

Fire Performance of Calcium Silicate Board

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ABSTRACT

The article presents fire performance investigation of the Calcium Silicate Board (CSB). The CSB was tested on different fire standard test apparatuses to determine the “Reaction to fire characteristics” such as surface spread of flame (SSOF), fire propagation index (FPI), ignitability (IG) and non-combustibility (NC). BS standards were used to determine above said characteristics. To determine the fire characteristics SSOF, NC, FPI, IG test apparatuses were used.

Different kinds of woods and wood based products are being used in buildings for door, window, ceiling and flooring purpose. But wood and their products are flammable in nature. They catch fire very easily; flame spreads on it rapidly and releases the heat during fire situation. The fire behaviour of wood was exceptionally dangerous and their use in buildings is very risky. So there is a need of some non-combustible materials which can easily be used as “fire safe” material in buildings.

CSB does not have any asbestos content. The main ingredients of this board are cement, sand, cellulose fibre, and water which are mixed in a tank and heated up to a certain temp. Then the dove is put in moulds and incubator. A chemical reaction takes place there to form calcium silicate. After that finally the board is cut in to pieces.

Keywords- fire performance, Calcium Silicate, materials, CSB, Plywood, etc.

S. No.	SHORT FORM	FULL FORM
1.0	SSOF	Surface Spread of Flame
2.0	FPI	Fire Propagation Index
3.0	RTFC	Reaction to Fire Characteristics
4.0	CSB	Calcium Silicate Board
5.0	IG	Ignitability
6.0	NC	Non-Combustibility
7.0	FT	Furnace Tube

NOMENCLATURE

INTRODUCTION

The CSB is safe to use in buildings as lining material. The CSB is used as a thermally insulated product which can withstand high temperatures during fire situations. It is “fire safe”, light weight in nature, have low thermal conductive, very

good strength, easy to use, moisture and heat resistant product.

This article states about the manufacturing of CSB and their testing w.r.t thermal conductivity and flexural strength. This may be used as improved building material

due to good strength and thermal conductivity¹.

This article states about preparation of board using calcium silicate, vermiculite, silica. This board can be cut, screw, saw, and nails easily. The board can also control humidity².

This technical note states about some small scale fire exposure test (total 12 nos.) as per ASTM E-119 on CSB, gypsum board and plywood. Plywood and gypsum board resist fire for 15 mint. and CSB resist fire for 12 mint.³

This research states about determination of thermal and moisture properties of CSB. Pressure plate test was carried out on CSB and calcium hydroxide board to measure desorption isotherms in capillary range⁴.

The study states about the performance of CSB partition against standard test of fire. The examination results that CSB play a big role against fire proof effectiveness. The board was tested in composite form not separately⁵.

This research states about physical properties of calcium silicate cement board on kaolin. The board was made by using silica sand, pulp (cellulose), clay and cement.

The board was tested for their physical and mechanical properties. Scanning Electron Microscopy (SEM) testing was also carried out to check the surface morphology for the prepared boards⁶.

The research was done to find out the effects of pulp on CSB discover and establish the level of regulation on factors that affect the type / characteristics of the pulp so that it can generate optimal quality CSB. The evaluations were performed by the Taguchi technique and quality characteristics like deflection, strength, density and water absorption⁷.

A CSB was prepared using solid waste of coal, calcium silicate slag, fly ash and flue gas desulfurization gypsum. To find out changes in mineral phases, chemical

structure and morphology etc some testing were performed like X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM)⁸

EXPERIMENTAL DETAIL AND METHODOLOGY

Some specimens of CSB of different sizes were purchased from local market to determine the different fire characteristics and British standards were used for characterization of same. To determine the SSOF, BS-476 Part 7, to determine NC, BS 476 part 4, to determine IG, BS 476 part 5, to determine FPI, BS 476 part 6 were used.

FPI

The FPI of materials is used to identify the likely hazard of products in terms of their property to contribute towards the growth of fire inside the occupancy. The higher the FPI, the higher was the effect of the material in accelerating the increase of fire. The evaluation details of determination of the FPI which specified in BS 476 Part-6, were adopted.

