples which compressed in a steel mold surrounded by a trace heater. Each group of samples divided into 3 subgroups to treated thermally with (1250, 1300, and 1350) ºC. Volumetric shrinkage, compressive strength and bending strength are measured. The study showed that, the highest values of compressive strength and bending strength are at 1300ºC, and volumetric shrinkage is influenced by Dwekela kaolin ratio and temperature degree of burning.

Key words: Composites; Compressive strength; Bending strength; volumetric shrinkage; insert.

INTRODUCTION

Composites can be defined as a multiphase materials obtained by artificial combination of different materials to attain properties that the individual component cannot attain (Mussa, S. and F. Basheer, 2003; Deborah, D.L. Chung, 2001).

The composite is comprised of two major components: the matrix which is the basic material, and the additives. The matrix is the basic material, serving to enclose the composite and give it bulk form. It surrounds other constituents and makes them more cohesive to form a "compact system". Additives are constituents added to polymers to provide them with specific properties and improve basic properties. These constituents are added in a granular form or as small particles. Additives can increase the overall conductivity, reduce porosity, and improve friction and some magnetic properties …etc (Long," A.C., 2007). In the last few decades, polymers have been used in the production of a unique composite material with improved mechanical strength and durability (Fowler, D.W., 2001; Fowler, D.W., 1999).

The aim of this study was to investigate the effect of the use of polyvinyl butyral as a binder material on the mechanical properties of composite bodies which mainly composed from the low price material, Dwekela kaolin.

Materials:
Dwekela Kaolin:
There Dwekela kaolin crude in sufficient quantities in Dwekela in the Western desert in Iraq (Hani, M.H., 2003). Figure (1) showed the phases of Dwekela kaolin by using the X-Ray Diffraction Unit Siemens, Model D500.

Poly Vinyl Butyral:
Poly Vinyl Butyral is used as a binder material. Generally, polymer with staff net work structure is used as binder materials operating at high temperatures (Nosal, V.S., 1972).

Phathlic Acid Ester:
Phathlic acid ester, also named (1,2 Benzendicarboxylic) (Ulfat, A.M.A. AL-Majmaee, 2005).

Paraffin Wax Pastillated:
Lubricated Materials are used to prevent adhesion between polymer and the processing equipment (Herman, F. Mark 1968).

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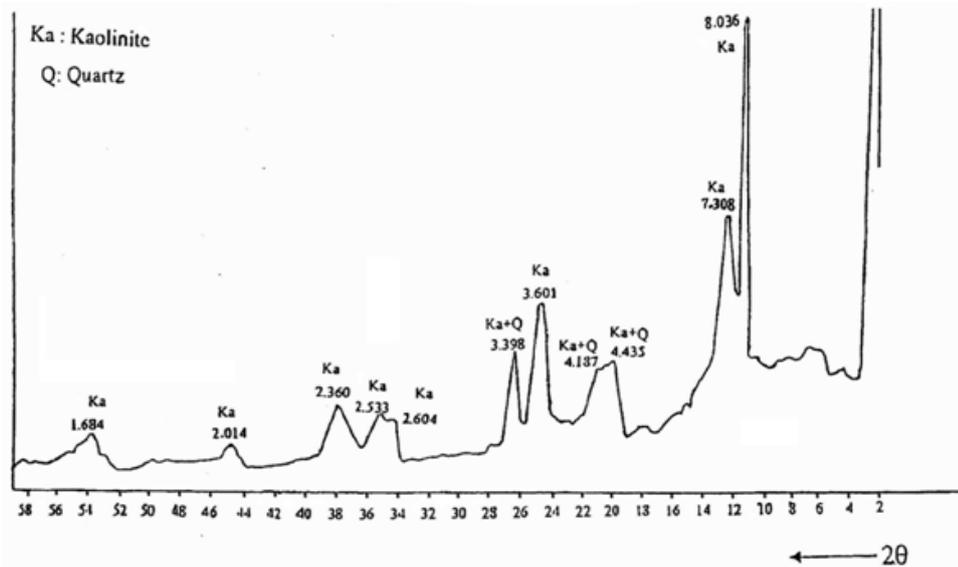E-mail: Alaa.algidsawi@yahoo.com

Fig. 1: The phases of Dwekela kaolin.

Experimental Procedure:
Samples are fabricated by the following steps:

1. Dwekela kaolin washed with distilled water to get rid of impurities and organic compounds, as much as possible, then it dried by dryer of memmert type, Germany made.
2. Dwekela kaolin is grinded by balls grinder, type Crosc Hop, Germany made with pure alumina balls. The grinding process continued for 8 hours, to obtain the required particle size.
3. Two mixtures A1, A2 are prepared consisted of (Polyvinyl butyral, Phathlic acid ester and paraffin wax pastillated) with the help of Xylolzul analyse, as a solvent, and water bath heated to 90ºC. Table (1) shows the weight percentages for each mixture.

