A COMPARISON OF MECHANICAL AND FIRE PROPERTIES OF ECO-CORE WITH A COMPATITIVE COMMERCIAL MATERIAL

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ABSTRACT

A fire resistant insulation panel material called Eco-Core has been developed at North Carolina A&T State University. Eco-Core is composed of about 83% fly ash, a waste material from coal-fired power plants. The remainder is a fire resistant organic binder. It is visualized that one application of this new material would be in the construction industry where fire resistance is of primary concern. The mechanical and fire resistant properties of a commercial material, U.S. Gypsum's Type X SHEETROCK, commonly used for these type applications was compared with those of Eco-Core. The results of this study have indicated that the mechanical properties of the Eco-Core are superior in virtually all respects, for example the compression strength was about 4x greater, the tension strength 3x greater, and the flexural strength was 8x greater. In addition, the fire resistance is comparable and the density is about 40% less. The details of this research are provided in the paper.

KEY WORDS: Fire Resistance, Syntactic Foam, Flyash

1. INTRODUCTION

Flyash is a waste product of thermal power plants that utilize coal as the fuel. The coal is ground into a fine powder and injected into the hot furnace. The coal being composed mostly of carbon products burns rapidly to provide the thermal energy to drive the turbines. However, since coal is a natural product, some impurities are present and must be considered. One impurity is natural glass. Since the coal is ground into a fine powder, the natural glass residue is carried out of the furnace as a component of the flue gas. Current environmental laws require that the flue gas be cleansed of components that should not be freely released into the atmosphere. These components must be filtered out of the flue gas, collected and disposal becomes an issue. An article in Science Daily reported that approximately 110 million tons of flyash is produced annually in the United States (reference 1.) Approximately 30% of the flyash waste is used in various processes. Concrete consumes the most as a partial replacement for sand although it does provide some additional desirable characteristics to the concrete mix such as higher compression strength, improved pump-ability, and lower permeability. The remainder of the flyash does not find a commercial use and ends being deposited in landfills.

Flyash can be divided into two classifications. The component that floats on water and one that sinks in water. For the concrete applications, the sinkers are ok but for the subject of this study the floaters are used. The floaters are used in this research because there is an interest to develop a product that is fire resistant, has good thermal insulation properties with a density as low as possible. The floaters are hollow natural glass spheres with diameters ranging from 10 to 300 microns. The sphere wall thickness is about 10% of the diameter with a sphere wall which also contains some closed-cell cellular structure. The flyash used in this study was purchased from Sphere Services Inc. and has been classified it into several grades depending on density and sphere size. The grade used for this research was SG-300 Cenospheres.

The flyash is mixed with a small amount of polymer binder and molded into rigid, lightweight syntactic foam. The primary attributes of the molded material are good thermal insulation, a high level of fire resistance and reasonable mechanical properties. Other properties of the material are being investigated for other than fire resistant applications.

One possible application for this material is for panels of interior walls in buildings that must be especially resistant to the spread of fire. Such buildings may be schools, hospitals and homes for the elderly in the civilian world and various military vehicles and ships in the military world.

The subject of this study is to compare the mechanical and fire resistance properties of flyash based syntactic foam which has been identified as “Eco-Core” with a commercial material extensively used in the building trade. The commercial material selected for this comparison was U.S. Gypsum’s Type X SHEETROCK.

2. EXPERIMENTAL

2.1 Sample Preparation Eco-Core panels were fabricated to resemble the commercial product. This required a face sheet be attached to each surface. Whereas the commercial material uses fire-retardant paper faces the Eco-Core panels were surfaced with a polymer impregnated glass fiber veil.

The formulation of the Eco-Core used for this study was about 83% flyash and 17% polymer by weight. The mixed material had the constancy of “wet sand” and panels were easily fabricated by compression molding. One difficulty encountered was that the flow of the molding compound during compression was limited and required a relatively uniform distribution in the mold to obtain a panel with uniform density.