APPARATUS

The Fire Propagation apparatus essentially contains of a rectangular combustion chamber. The product holder forms one large vertical face and air is entrained through an inlet on the opposite face. A tubular gas burner via a row of flames near the bottom edge of the product provides heat to the combustion chamber and supplementary radiant heat is also provided by two electrically heated element rods contained in transparent silica tubes.

The products of combustion generated during the evaluation are allowed to go through a chimney and cowl arrangement where the thermocouples were placed for measurement of temperature.

SAMPLE

The sample which represents the material is needed in the dimensions 225 ± 1.5 mm x 225 ± 1.5 mm and of nominal thickness not more than 50 mm. If the both surfaces of the sample differ then both the faces are to be tested. Before evaluation, the sample shall be conditioned to equilibrium with air at 21°C and 55–65% relative humidity.

PROCEDURE

For FPI assessment, a calibration run was done with a fire proof board of specified properties (12 mm thickness). Same runs were done on the products setting the gas flow rate of the flame burner and power supply. The all parameters were same as in the case of the calibration run for the

radiant heaters. The time–temperature values were recorded for the products and the calibrations.

OBSERVATION

For FPI determination the time–temperature values were recorded for the calibration board for twenty minutes. The temp. were also noted against time for the product.

EXPRESSION OF RESULTS

For FPI determination a comparative statement of the time–temperature history of the specimens of material with a time–temperature history of the calibration was used to calculate the sub–indexes i_1 , i_2 & i_3 and the overall performance i.e. the FPI (I) as follows for each specimen.

$$I = i_1 + i_2 + i_3$$

$$\frac{\sum \theta_m - \theta_c}{10 t} + \frac{\sum \theta_m - \theta_c}{10 t} + \frac{\sum \theta_m - \theta_c}{10 t}$$

1/2min interval 1 min interval 2 min interval.

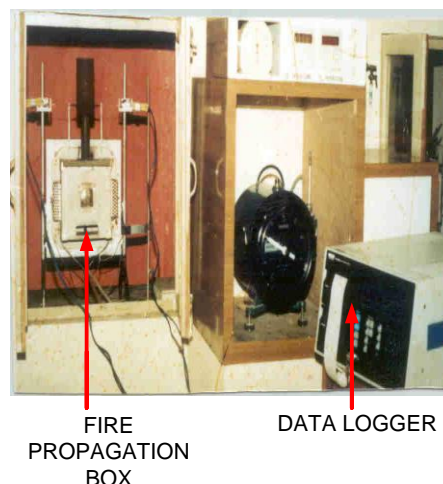


Fig.1:-Fire Propagation Index test apparatus

SURFACE SPREAD OF FLAME TEST APPARATUS

Flammable lining products once set on fire can support SSOF, so allowing the fire to spread over the surface of the sample. The SSOF evaluation was a method of

assessing this property and classifying these products on the basis of the rate and distance of SSOF. The classification, elaborated specified in BS 476 Part-7 was followed for assessing SSOF.

APPARATUS

The test apparatus having a straight up radiant panel of refractory, size 900 mm² which fired by air-gas mixture. The specimen holder was hinged with radiant panel. It has a provision for mounting a product to be evaluated. During the assessment the product was at 90° to one vertical side of the panel. The product was given a specified level of radiation decreasing along with length. A pilot flame was applied at hotter end.

SAMPLE

The products were required in dimensions 900 mm (L) x 270 mm (W) and of nominal thickness up to 50 mm. If product has two different faces of different materials then both the faces have to be tested. The products should be conditioned at a temp. of 23 ± 2°C and a relative humidity of 50 ± 10 prior to evaluations.

