Study of Nanoporous Silica Aerogel Composite for Architectural Thermal Insulation Application

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ABSTRACT

Silica aerogel is a nanostructure material with high specific surface area, high porosity, low density, low dielectric constant and excellent heat insulation properties. In this work, silica aerogel was incorporated in the building material such as cement and white cement to prepare lightweight material with thermal insulating property. Synthesis of Silica Aerogel has been carried out in sol-gel methods. However the sol-gel synthesis method is a fast and efficient method which can be easily carried out on a laboratory scale. Silica Aerogel was prepared using TEOS as precursor, Ethanol, water, ammonia and ammoniumflouride by two step process followed by sol-gel process and supercritical drying process. Characterization of the Silica Aerogel was carried out by BET Analysis to know the porosity. Cement and white cement composites were prepared by varying the loading of silica aerogel. Mixing of silica aerogel with cement and white cement were carried out by mechanical mixing. Composites were dried under ambient condition. Characterization of the composites was carried out by BET, Density of composites was calculated , compressive strength of the composites were tested to know the strength of the composited by increases in loading of silica aerogel. Thermal insulation testing was carried to know the insulating property of the composites.

Keywords: Silica aerogel , thermal insulation property , Nanoporous ,

1. INTRODUCTION

Silica aerogels are nanoporous materials with unusual properties such as light weight , high specific surface area (500-1200 m^2/g), high porosity (80-99.8%), low density (~0.03 g/cm^3), high thermal insulation value (0.05W/mK). High porosity of the silica aerogel is the important aspect of aerogel pore network and its interconnectivity. These pore structures of silica aerogels leads to application as filters, absorbing media for desiccation and waste containment[1]. Building through cooling and heating requirements are major contributors to energy consumption worldwide. In order to prevent current situations, building envelope is very important building components to provide thermal comfort for the residents as well as reduce energy consumption to maintain indoor conditions [2]. Kim et al. reported recently the insulation performance of aerogel cement prepared by mixing aerogel powder, methanol, and cement paste; thermal conductivity of aerogel cement with aerogel mass fraction of 2.0 wt.% was found to be decreased by maximum 75% of aerogel free cement [3].

The most of tradition products are made of the polystyrene and composite materials laminated with the organic and inorganic substances have been used in the building and manufacture fields because of affordable prices to reduce amount of construction costs [4]. The insulation materials are used by themselves in buildings, there is a negative behavior not to show their insulation performance in case of absorbing the leakage water or vapors through the air flow for long time being damaged by external impacts, or releasing toxic gases during a fire[5].

Light weight nanoporous silica aerogel were discovered in the early 1930. The preparation of silica aerogel were described by Brinker and Scherer [6]. The precursors used for preparation of silica aerogel are silica alkoxides such as TEOS (tetraethoxysilane) , TMOS (tetramethoxysilane) etc. Silica aerogel were dried under supercritical condition to remove the capillary force acting on the wall of the each pore, which reduces the surface tension and helps for forming the gel without cracking [7].

This work is interest to study silica aerogel incorporated in cement and white cement. The stability/durability of aerogel particles in concrete is worth studying since the alkaline environment during the hydration of cementitious materials may destroy silica aerogel. The results obtained would be very helpful for the applications of aerogel materials in building sector [8]. In this paper we report an experiment study on lightweight and thermal insulating of silica aerogel incorporated in cement and white cement composites are discussed.

2. EXPERIMENTAL

Materials And Methods

Tetraethoxysilane(TEOS), ethanol , ammonium fluoride , ammonia were used for the synthesis of silica aerogel. Ultra tech cement (Grasim) and white cement (wall care kutti) were used for the preparation of composites with silica aerogel.

Synthesis Procedure

Silica aerogel was prepared by using TEOS:H2O: C2H5OH :NH_3:NH4 F . 0.5M of ammonium fluoride was prepared. 10ml of Ethanol and 7ml of distilled water was pipette out to the breaker on the magnetic stirrer which is stirring at 400rpm. 0.03ml of Ammonium and 0.3ml of ammonia fluoride was added to the breaker after few minutes of stirring . 5ml of TEOS was added to the mixture , stirred after 5minutes. After 5min of stirring a clear sol formed . These sol was transferred to box where sol was formed gel. Gel was kept for one day to form a layer between the box and gel . after the layer was formed . Gel was kept for solvent exchange for one week . Silica gel was dried under supercritical condition. During supercritical drying, the silica aerogel is kept in the cylindrical vessel and the ethanol was added to the cylindrical vessel till the silica aerogel was completely deeped in the ethanol . The cylinder is covered with the lid , clamped and tightens the screws provided. The program was set in the controller in 4 steps , in the first step , the temperature was set to above the critical temperature of ethanol 243°C and critical pressure 80bar . second step was to kept the gel for soaking . third step was venting in two steps . venting step was done to release the pressure and temperature without causing shrinkage and damage to silica aerogel , therefore venting step was done in two steps.