Table 1: Weight percentage for each mixture

Symbol of mixture	weight percentage of the compounds		
	Polyvinyl Butyral%	phathalis acid ester%	paraffin wax pastillated%
A1	90	5	5
A2	85	10	5

4. Dwekela kaolin mixed with A1 and A2, each separately. The resultant, 4 different groups of samples, is shows in table (2).

Table 2: Weight percentage of groups compounds

Symbol of group	weight percentage of the compounds		
	A1%	A2%	Kaolin
B1	5		95
B2	10		90
C1		5	95
C2		10	90

5. Samples formed in a similar manner to injection molding method, Where the use of pressure and heat at the same time. Injection molding is a process allowing the adequate fabrication of complex geometrical structures (Ulfat, A.M.A. AL-Majmaee, 2005).electric piston (70 Mpa) type corver, US-made, and steel mold surrounded by a trace heater Germany made (220-240V, 1500Watt)are used for the fabrication of two shapes of samples in the form of a parallel rectangles and cylinders.
6. Each group divided into three sections and burned at (1250, 1300, and 1350) ºC in an electric oven, type Naber Therm , with ripening time 2 hr. , temperature altitude speed 2 ºC/min. and temperature declining hod (10-2Toor) for measuring.

Measurements and Mathematical Formulas Used:

The Samples dimensions, before and after burning, are measured by vernier caliper to calculate the volumetric shrinkage by applying the following equation:

$$V.sh\% = [(Vo - V)/Vo]*100 \tag{1}$$

Where V.sh is the volumetric shrinkage; Vo is the sample volume before burning; V is the sample volume afterburning (Griffilths, R. and C. Raeford, 1965). Bending strength was determined applying the following equation:

$$Ɵb = (3PL)/(2bh) \tag{2}$$

Where Ɵb is the Bending strength; P is the maximum load recorded; L is the span length; b and h are respectively, the width and height of the prismatic specimens (ASTM, 2002).

Compressive strength were calculated according to the following equation

$$Ɵc = F/A \tag{3}$$

Where ƟC is the Compressive strength; F is the maximum load recorded; A is the cross section area of cylinder specimens (ASTM, 2005).
The results and desiccation
Tables (3) and (4) represent the experimental results.

Table 3: The experimental results

T(ºC)	5% A1 + 95% Kaolin			10% A1 +90% Kaolin		
	V.sh%	Ɵc. (Mpa)	Ɵb. (Mpa)	V.sh%	Ɵc. (Mpa)	Ɵb. (Mpa)
1250	27	7.5	34	18	6.5	10
1300	31	14	38	29	19	39.4
1350	33	16	36	30.5	12	26

Table 4: The experimental results

T (ºC)	5% A2 + 95% Kaolin			10% A2 +90% Kaolin		
	V.sh%	Ɵc. (Mpa)	Ɵb. (Mpa)	V.sh%	Ɵc. (Mpa)	Ɵb. (Mpa)
1250	26	6.7	25	17	5.5	30
1300	29	12	27	28.5	13	37
1350	31	13	26	29	6.5	31

The experimental results appear the following:

1. Volumetric shrinkage proportioning ejectively with Dwekela kaolin weight percentage, because the kaolin at high temperature, above 700 °C, acted as a binder to the raw material (Zheng Xun Yang, 2009). volumetric shrinkage proportioning ejectively with Poly Vinyl Butyral weight percentage , where, the increase of the binder lead to more incorporation of the pores, and the convergence of particles to the degree which is expected to turn into very small pores (Ulfat, A.M.A. AL-Majmaee, 2005). Also, the volumetric shrinkage proportions with the temperature and this is consistent with Suchller(Schuller, K.H., 1964) and AL-Majmaee (Ulfat, A.M.A. AL-Majmaee, 2005), This result shown in figures (2) and (3).
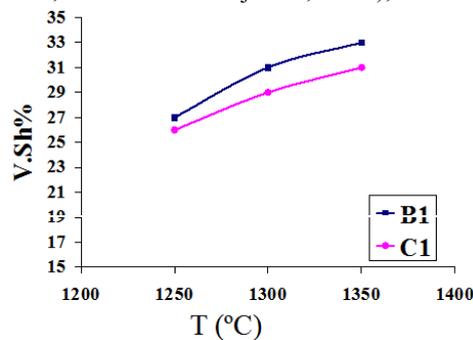
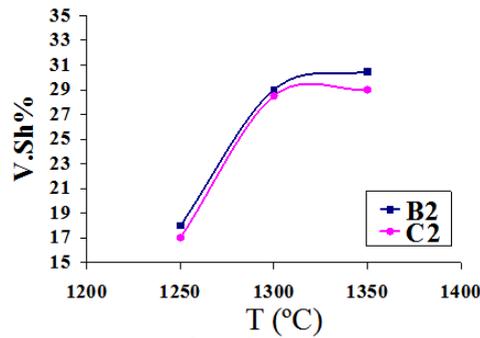**Fig. 2:** Volumetric shrinkage versus temperature for B1, C1.

