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Improvement of Thermal Insulation and Crack Resistance of Plaster of Paris Composites at High Temperature

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In the present work, silica gel is extracted from raw rice husk, incorporated in Plaster of Paris formulations and casted into sheets of varying thicknesses. The sheets were tested for thermal insulation at 60, 100, 150 & 200 °C and compared with blank formulations. Plaster of Paris composites with silica gel have shown remarkable increase in thermal insulation properties and crack resistance. Thermally insulated Plaster of Paris composites with excellent crack resistance have been developed which can be used competently for prolonged times even at high temperatures offering better serviceability and safety to the buildings.

Keywords: Silica Gel, Plaster of Paris, Rice husk, Thermal insulation

Introduction

Plaster of Paris (POP) finds application as fire proofing material and is well known for biomedical applications.[1,2] It has poor resistance to cracking which decrease the durability of finished POP products and pose limitations to its use. However these problems can be minimized by considering precautions in design, appropriate reinforcements, choice of materials and their proportions. From the last two decades, utilization of different types of synthetic and agricultural wastes has come into practice to obtain value added products.[3–9]

Rice husk is an agricultural waste containing about 90–98% silica[10] which is widely being used as low cost adsorbents,[11] silica aerogels,[12] reinforcing agents in thermoplastic composites,[13] cement & construction industries.[14] Herein, an attempt has been made to improve the performance behaviour of Plaster of Paris composites by incorporating silica gel extracted from raw rice husk. Plaster of Paris and silica gel composites with varying thicknesses have been casted using hand layup technique and tested for difference in surface temperatures by keeping them at 60, 100, 150 & 200 ºC. The structural deformations after thermal treatment at different temperatures have also been compared.

Material and Methods

Materials

The Rice husk used in the production of silica gel was collected from a rice mill in Saharanpur. Sodium hydroxide flakes, Sulphuric acid and Calcium oxide were procured from Qualigens fine chemicals and used as received without further purification. Commercial silica gel was procured from Fischer scientific and Plaster of Paris was procured from Jai Durga Plaster Industry (Rajasthan).

Extraction of Silica gel from raw rice husk

The collected rice husk was washed with water and dried in oven at a temperature of 80 ºC for 4 hours. Dried rice husk was taken in silica crucible and kept in the muffle furnace at 700 ºC for 5 hours and a white coloured ash was obtained. 1.5 gm ash was mixed with 50 ml of standard NaOH (1N) solution with the help of glass rod for the complete dissolution of ash in NaOH solution. The reaction mixture was refluxed for 1.5 hours and then filtered to remove the undissolved residues to obtain a homogenous solution containing high amount of silica.

Sulphuric acid solution (1N) was added to adjust *p*H in the range of 7. The precipitated silica gel was washed repeatedly with de-ionized water to remove alkaline impurities and dried in an oven at 80 ºC for 4 hours. The dried silica gel was finely powdered through mechanical crushing and then used in the development of formulations for casting of sheets.

Casting of sheets

Five sheets for each thickness i.e., 2, 4, 6, 8 & 10 mm were casted having square dimensions of 2×2 inch. Distilled water (100 g), POP (35 g), CaO (15 g) and silica gel (40 g) were mixed for casting POP-Silica composites (SGF). Control samples (CS) of

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POP were also prepared in the similar manner without incorporation of silica gel.

Measurement of temperature difference readings and crack resistance of the casted sheets

The temperature difference readings for the casted sheets were recorded on a heating plate kept at a constant temperature. Both the Silica gel filled sheet and its control sample were placed on the heating plate simultaneously and connected to digital thermometers. The readings were noted for initial temperatures of 60, 100, 150 and 200 ºC. The sheets after thermal treatment were also inspected for structural deformations, at different temperatures and for different thicknesses. The observations after thermal treatment of 60 minutes for Silica gel filled sheets and control samples have been tabulated in Table 1.

Results and Discussion

Effect of the Silica gel on Thermal insulation and crack resistance properties of POP-Silica composites

18% of rice husk ash was obtained after keeping raw rice husk at 700 ºC for 5 hours and 85% of silica gel was recovered from rice husk ash through refluxing and precipitation methods. Surface temperatures of casted sheets for SGF and CS samples were measured simultaneously and the data obtained have been plotted as temperature versus time for all the initial temperatures. Figure 1 depict the comparative temperature rise analysis for 2, 4, 6, 8 & 10 mm sheets respectively, solid lines represent control samples however silica gel filled samples have been shown as dash and dot lines. On very close inspection of the data, it was found that at 60 ºC, the surface temperature of 2 mm sheet of control sample after 60 minutes was 57 ºC i.e., a difference of 3 ºC was obtained, however for SGF sheet the difference was observed as 12 ºC. And this temperature difference between CS sheet and SGF sheet was found to increase in a progressive manner as the temperature approaches 200 ºC. From these results it can be stated that incorporation of Silica gel in the sheets has led to increase in thermal insulation properties.

