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Paper #13

CALCIUM SILICATE BOARD SYSTEMS FOR FIRE RESISTANT STRUCTURES

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ABSTRACT

The system which is presented in this paper describes a drywall system structure which consists of inner cladding and outer cladding using calcium silicate boards. The structural elements used are zinc-galvanized steel.

The system is called DURA FireStop. This system was tested according to ISO 1182:2010 for non-combustibility and BS 476-22:1987 for fire resistant systems. Physical properties such as flexural strength, density and moisture movement were tested according to ASTM C1185-08.

The DURA FireStop structural system passed all the tests mentioned above and can be considered to be a successful product for wall systems in building products.

KEYWORDS:

DURA FireStop, Fire resistance, Calcium silicate, Non-combustible, Hiep Phu Corporation

1. INTRODUCTION

Calcium silicate products are very popular for dry wall and non- supporting structures. Its non-combustibility and prevention of flame spread properties are excellent and can stop the flame propagation from the room where the fire started to any neighbouring rooms. It's really useful for protection of people and their belongings; DURA FireStop is the solution for this application.

Fire resistant properties of the product depend on density and some additives such as perlite, mica, vermiculite and others. Perlite and mica contribute to lightweight boards and lower wet/dry shrinkage whereas the alumina component is very useful for heat control.

Lower density and lower moisture expansion can be achieved using the Autoclave process. During autoclaving some mineral components in cement such as C2S, C3S will react with SiO2 at 1800C to form Tobermorite. Tobermorite is the major component for calcium silicate boards and provides the structure for improved flexural strength and stability of the board.

Calcium silicate products have been tested according to international standards, in particular ISO 1182 – non-combustible test, BS 476-22 for a fire resistant system for non-supporting structures. Physical properties such as flexural strength, density, moisture movement were tested according to ASTM C1186.

Another competitive advantage of this product is resistance to moisture movement and is a big advantage in high humidity environments.

2. FIREPROOF WALL SYSTEM STRUCTURE DURA FIRESTOP

Fireproof wall system is structured as in Figures 1, 2, 3 and 4.

No.	Material	Brand name / Supplier
1	Vertical studs	VT V-Wall, Zinc-galvanized Steel C 75x35x0.5 (mm)/ Vinh Tuong
1	Track runners	VT V-Wall, Zinc-galvanized Steel U 76x32x0.5 (mm)/ Vinh Tuong
2	Insulation rockwool	Rockwool (Thailand) Ltd. Norminal Density of 100kg/m3
3	Inner Cladding Calcium Silicate Boards	DURAflex : 6.0 x 1220 x 2440 (mm) Density: 1.36 g/cm3
4	Outer Cladding Calcium Silicate Boards	DURA FireStop : 10.0x1220 x2440 (mm) Density : 0.9 g/cm3
5	Screw	W-25, 40/ Vinh Tuong
6	Fiber mesh tape	Vinh Tuong Fiber Mesh Tape Vinh Tuong
7	Expansion bolts	
8	Joint treatment powder	GYPFILER JOINTING
9	Fire resistance sealant	KCC 9535/ Korea

Table 1: Description of detail of tested specimen.