A prepreg was prepared by impregnating the glass fiber veil (0.2 ounce/square yard) with the polymer. The addition of fumed silica (Cab-O-Sil) to the polymer was found to be useful for providing the viscosity adjustment required to obtain proper flow and adhesion. Two plies of the prepreg were laminated to each surface of the Eco-Core using a compression press with heated platens. The formula used provide for the prepreg resin to penetrate into the Eco-Core approximately 0.007 inches, which was within the desired target range.

The addition of the veil prepreg to the surface enhanced the usefulness of the Eco-Core by providing a hard tough surface. One limitation of the Eco-Core was the friability of the surface. One could damage the surface by scratching the surface with a fingernail. The downside of surfaced Eco-Core was the additional processing steps and materials required to fabricate it plus an increase in overall density.

2.2 Test Procedures

2.2.1 Mechanical Tests Mechanical tests were performed on Eco-Core and Type X SHEETROCK using the same test procedures. The test coupons were machined to dimensions contained within the ASTM Standards applicable for that test. Because the Type X SHEETROCK was 5/8 inches thick the various test coupon dimensions had to be scaled to accommodate the greater thickness.

2.2.2 Density The density is particularly important in evaluating the mechanical properties of any foam material because the properties are highly dependant on the density. Foams with higher density result in increased strength. For this project, low density is desirable so that the formulations and processing steps were designed to provide the lowest possible density. However, the greatest strength for a given low density is one of the objectives of this research. The density in grams/cc is calculated by weight in grams divided by the volume in cubic centimeters. The volume is determined by dimensional measurements. Since the properties are density dependent, the density of each coupon was determined before testing.

2.2.3 Mechanical Test The tensile strength tests were performed in accordance with ASTM D-3039/D-3039M except the test coupons were scaled to a larger dimension to accommodate thicker material. The compression strength test was performed in accordance with ASTM C-365. The shear strength test was determined by Iosipescu shear tests that were performed in accordance to ASTM D-5379/D-5379M. The fracture test was performed in accordance with ASTM E-399. The details of the coupon dimensions are given in references 3 & 4.

2.2.4 Nail Fastening Test For wall panels, nailing is one of the optional methods of attachment. A number of different nail and screw designs and sizes were driven into the Eco-Core panel to determine if this was a viable option for attachment. A wooden backup board was used to minimize “breakout” on the backside of the panel.

2.2.5 Fire Test The fire tests were performed using a propane torch as purchased at a local hardware store. The test coupons were machined to approximately a 15 X 15 centimeter square. All fire tests were performed in a fume hood to exhaust any fumes or smoke that would be generated during the test. The specimens were firmly mounted perpendicular using mechanical supports. The propane torch was firmly positioned two inches from and perpendicular to the face of the panels. This setup is illustrated in figure 1.The test panels had three thermocouples mounted against the panel surface to monitor the temperature rise during the test. The positions of the thermocouples are illustrated in figure 2. The tests were scheduled to run for 30 minutes. A video camera was used to record the visual information during the 30-minute test. A photograph of the propane torch flame impinging on the coupon is shown in figure 3.

Figure 1 Photograph of fire test setup showing video camera, propane torch and test coupon

