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Fire Resistant Testing on Gypsum Composite Mixture with Clay

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Abstract – *This paper presents the result for experimental analysis of fire resistant testing of Gypsum composite mixture with clay, taken in hour (H) unit when either failure criteria stated in BS 476-20: 1987 [1] occur on the samples. The analysis were done using samples of three different Gypsum and clay ratios, 900 gram of Gypsum and 100 gram of clay; 800 gram of Gypsum and 200 gram of clay and; 700 gram of Gypsum and 300 gram of clay. Each of these ratios is fabricated with 3 different thicknesses of 6.4 mm, 9.5 mm and 12.7 mm. The results showed that sample 800g Gypsum and 200g Kaolin clay of thickness 12.7 mm has the longest fire resistance rating of 120 minutes and of thickness 6.4 mm has the shortest fire resistance rating of 27 minutes.*

Keywords: Fire Resistant Testing, Fire Resistant Rating, Gypsum, Clay

1.0 INTRODUCTION

Accidents involving fire is a recurring tragedy ever since the beginning of time. Not only properties were damaged countless lives were lost during the incidents, it is also affecting the psychological and the growth development of a constitutional in a society. Fire resistant structural usually are not capable of indefinitely withstanding the high temperature condition of fire but mainly are designed to maintain the condition of the fire wall for a time to permit the occupants of a building to escape and to delay the spread of fire until fire control equipments are nearby and is of reached. According to ASTM Method E 152, the standard requires a door to maintain its integrity for a period ranging up to 1.5 hours while withstanding progressively higher temperature [1,2]. Fire resistant structural with conventional Gypsum installed may lose their fire resistant capabilities when exposed to high temperature fire. This is because Gypsum calcines when in contact with sustained heat [3,4]. Calcination of Gypsum may cause the structure to lose strength and fail to maintain its integrity. Mineral fibers such as clay are thus employed and act as a binder to provide sufficient strength [5-7].

2.0 METHODOLOGY

Fire protection elements of known limits and a sufficient data of which they will be irreparably damaged by fire need to be made available to ensure that the required fire-resistance rating is not reduced. To obtain this, Gypsum is first weighed according to the required ratio of 900, 800 and 700 g, so is the Kaolin clay to the required ratio of 100, 200 and 300 g respectively as shown Table 1.

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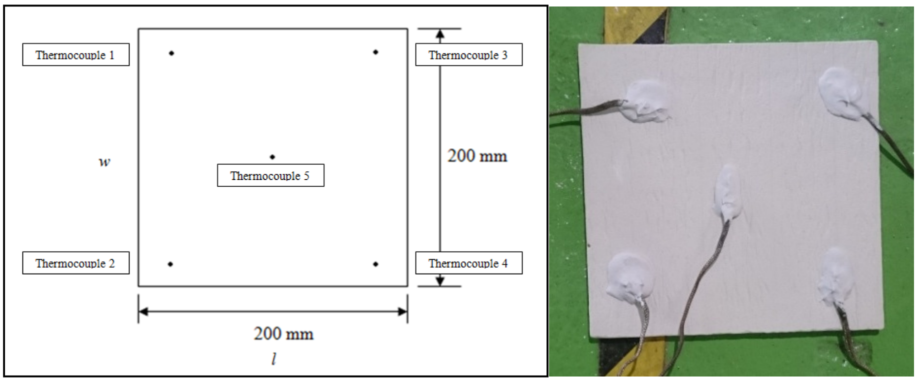
Table 2.1: Ratio of Mixture.

Ratio of Mixture	
Gypsum (gram)	Clay (gram)
900	100
800	200
700	300

Water and Kaolin clay is poured into the Gypsum until the mixture is slurry. The mixture is poured into the mold according to the required thickness. The wall of each side of the mold has been marked with thicknesses of 6.4, 9.5 and 12.7 mm prior to the mixing process. The sample is left to air-dry before releasing the mold from the pallet. Dried sample is fixed with 5 thermocouples as shown in Fig. 1(a) and (b) and will be positioned opposite to the fire source. The above steps are repeated for each thickness of each ratio. Healed sample will then be attached with thermocouples at five different spots to obtain the average temperature.