PROCEDURE

For **SSOF** evaluation, a radiant panel was used designed to give effective combustion of gas and air mixture. There was no flaming occurring on the face of panel when lighted. Air and gas flow were set for a uniform radiation existing on the face of the radiant panel. The product holder with board used for calibration was put to the 90° angle against the radiant panel. After attaining the thermal equilibrium on the front of the calibration board the irradiances were noted at specified distances given in standard (e.g. 75 mm & 825 mm) from the radiation panel. The irradiance achieved at specified distances was 32.5 kw/m² and 6.5 kw/m², respectively denote thermal equilibrium and the test apparatus was ready for SSOF determination. The classification of product was done as per distance covered by fire on the surface of product as per given in table-1.

Table 1:-Classification for SSOF test as per BS-476 Part -7

SURFACE SPREAD OF FLAME CLASSIFICATION		
Classification	Flame Spread at 1.5 Min. Limit(mm)	Final Flame Spread Limit(mm)
Class 1	165	165
Class 2	215	465
Class 3	265	710
Class 4	Beyond the limit for class 3	

OBSERVATIONS

For determination of **SSOF**, time was recorded for each product at which the sustained flaming, on the front, travelling along the horizontal reference line, crosses each vertical reference line. The increase in flame spread was also recorded along the reference line at 1.5 minute and 10 minute. Behavior of the product was carefully observed continuously during evaluation for flashing, debris falling away from the product, flaming or not flaming, intumescences deformation and transitory flaming etc.

Observations were made of any kind of softening, dripping, melting or disintegration of product during first sixty seconds. Observations for the separation of the facing from the product or any other behaviour which results in the exposed face not being exists for flame spread travel were also made.

For spread of flame measurement on the surface of every product results were given as follows

The time at which the front of flame crosses every vertical reference line,

The maximum area of flame spread during first, one and half minutes from start of the assessment,

The maximum extent of travel of flame during the complete assessment period i.e. ten minutes or less,

The time and distance at which maximum flame spread is attained.



Fig.2:-Surface Spread of Flame test apparatus

Non-combustibility

The NC of a material is found out in order to ascertain whether it will or will not contribute directly to fire growth. It is essential for selection of materials, which, while flammable, may generate only a limited amount of heat and flame when come in to contact of fire @ temperature of approximately 750°C under the specified exposure conditions.

Furnace

The NC furnace contains of a FT which can be operated electrically and is thermally insulated from outside. The furnace gives a cylindrical space of 75 mm diameter and 150 mm height, in which specimens of a material to be evaluated are placed during experiments. An airflow stabilizer at the base and a draught shield at the top of the FT are provided. The furnace is raised to a temperature of 750°C and maintained at a temperature, $750^{\circ}\text{C} \pm 10^{\circ}\text{C}$ as specified in BS 476-Part 4 be the start of the evaluation. Two thermocouples are placed for measuring temperatures at specimen centre and near the furnace wall.

Specimen

The specimens of a material are required in the following measurement 40 mm x 40 mm x 50 mm. Three specimens are normally needed for the evaluation of a product. Specimens of thickness less than 50 mm are joined in layers to get the specimen of 50 mm total height.

PROCEDURE

For **Non-combustibility** determination, before evaluation, the furnace is set to $750 \pm 10^{\circ}\text{C}$ as monitored by the furnace wall thermocouple. The furnace is stabilized at this temperature for a given time period. The specimen, whose weight is already taken, is put in a specimen holder, which also have provided with thermocouple for measuring temperature of the specimen at centre position. The thermocouple placed in the centre is now pushed inside a hole made in the centre of the specimen such that a good thermal contact is achieved between the specimen and the tip of the centre thermocouple. The specimen holder takes the specimen and thermocouple is pushed into the furnace environment in a given position so the

specimen is uniformly exposed to the heating environment of the furnace.

At the time of experiment, the temperature and time are measured. Observations of duration of sustained flaming indicated by continuous presence of flames in to the furnace for more than 5 sec. are also measured. The total time of experiment with each specimen is twenty minutes. The specimen and the holder are pulled out of the furnace, after the experiment is over. On cooling the specimen to the ambient temperature, the specimen is taken out from the holder and weighed. Where char, other debris breaks off and falls down the tube during experiment and ash are recovered and taken in to account as a part of the unconsumed specimen mass.