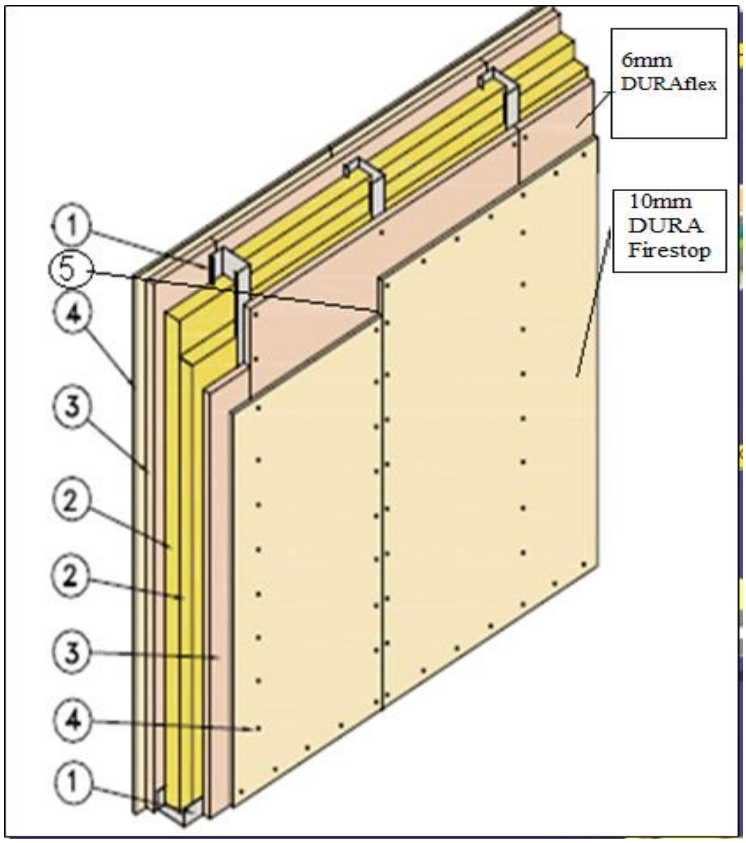


Figure 1: Fireproof wall system structure