(a) **(b)**

Figure 1(a), 1(b): Positions of Thermocouples.

Figure 2: Apparatus setup.

The initial T_{mean} of the sample and the ambient temperature are recorded. Before placing the sample, the furnace is pre-heat at 750°C for 10 minutes. This is to avoid any shock reading on thermocouple scanner. After 10 minutes, the sample is placed inside the furnace with the surface of attached thermocouples is positioned opposite to the fire source. The temperature

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readings of each thermocouple and the temperature of the furnace are collected at every 3 minutes interval. The testing is done until failure time for the sample occurs. This time is known as R, the fire resistance rating [2]. The criteria for the failure to occur are cracks and propagation of gaps on the sample, the temperature of either thermocouple placed on the sample is in excess of 180°C from the initial value and temperature of T_{mean} of the unexposed face increases by more than 140 °C above its initial value. The steps mentioned above are repeated for other samples.

3.0 RESULTS AND DISCUSSION

Figure 3 shows the graph for T_{mean} against rating for the composition of 900g Gypsum: 100g Kaolin clay. The longest rate obtained is 120 minutes for sample of thickness 9.5 mm, followed by 90 minutes of thickness 12.7 mm and the shorter rate is 36 minutes of thickness 6.4 mm.

Figure 4 shows the graph for T_{mean} against rating for the composition of 800g Gypsum: 200g Kaolin clay. The longest rate obtained is 120 minutes for sample thickness of 12.7 mm, followed by 81 minutes for sample thickness of 9.5 mm and the shorter rate is 27 minutes for sample thickness 6.4 mm.

Table 2: Fire resistant rating.

Composition		Thickness, t_h	Rating, t	$T_{mean, max}$ (°C)	Density, ρ
Gypsum (g)	Kaolin clay (g)	(mm)	(minutes)		(kg/m^3)
900	100	6.4	36	177.50	1289.06
		9.5	120	109.2	1289.47
		12.7	90	148.80	1122.05
800	200	6.4	27	165.98	1328.13
		9.5	81	171.80	1315.80
		12.7	120	157.0	1240.16
700	300	6.4	57	167.20	1445.30
		9.5	81	168.30	1315.80
		12.7	54	111.9	1230.31

Figure 5 shows the graph for T_{mean} against rating for the composition of 700g Gypsum: 300g Kaolin clay. The longest rate obtained is 81 minutes for sample thickness of 9.5 mm, followed by 57 minutes for sample thickness of 6.4 mm and the shorter rate is 54 minutes for sample thickness 12.7 mm. When compared between the three compositions, sample of thickness 12.7 mm with composition 800g Gypsum and 200g Kaolin clay gives the longest fire resistance rating which is 120 minutes with the maximum T_{mean} equals 157.0 °C, and sample of thickness 9.5 mm with composition 900g Gypsum and 100g Kaolin clay also gives the longest fire resistance heat of 120 minutes with maximum T_{mean} equals 109.2 °C.

However, sample of composition 900g Gypsum and 100g Kaolin clay showed a slight crack along the surface of exposed as shown in Fig. 6 and unexposed as shown in Fig. 7 to fire source after being exposed for 120 minutes, but the sample of composition 800g Gypsum and 200g Kaolin clay did not exhibit any attribute failure.

Sample of 900g Gypsum and 100g Kaolin clay for thickness 9.5 mm have low value of thermal diffusivity and conductivity as shown in *Table 3.2*, which α = 0.01226 m^2/s and k = 8.484

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kW/m.K which explains why the T_{mean} is the lower than the sample of thickness 12.7 mm for composition of 800g Gypsum and 200g Kaolin clay.