OBSERVATIONS

During **Non-combustibility** experiments, the following observations are made

- * The mass before and after the experiment for each specimen and any relating to the behaviour of the specimen during experiment is recorded.

- * The occurrence of any sustained flaming and duration of such flaming are recorded.

- * The following temperatures, as measured by the appropriate thermocouples during the experiment period are recorded

The initial furnace temperature, T_F (initial)

The maximum furnace temperature, T_F (max)

The maximum specimen centre temperature, T_C (max)

IGNITABILITY

The reaction to fire with respect to the tendency of a material to get ignited by a small flame at ambient temperature was determined of CSB on the IG apparatus. The evaluation details of the determination of ignitability, specified in BS 476 Part-5 were adopted. This evaluation enables the identification of 'easily ignitable' and 'not easily ignitable' materials.

APPARATUS

The apparatus consists of a U-shape frame fixed to a steel base having clamps to hold the specimen vertically in the centre. Two supports were welded vertically to the base on which the lower edge of the product rests during evaluation. A copper tube was reduced at one end to 1.5 mm diameter orifice and riveted on a set strap jointed to the base and provided with a changeable stop so that when set-up to a position the tube was leaning at an angle of approximately 45° to the vertical and the orifice centre was 3 mm from the centre of the front of the product.

SAMPLE

The specimens should be 228 mm x 228 mm (+0 - 1.2 mm) and of the thickness of the product, which they represent is 50mm (max.). The evaluation was done either for individual products or for composite materials. Three fresh specimens were used for each face evaluation. Before evaluation, the specimens shall be conditioned to equilibrium with air at 10–21°C and 55-65% relative humidity.

PROCEDURE

The samples of the material were situated in a vertical position by the cinches and the gas burner opening was set on to its right position. The burner hole was set away from its trial position and the gas was set on for getting a fire freeing a predefined calorific result. After start of the gas stream, the burner was put rapidly to its test position; a halted clock was placed on at the same time. The fire was applied uniquely for 10 seconds on the essence of the item and eliminated the stream following 10 seconds. The observations were taken for blazing if any, after the utilization of fire.

OBSERVATIONS

Observations were taken of item blazes for over 10 seconds subsequent to putting off the fire. Observations were additionally

taken for the degree of consuming on the uncovered essence of the sample.

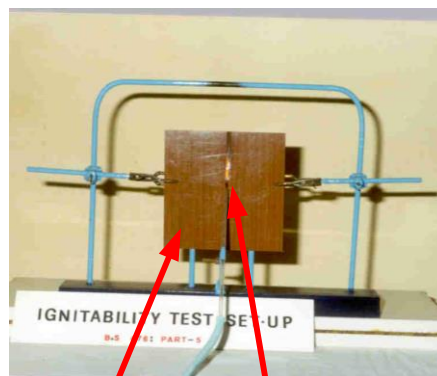
EXPRESSION OF RESULTS

Ignitability

If any flame observed on the surface of specimen for more than 10 seconds after the putting off the flame or if burning of the product moving toward the edge within this 10 second, the material was classified

as ‘Easily Ignitable’ and the performance was indicated by the letter ‘X’.

If no flame observed on the surface of specimen more than the period of 10 seconds after setting off the flame and flame does not move towards the edge in this duration, the product was classified as ‘Not Easily Ignitable’ and the letter ‘P’ indicates its performance.



TEST SPECIMEN PILOT FLAME

Fig.3:-Ignitability Test Apparatus

EXPRESSION OF RESULTS

For **Non-combustibility** determination the following expressions are made

Temperature Rise

The temperature rise, recorded by the furnace and specimen centre thermocouples for each specimen is calculated as follows

* Furnace temperature rise, $\Delta T_F = T_{F(max)} - T_{F(initial)}$

* Specimen centre temperature rise, $\Delta T_C = T_{C(max)} - T_{F(initial)}$

Flaming

- ❖ For each specimen the sum of recorded duration of sustained flaming is noted.
- ❖ The arithmetic mean of the sustained flaming of the three specimens is calculated and recorded as the “mean duration of sustained flaming.