Similar trends have been observed for 4, 6, 8 & 10 mm sheets (Fig. 1(b)–(e)). And also the difference in surface temperatures of CS and SGF sheets was enhanced significantly with increase in thickness. If we compare the surface temperatures of all the sheets at 200 ºC, a large difference in values was obtained for 2–10 mm sheets of CS and SGF Composites. The surface temperature values for control sample and Silica gel filled composites with thickness of 2, 4, 6, 8 & 10 mm sheets were 155, 132, 119, 116 & 102 ºC and 121, 93, 71, 60 & 45 ºC respectively.

Table 1 shows the effect of thermal treatment on structural integrity of POP and POP-Silica composites of varying thicknesses at different temperatures after 60 minutes. The data reveals that incorporated Silica gel has increased the strength of POP-Silica composites and also provided more smooth and finished surfaces after setting. POP sheet of 2 mm was found broken even at 60 ºC, however no effect was observed for POP-Silica composites even at 200 ºC. Similarly, as the thickness of the sheets was increased from 2 to 10 mm, improvement in structural deformation was obtained for control samples but POP-Silica composites offered added crack resistance and no defect was observed at higher temperatures. Hence it can be concluded that Silica gel is reinforcing POP to obtain more crack resistant composites.

Table 1 — Structural deformations of POP and POP-Silica composites after 60 minutes at different temperatures

Thickness (mm)	Temperature (°C)							
	60 °C		100 °C		150 °C		200 °C	
	CS	SGF	CS	SGF	CS	SGF	CS	SGF
2	Broken into pieces	No effect	Completely disintegrated	No effect	-	No effect	-	No effect
4	Cracks were developed	No effect	Broken into pieces	No effect	Completely disintegrated	No effect	-	No effect
6	No effect	No effect	Cracks were developed	No effect	Completely Disintegrated	No effect	-	No effect
8	No effect	No effect	No effect	No effect	Broken into pieces	No effect	Completely disintegrated	No effect
10	No effect	No effect	No effect	No effect	Cracks were developed	No effect	Broken into pieces	No effect