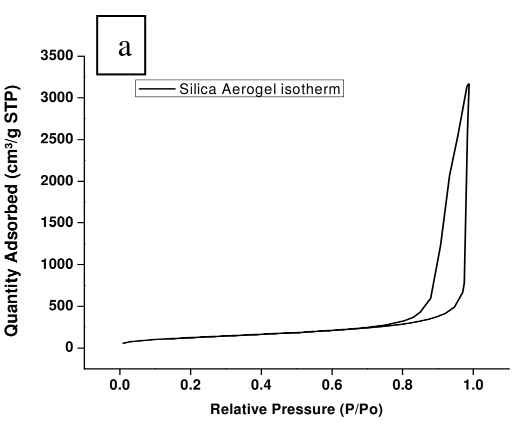
Preparation of cement and white cement composites:

Cement and white cement were taken. Loading of silica aerogel at different weight percent such as 5%, 8%,10% and 12%. The volume percent of silica aerogel for corresponding weight percentage is 25ml, 30ml, 36ml and 45ml. Incorporation of silica aerogel with building material such as cement and white cement was done by mechanical mixing. Mechanical mixing of different weight % of silica aerogel with cement and white cement was done. After that addition of water to the mixture and mixed well. The paste was put to the molds and removal of molds, gives the cement and white cement composites. These composites were dried under ambient condition till it is completely dried. Each one of the cement and white cement composite were kept for curing under water for 3days. After curing, the composites were dried under ambient condition.

3. RESULTS AND DISCUSSION

Silica Aerogel

Brunauer-Emmett-Teller (BET)



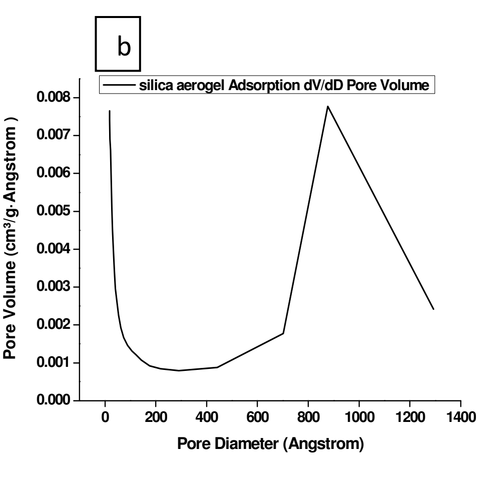


Fig 1(a); silica aerogel isotherm, 1(b); silica aerogel dV/dD pore volume.

From fig 1(a) & 1(b) gives the BET surface area of silica aerogel and adsorption dV/dD pore volume . Brunauer, Emmett and Teller (BET) is the common method used to describe specific surface area, pore size distribution Silica aerogel having surface area of 462.0828 (m^2/g) , Pore Volume 1.030935 (cm^3/g) & Pore Size 89.2424 (Å) .

Silica Aerogel composites:

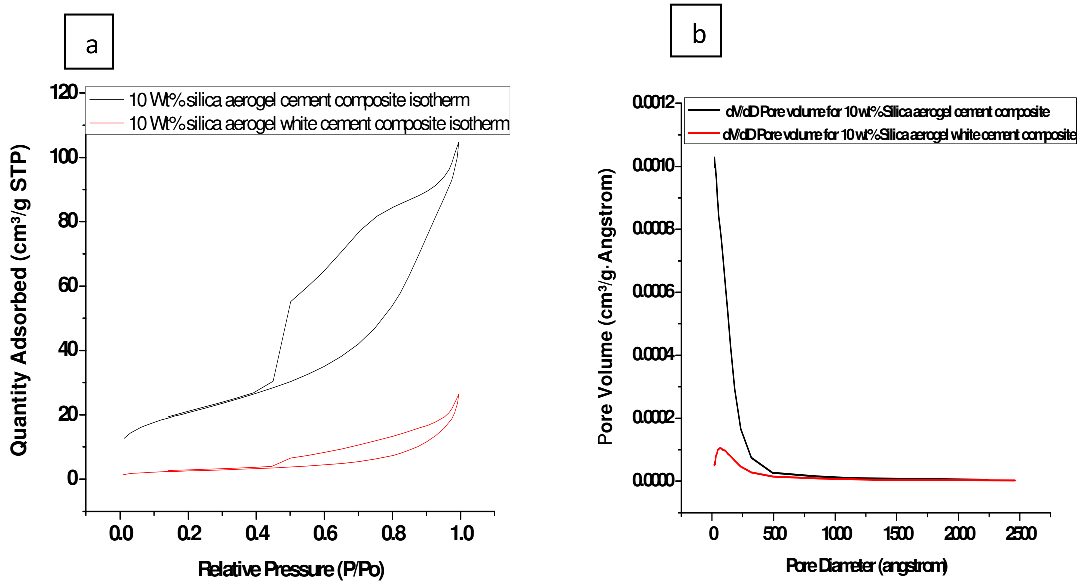


Fig 2: a) comparison graph for 10 wt % silica aerogel with cement and white cement composite isotherm , b) comparison graph for 10 wt% silica aerogel with cement and cement composite dV/dD pore volume.