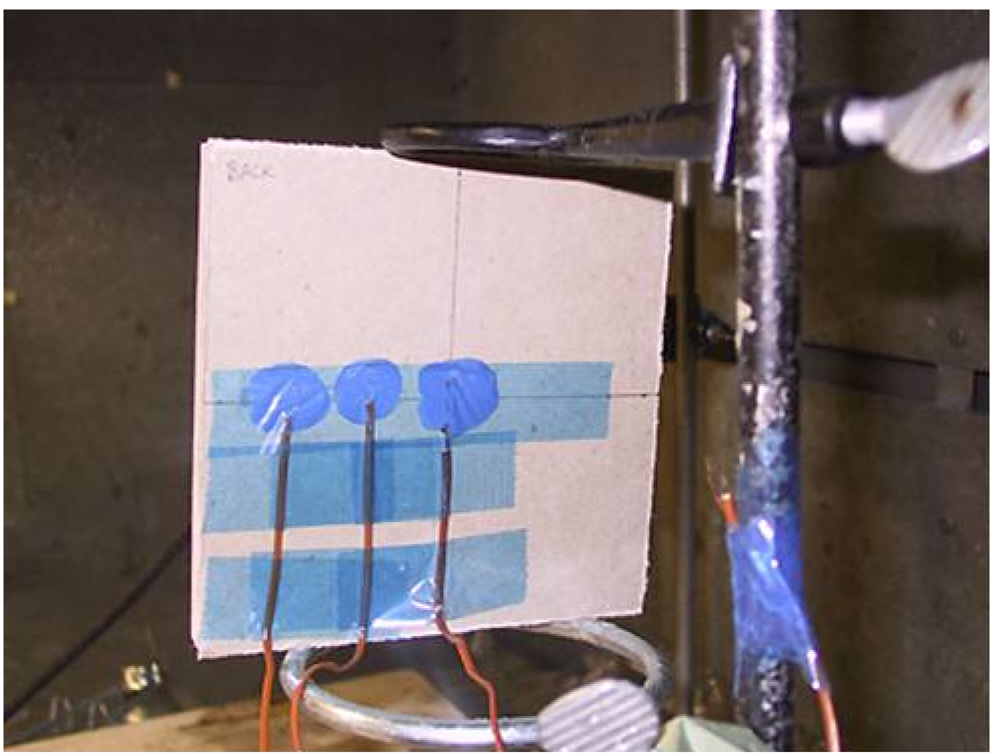

Figure 2 Photograph illustrates the location of the three backside thermocouples on the Type X SHEETROCK before the fire test

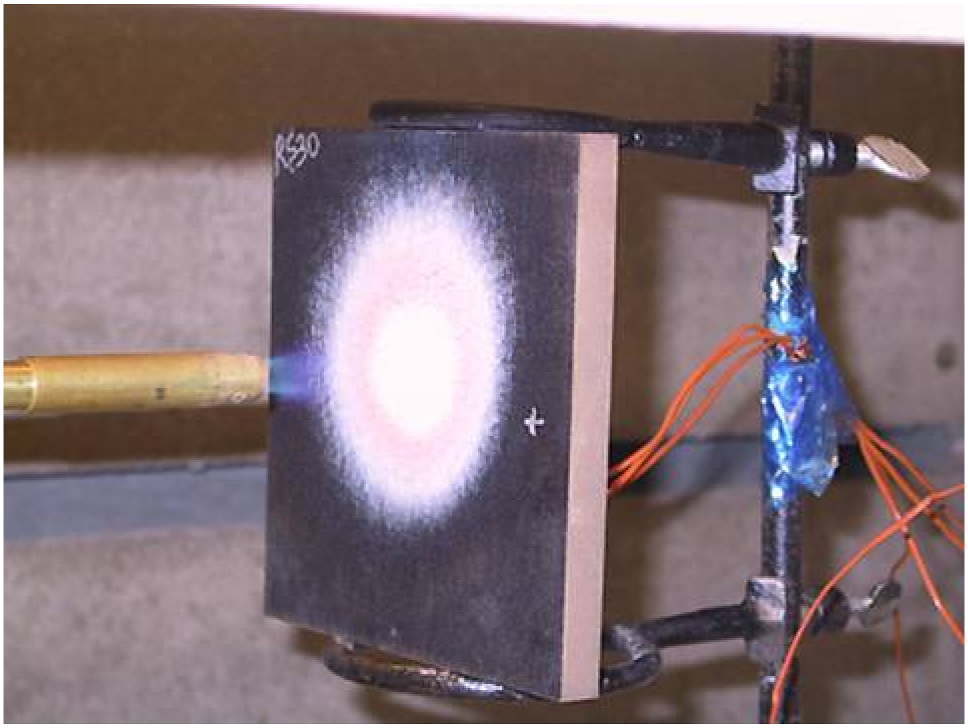

Figure 3 This photograph illustrates the impingement of the propane torch flame on the Eco-Core coupon.

3. RESULTS AND DISCUSSION

Table 1 is a summary of the properties determined for the Eco-Core and Type X SHEETROCK. The data reported here represents the average of four or five coupons.