Fig. 3: Volumetric shrinkage versus temperature for B2, C2.

2. Top value of Compressive strength and bending strength is in group B2 at temperature 1300ºC as shown in Fig.(4),(5) i.e., when the highest value of Poly Vinyl Butyral. The polymerization bonded particles together will lead to a better performance. Both bending strength and compressive strength of mortar could meet common construction requirement (Zheng Xun Yang, 2009).

The binder permits the mechanical strength of the raw material to be utilized to the high degree, Also the interaction between raw material and binder is an important factor that the mechanical properties are depending on (Nosal, V.S., 1972).
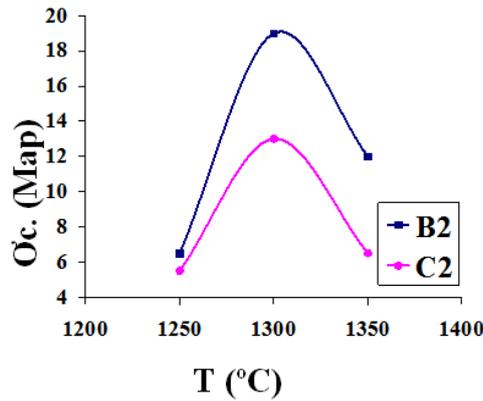

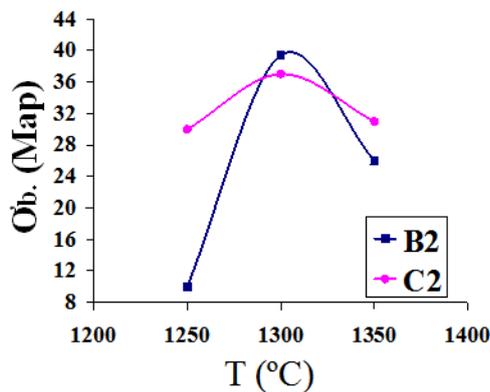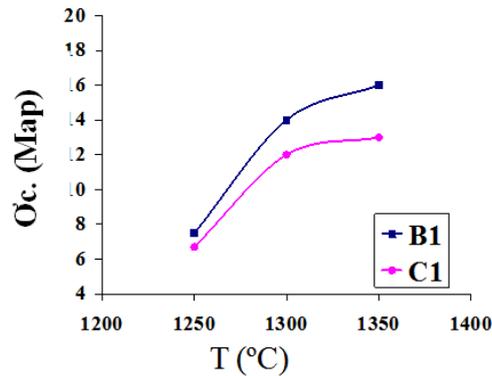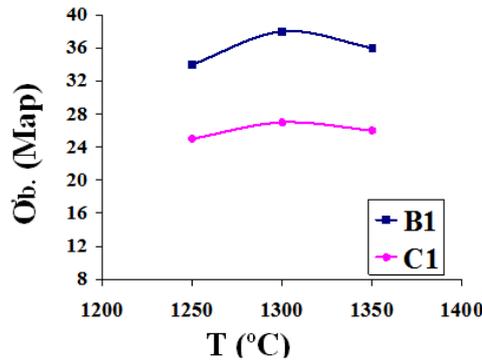**Fig. 4:** Compressive strength versus temperature for B2, C2.

Fig. 5: Bending strength versus temperature for B2, C2.

3. In the range between (1250 – 1300) ºC both the compressive strength and bending strength are increase. While at 1350ºC; these two properties become lower in most samples as shown in Fig.(4),(5),(6)and (7).

Fig. 6: Compressive strength versus temperature for B2, C2.

Fig. 7: Bending strength versus temperature for B1, C1.

The lose of the strength can be attributed to an increase of porosity which weakens the bond between the aggregate (Reis, J.M.L., 2009).

Conclusions:
1. The beast mechanical properties of the sample can be obtained at 1300 ºC.
2. Compressive strength and bending strength proportioning ejectively with binder.
3. Dwekela kaolin participates in the binding process in high temperatures.
4. Volumetric shrinkage influenced by burning temperatures.

Suggestions:
1. Study the microstructures of the samples by scanning electron microscope (SEM).
2. Study the influence of distribution of porosity and particle size on the properties of the product.
3. Study other mechanical properties such as resistance to shock and hardness.
4. Treating the sample thermally with a wide rang of temperature to get more accurate perception for changes.

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