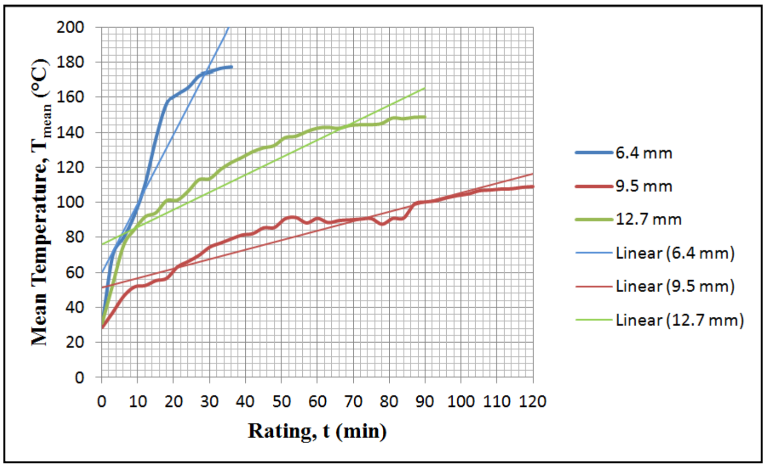

Figure 3: Graph of Gypsum 900g: Kaolin clay 100g.

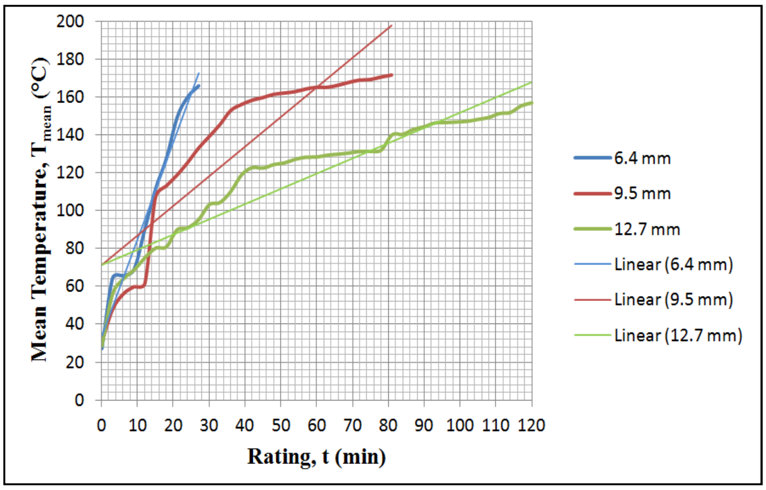

Figure 4: Graph of Gypsum 800g: Kaolin clay 200g.

Three samples showed moderate performance of having fire resistance rating of more than 1 hour, which is the required rating for conventional Gypsum. The sequence of performance are sample of 900g Gypsum and 100g Kaolin clay of thickness 12.7 mm, followed by 700g Gypsum and 300g Kaolin clay, and 800g Gypsum and 200g Kaolin clay of thicknesses 9.5 mm. T_{mean} for sample 800g Gypsum and 200g Kaolin clay and 700g Gypsum and3100g Kaolin clay is higher since it exhibits higher thermal diffusivity and thermal conductivity between the three samples as shown in Table 3.2, $\alpha = 0.02133$ m^2/s and $k = 14.821$ kW/m.K and $\alpha = 0.02156$ m^2/s and $k = 14.737$ kW/m.K respectively, which explains why the T_{mean} for both samples are quite similar.

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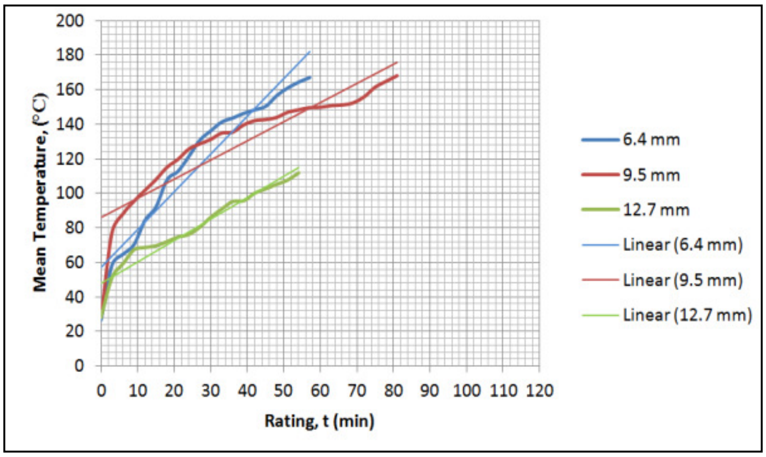

Figure 5: Graph of Gypsum 700g: Kaolin clay 300g.