The mass loss is calculated and recorded as follows

- The mass loss of each individual specimen in each experiment given as percentage of the initial weight of the specimen.

- The arithmetic mean of the mass loss of the three specimens in each series of experiments, expressed as a percentage. The specimens of CSB were evaluated for Non-combustibility in accordance with BS 476-Part 4. The specimens of the dimensions 40 mm x 40 mm x 48 mm

were exposed in Non-combustibility furnace for 20 minute; temperatures of the furnace and specimen centre for each specimen were recorded continuously.

The mass of each specimen was recorded before and after evaluation. Occurrence of any sustained flaming and record of duration of such flaming was made.



Fig.4:-Non-combustibility

FIRE PROPAGATION INDEX TEST

The time v/s temperature values for the samples of CSB and those for the calibration run done during experimental examinations of FPI were utilized to figure

out the values of three sub-lists and overall FPI. The normal of the figured upsides of the sub-lists and the general FPI for CSB are given in Table-2.

Table 2:-Fire Propagation Index of CSB

S. No.	Material	Fire Propagation Index	
		i_1	I
1.0	CSB	1.36	5.40

SSOF

The SSOF classification of the sample of CSB was determined by its property to travel of fire over the front surface as shown by the distance of fire travel along

the reference line on the heated surface. The method specified in BS 476 Part-7; 1987 was followed for determination of ssf. The classifications of test results are summarized in Table 3.

Table 3:-SSOF classification of CSB

S. NO.	Material	Observations	SSOF Classification
1.0	CSB	Nil flame on the surface of sample	Class-1

7.5 Non-combustibility

The results of the Non-combustibility experiments on the specimens of CSB are given in Table 4

Table 4:- Computed mean results of Non-combustibility evaluations carried out on the specimens of CSB, (Nominal Bulk Density $400 \pm 50 \text{ kg/m}^3$)

Furnace Temperature Rise $\Delta T_F = \{T_{F(\text{max})} - T_{F(\text{initial})}\}$	24 deg.C
Specimen Centre Temperature Rise $\Delta T_C = \{T_{C(\text{max})} - T_{C(\text{initial})}\}$	19 deg.C
Duration of Sustained Flaming (Second)	NIL
Mass Loss (Percent)	9.9

Classification/Designation Non-combustible

IGNITABILITY TEST

The CSB was tested on IG test apparatus according to BS 476 Part 4. The outcomes got during trial examination for the Ignitability of CSB were summed up in following Table-5.

Table 5:-Ignitability Classification of CSB

S.No.	Material/Products Details	Classification
1.	CSB Board Thickness 10mm)	“P” Not Easily Ignitable

During the evaluation of Ignitability on the samples of CSB, no blazes on the outer layer of samples were seen after the removal of the standard flame and burning did not extended to any edge.

CONCLUSION

The “Reaction to fire characteristics” of CSB were found very well. In ssot test CSB found was class- I, which means there was no flame observed on the surface of specimens. Fire Propagation Index (I) and sub index (i) were 5.40 and 1.36 which are good. The FPI should be $i \leq 6$ and $I \leq 12$ as per BS 476 Part 6.

It means it contributes less heat in fire growth. As per Ignitability test it was found “Not Easily Ignitable” which means after removal of burner there was no flame observed on the surface of specimens. So it does not catch fire easily during fire conditions. The CSB classified as Class-1

on Surface Spread of Flame Classification test which means no flame or flame less than 75 mm of distance travelled on specimens surface. The CSB also found non-combustible means there was no flame sustained on the specimen during the test.

As per the result of tests for “RTFC” one can say that CSB is “fire safe” material which do not spread fire over its surface, contribute less heat during actual fire conditions, don’t ignite easily and also it is non-combustible. As per National Building Code the materials which are non-combustible and which have class –1 classification in ssot test, can easily be

used in any situation in buildings.

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