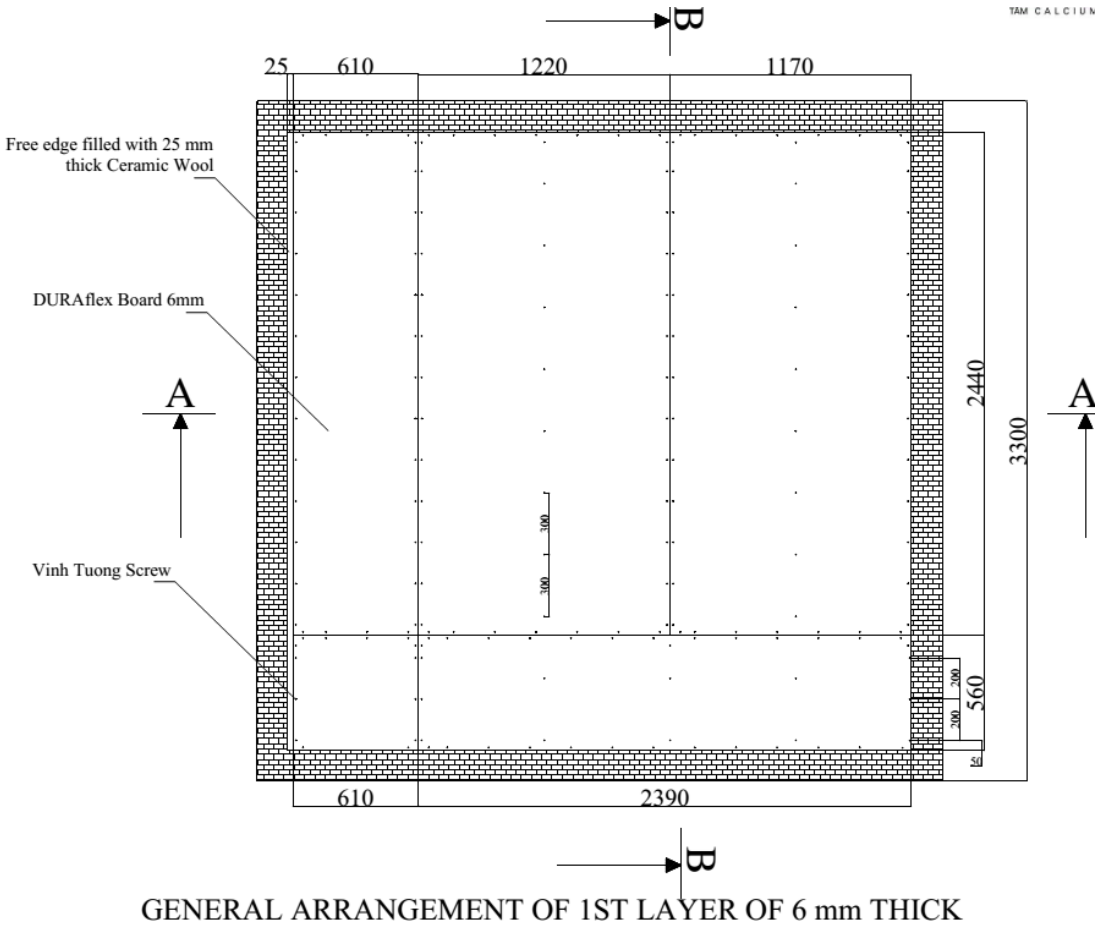
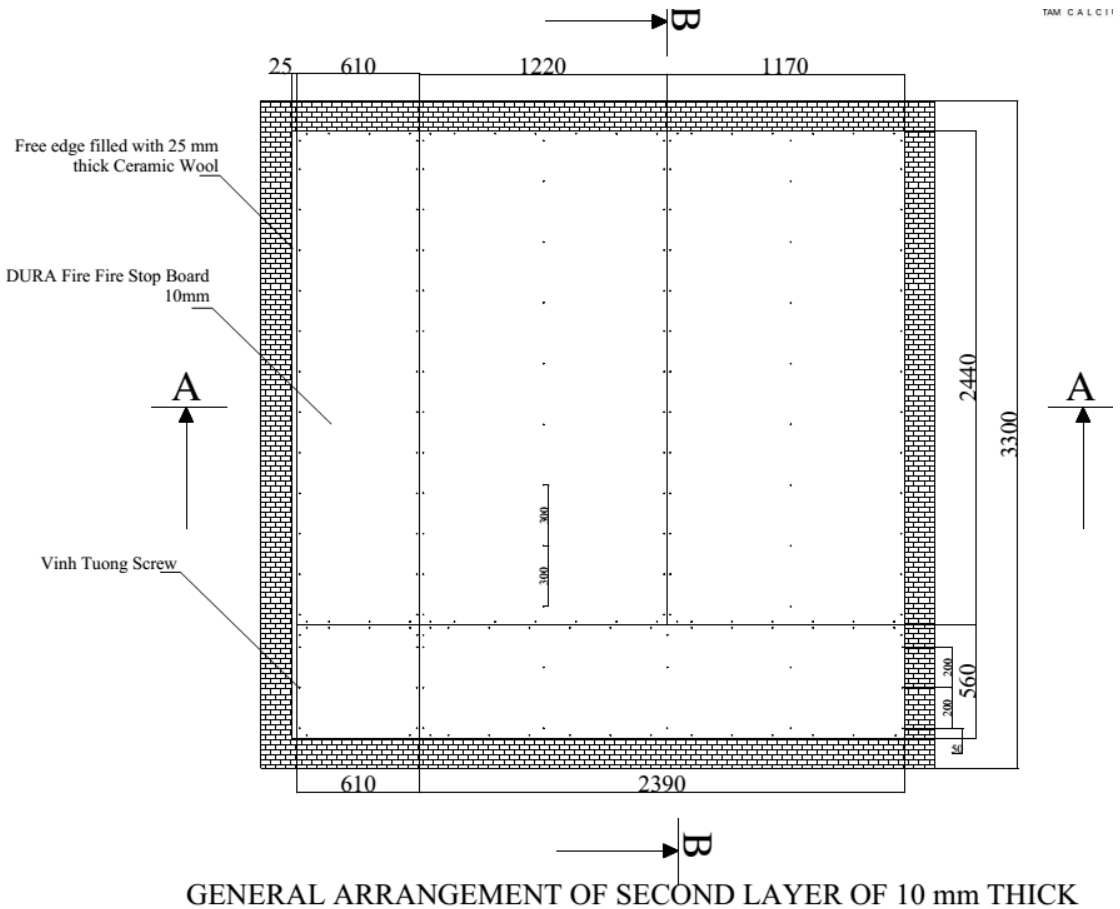