There are four failed samples in this study since they have fire resistance rating of less than 1 hour. The first sample is 900g Gypsum and 100g Kaolin clay of thickness 6.4 mm with the highest T_{mean} = 177.50 °C since it has the highest α = 0.03328 m^2/s and *k* = 23.016 kW/m.K, followed by samples of 800g Gypsum and 200g Kaolin clay with of thickness 6.4 mm, having T_{mean} = 165.98 °C and α = 0.03094 m^2/s and *k* = 21.70 kW/m.K, then, sample 700g Gypsum and 300g Kaolin clay with thickness 6.4 mm despite having the highest density and sample 700g Gypsum and 300g Kaolin clay of thickness 12.7 having the least α = 0.01030 m^2/s and *k* = 6.583 kW/m.

Figure 6: Crack on Exposed Face (900g Gypsum and 100g Kaolin clay of 9.5 mm).

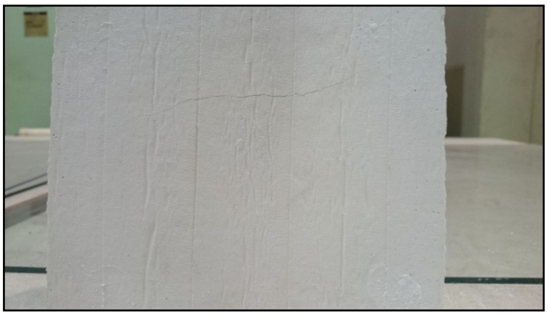

Figure 7: Crack on Unexposed Face (900g Gypsum and 100g Kaolin clay of 9.5 mm)

When air-dried, particles of water adsorbed between the layer of clay is gradually evaporated, resulting in shrinkage. Water that is left on the layers are then will be fully evaporated when

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the temperature reached 100 °C, since the furnace temperature is kept constant, approximately, between 750 °C – 850 °C, thus, the sample shrunk more.

Table 3: Properties of Gypsum Composite Mixture with Clay.

Composition		Thickness, t_h (mm)	Thermal Conductivity, k (kW/m.K)	Thermal Diffusivity, α (m^2/s)	Mass of sample, m (g)	
Gypsum (g)	Kaolin clay (g)				Before	After
900	100	6.4	23.016	0.03328	330	330
		9.5	8.484	0.01226	480	440
		12.7	9.260	0.01538	570	500
800	200	6.4	21.70	0.03094	340	330
		9.5	14.821	0.02133	500	480
		12.7	10.118	0.01545	630	620
700	300	6.4	21.938	0.02992	370	350
		9.5	14.737	0.02156	500	460
		12.7	6.583	0.01030	625	605

4.0 CONCLUSSION

The sample which shows a close manner to the successful criteria based on the standard is 800g Gypsum and 200g Kaolin clay of thickness 12.7 mm with fire resistance rating of 120 minutes, no structural failure appear on the surface, having quite low of thermal conductivity and diffusivity value which is $\alpha = 0.01545\ m^2/s$ and $k = 10.118$ kW/m.K. This means that the movement of heat through the sample is rather slowly, thus heat is conducted rather slow across the thickness of the sample.

Figure 8: Crack

The lowest fire resistance rating is 27 minutes by sample 800g Gypsum and 200g Kaolin clay of thickness 6.4 mm and exhibit crack as shown in Fig. 8. Thus, thickness of sample plays an important role to determine fire resistance rating of a sample. In conclusion, Gypsum reinforced with clay can be made into good fire resistant structures such as fire doors and ceilings.

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