Table 1 Comparison of properties

Property	Eco-Core	Type X
Density (g/cc)	0.50-0.51	0.80-0.83
Tensile Strength (MPa)	4.18	1.40
Compressive (MPa)	8.85	2.09
Shear (MPa)	2.24	1.16
Fracture (MPa-m $^{1/2}$)	0.32	0.15
Flexural (MPa)	10.14	1.40

For each of the properties measured, the Eco-Core stands out as a more desirable material. The lower density of the material, 0.5 versus 0.8, is quite significant considering it also has greater mechanical properties. The tensile strength of the Eco-Core is roughly three times greater than the Type X material whereas the compressive strength is about four times greater. In addition, the shear strength is two times greater and the flexural strength came in at eight times greater. The fracture resistance was greater by a factor of two.

The Eco-Core responded to the nail and screw test very much like the Type X SHEETROCK indicating the same mechanical attachment techniques would be applicable.

During the propane torch fire test, the Type X SHEETROCK produced flame and smoke as the paper was burned away during the early part of the test. Under the same conditions, the Eco-Core produced neither flame nor smoke.

The thermocouple mounting scheme for the most part worked well. However, an analysis of the data indicates that one thermocouple on the Type X material did give erratic results indicating intimate surface contact was lost during the test.

As illustrated in figure 4, the maximum temperature reached during the propane flame test of the Eco-Core stabilized at about 304 C about 10 minutes into the test. Whereas about one inch from the coupon center, the temperature stabilized at about 238 C about 15 minutes into the test. About two inches from the center the temperature continued to increase during the entire 30-minute test ending at 132 C.

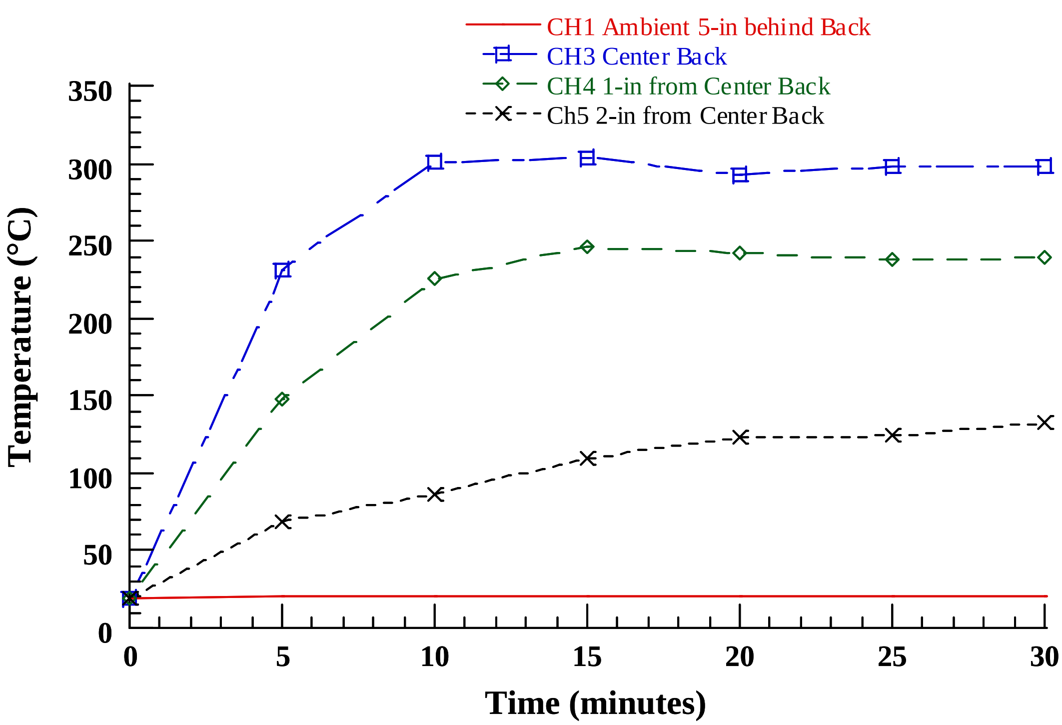

Figure 4 Temperature measurements during the propane flame fire test of Eco-Core

As illustrated in figure 5, the center thermocouple on the Type X material stabilized in about 20 minutes at about 360 C. The thermocouple measuring the temperature one inch from the center seems to have lost contact with the surface as the reading were erratic. The thermocouple two inches from the center rose slowly to about 60 C.