Surface area of the cement is 2.1680 (m^2/g). 10wt% of silica aerogel incorporated cement composites having a surface area is 74.839 (m^2/g). Pore volume of 10 wt% of silica aerogel incorporated cement composite is 0.1436 (cm^3/g) . Pore size of 10wt% of silica aerogel incorporated cement composite is 76.75(Å). Surface area of the composites increases as the weight percent of silica aerogel content increases.

Surface area of the white cement is 1.1789 m^2/g. 10wt% of silica aerogel incorporated white cement composite having a surface area is 9.2610 (m^2/g) . Pore volume of 10wt% of silica aerogel incorporated white cement composite is 0.0289 (cm^3/g). Pore size of 10wt% of silica aerogel incorporated white cement composite is 125.013(Å). Pore size of white cement composite is high compare to pore size of cement composite.

4. DENSITY VARIATION FOR COMPOSITES:

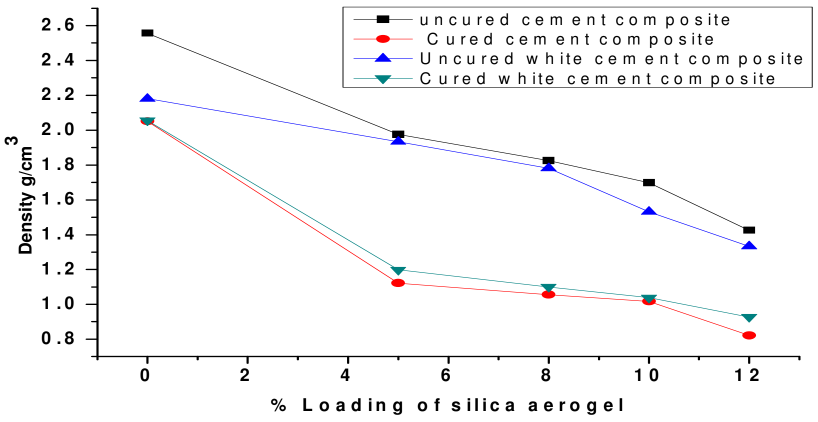


Fig 3: density Vs % loading of silica aerogel for cement and white cement composite

Silica aerogel is characterized by low density and high porosity where the density is correlated to the porosity. The above graph shows the density variation of cement composite with and without curing. On comparing the cement composites with and without curing, cured cement composite is having low density. Comparing the cement and white cement composite, white cement composite shows less density. The density of the composites decreases with the increase in loading of silica aerogels.

5. COMPRESSIVE STRENGTH VARIATION FOR COMPOSITES:

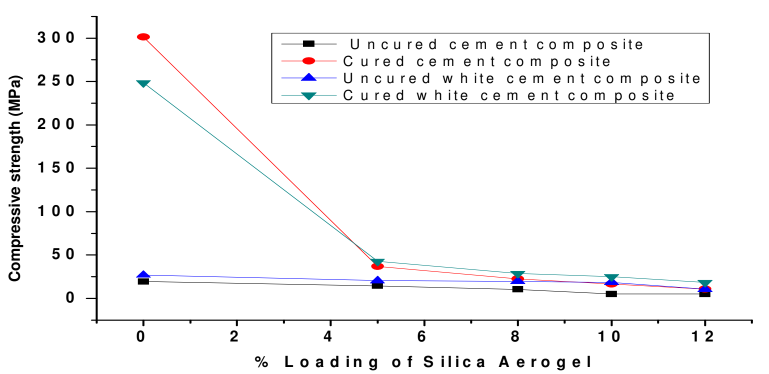


Fig 4: Compressive strength Vs % loading of silica aerogel for cement and white cement composite.

cement composites (with and without curing) were prepared . The strength of the composites were increased when the cement composite kept for 3days curing. Compressive strength of the composites decreases as the % loading of silica aerogel increases. White cement composite with and without curing were prepared . Compressive strength of the cured white cement composite shows more strength than uncured composites.

6. THERMAL INSULATION TESTING

Thermal insulation test was done by placing the composites on heater which is connected to two thermocouples one at bottom of the composite (hot side) and other at top of the composite (cold side). Comparison study of heat transfer from hot side to the cold side of the composites. By comparison uncured cement composites gives better insulation than cured cement composites. Uncured white cement composites shows good thermal insulating properties than the uncured cement composite.

7. CONCLUSION

Synthesis of Silica Aerogel was carried out by sol-gel process. Drying of silica aerogel was carried by supercritical condition. Characterization of silica aerogel shows that silica aerogel have high surface area, low thermal conductivity and porous material. Cement is building material when silica aerogel incorporated with cement, it gives low thermal conductivity and also light weight composites. Cement and white cement composites were prepared by varying the loading of silica aerogel. Density of the composite decreases by increasing the loading of silica aerogel. Cured composites shows the increases in compressive strength compare with uncured composites. Thermal insulation testing results shows that uncured cement composites gives better insulation than cured cement composites. Further study of incorporation of silica aerogel with building material required to increase the strength of the composites and also increase the thermal insulation properties of the composite.

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