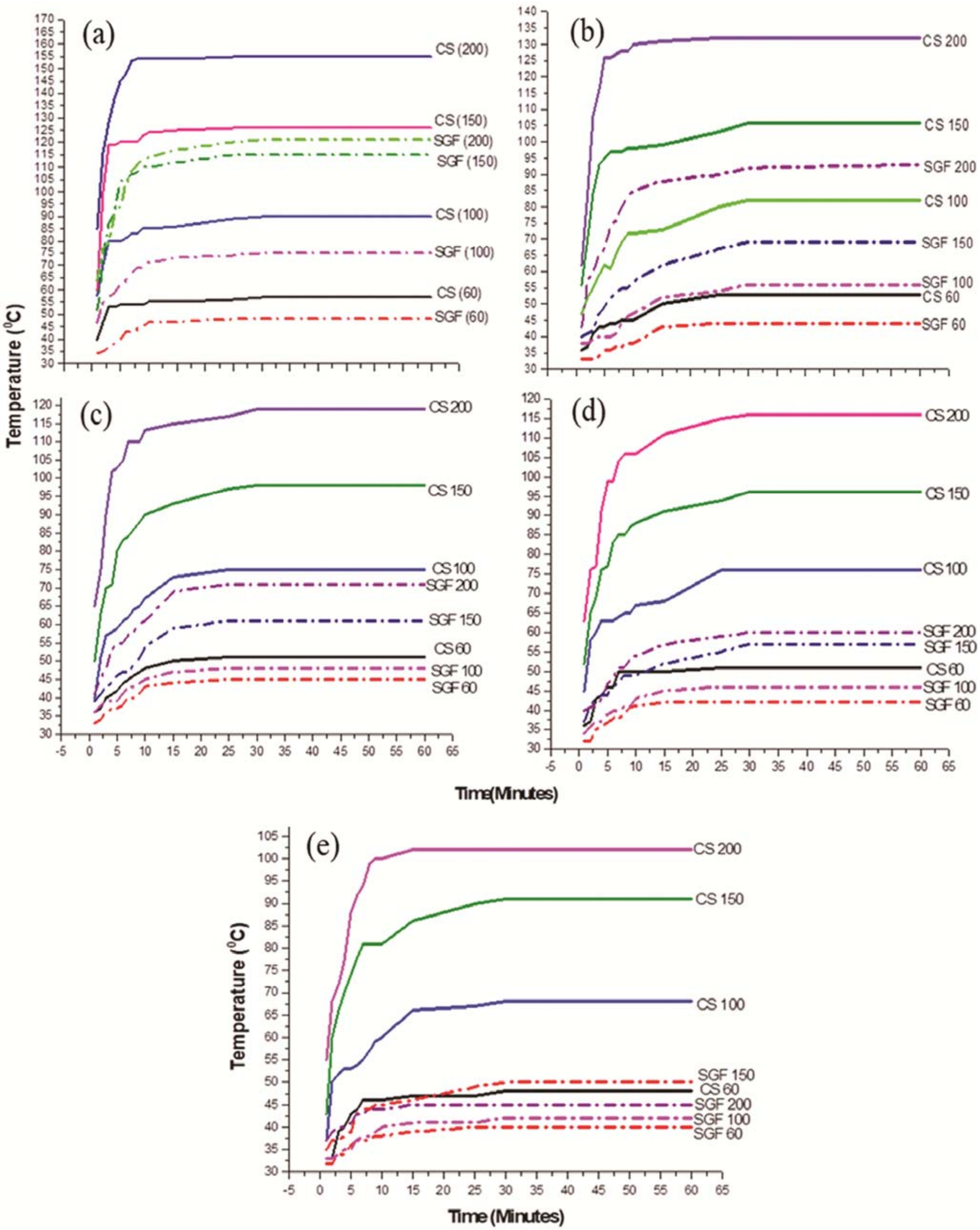

Fig. 1 — Comparative data of CS Vs SGF sheets of varying thickness 2 (a), 4 (b), 6 (c), 8 (d) and 10 (e) mm

Conclusion

Plaster of Paris is widely used as a decorative material in buildings to provide aesthetic appearance to the ceilings and walls. This paper highlights the reinforcement of POP through incorporation of silica gel extracted from raw rice husk. POP-silica composites were casted and at 200 ºC, the difference in surface temperatures between control samples and POP-silica composites was observed as 34, 39, 48, 56 & 57 ºC for 2, 4, 6, 8 & 10 mm thickness respectively, which indicates that silica gel is enhancing thermal insulation significantly and also improving crack resistance of the casted POP-silica composites. The development of these thermally insulated and crack resistant POP-silica gel composites also accounts environmental issues caused due to disposal of raw rice husk. The developed composites may find potential applications where these properties are essentially required under high temperature conditions.

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References

1 Gandhi P, Jagdish V, Karthikeyan G, Chakravarthy A, Nakrani D, Ghoroi C & Srivastava G, Performance of glass-ACP façade system in a full-scale real fire test in a G+ 2 structure, *Procedia Eng*, **210** (2017) 512–519.

2 Chaudhury S, Hazlerigg A, Vusirikala A, Nguyen J & Matthews S, Lower limb intracast pressures generated by different types of immobilisation casts, *World J Orthop*, **8** (2017) 170–177.

3 Soni R K, Teotia M & Dutt K, Studies on synthesis and characterization of a novel acrylic aromatic amide oligomer of aminolysed endproducts generated from pet waste with hydrazine monohydrate and its photocuring with acrylate monomers, *J Appl Polym Sci*, **118** (2010) 638–645.

4 Teotia M, Verma A, Akitsu T, Tanaka S, Takahashi K & Soni R K, TGA Decomposition and Flame Profile Measurement of Terephthalamide Stabilized PVC by Cone Calorimeter, *J Sci Ind Res*, **76** (2017) 438–441.

5 Teotia M, Verma A, Akitsu T, Tanaka S, Haraguchi T & Soni R K, Salen Type Copper (II) Complexes as Flame Retardants for PVC Sheets, *J Sci Ind Res*, **78** (2019) 46–49.

6 Teotia M, Tarannum N, Chauhan M & Soni R K, Structure-based rational design, synthesis, crystal structure, DFT and molecular docking of 1, 4 benzene dicarboxamide isomers with application as hardeners, *New J Chem,* **43** (2019) 7972–7983.

7 Teotia M, Verma A & Soni R K, Prevention of PVC degradation through organic Terephthalamides generated from PET waste, *J App Polym Sci,* **136** (2019) 48022.

8 Teotia M, Tarannum N & Soni R K, Depolymerization of PET waste to potentially applicable aromatic amides: Their characterization and DFT study, *J App Polym Sci*, **134** (2017) 45153.

9 Mittal A, Teotia M, Soni R K & Mittal J, Applications of egg shell and egg shell membrane as adsorbents: a review, *J Mol Liq*, **223** (2016) 376–387.

10 Patil R, Dongre R & Meshram J, Preparation of Silica from Rice husk, *J Appl Chem*, 27 (2014) 26–29.

11 Hubadillah S K, Othman M H, Harun Z, Ismail A F, Rahman M A & Jaafar J, A novel green ceramic hollow fiber membrane (CHFM) derived from rice husk ash as combined adsorbent-separator for efficient heavy metals removal, *Ceram Int*, **43** (2017) 4716–4720.

12 Feng Q, Chen K, Ma D, Lin H, Liu Z, Qin S & Luo Y, Synthesis of high specific surface area silica aerogel from rice husk ash via ambient pressure drying, *Colloids Surf A*, **539** (2018) 399–406.

13 Chen R S, Ahmad S & Gan S, Rice husk bio-filler reinforced polymer blends of recycled HDPE/PET: Three-dimensional stability under water immersion and mechanical performance, *Polym Compos*, **39** (2018) 2695–2704.

14 He Z H, Li L Y & Du S G, Creep analysis of concrete containing rice husk ash, *Cem Concr Res*, **80** (2017) 190–199.