The temperature rise at the center of the coupon was slower for the Type X material although the temperature reached was about 38 C higher than the Eco-Core. It is speculated that the Type X material was losing water of hydration within the Calcium compound. The water loss would have a cooling effect until the water supply was exhausted.

The propane torch flame test indicated the temperature response of the two materials were different but either would be good fire resistant material for construction.

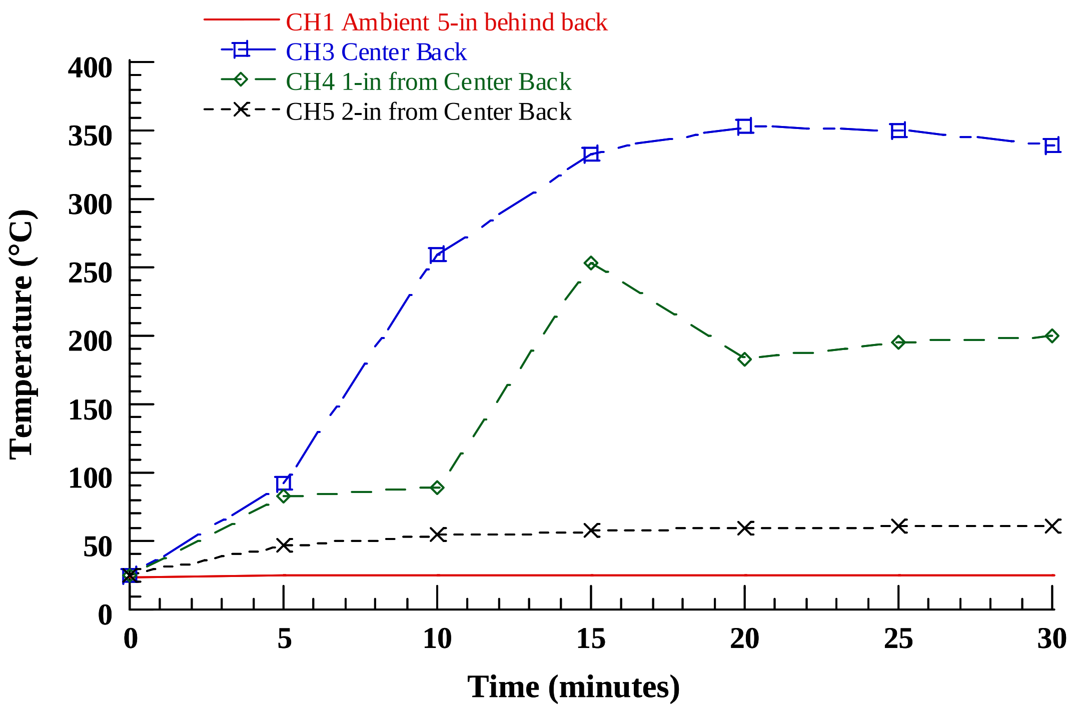

Figure 5 Temperature measurements during the propane flame test of Type X SHEETROCK

4. SUMMARY

The significantly higher mechanical properties as well as lower density would indicate that the Eco-Core material would have significant advantages over the Type X material. The fire resistant characteristics illustrated in this research indicated the two materials are somewhat equivalent. However, the Eco-Core material has only been produced under laboratory conditions and Type X SHEETROCK is a commercial material with full fire code certifications.

The Eco-Core material production should be scaled up to a pilot plant level so that sufficient material would be available for fire certification test such ASTM E-19 and E-84. The commercialization of Eco-Core would be a big step in making use of a waste product now destine for a landfill as well as adding a valuable alternative to architects designing future buildings or engineers designing future military hardware.

5. ACKNOWLEDGMENTS

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