Figure 2: General arrangement of 1st layer of 6mm thick DURAflex board dry wall partition on the exposed side



GENERAL ARRANGEMENT OF SECOND LAYER OF 10 mm THICK DURA FIRE STOP BOARD DRY WALL PARTITION ON THE UNEXPOSED SIDE

Figure 3: General arrangement of 2nd layer of 10mm thick DURA FireStop board dry wall partition on the unexposed side

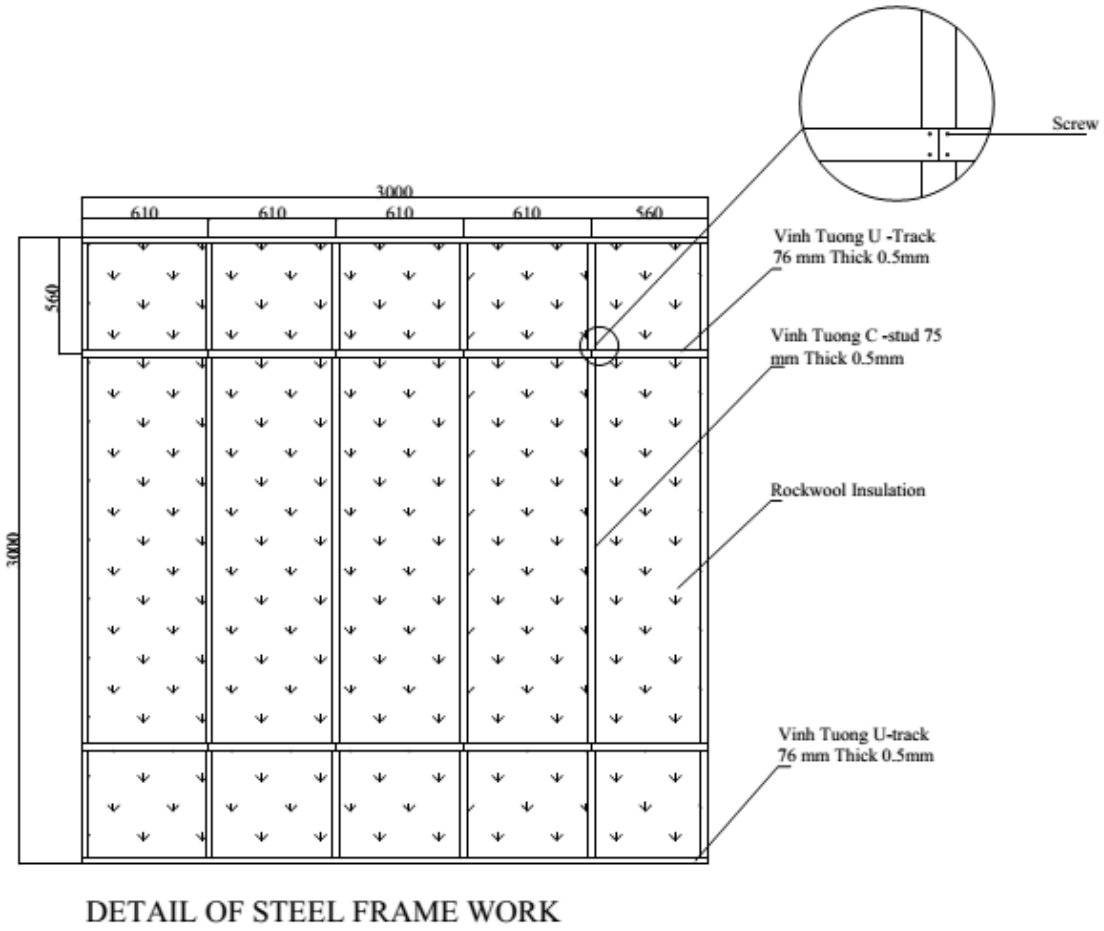


Figure 4: Detail of steel frame work

3. CONSTRUCTION MATERIAL CALCIUM SILICATE BOARDS

3.1 Material

Calcium silicate Fire resistant board (DURA Firestop 10mm) made of perlite, mica, vermiculite, alumina, cement , lime, silica sand & pulp.
Perlite, Vermiculate, Mica are analysed XRF as Table 2, their density are 0.3 g/cm^3, 0.4 g/cm^3, 0.3g/cm^3.

No.	*Oxides*	*Mica*	*Perlite*	*Vermiculite*
1	SiO_2	41,1 %	71,8 %	33,8 %
2	Al_2O_3	29,5 %	14,1 %	10,8 %
3	K_2O	16 %	7,7 %	9,76 %
4	Fe_2O_3	10,7%	1,56%	15,1%
5	TiO_2	1,29%	0,157%	2,6%
6	Na_2O	0,411%	2,68%	0,6%
7	MgO	0,359%	795 ppm	23,4%
8	BaO	0,251%	376 ppm	0,792%
9	RbO_2	0,171%	0,192%	0,235%
11	CaO	535 ppm	1,27%	1,73%
13	MnO	294 ppm	882 ppm	757 ppm
14	SrO	216 ppm	551 ppm	0,114%
16	NiO	145 ppm	132 ppm	0,159%
17	SO3	145 ppm	133 ppm	215 ppm

Table 2: Chemical composition of Mica, Perlite, Vermiculite

3.2 Production Process (DURA FireStop)

Calcium silicate Fire resistant board was produced with Flow-on technical (Figure 5), dimension 10x1220x2440mm. The raw materials consisted of sand, cement, lime, paper, perlite, mica, vermiculite, alumina and water are mixed. Then the sheets are created by technology flow-on. They are pre-cured and moved to autoclave at steam temperature 170^0C - 180^0C up within 8 h. In Autoclave some mineral in cement such as C_2S, C_3S will reacted with SiO_2 at 180^0C to form tobermorite crystal. Samples to test some physical properties according to ASTM C1185:2008[1] product for fiber cement panels to assess applications: bending strength, density, water absorption, moisture movement, test Non-Combustibility test according to ISO 1182:2010[3], installed of Fireproof wall system and test the fire resistance of non-structural elements according to BS476-22:1987[5].

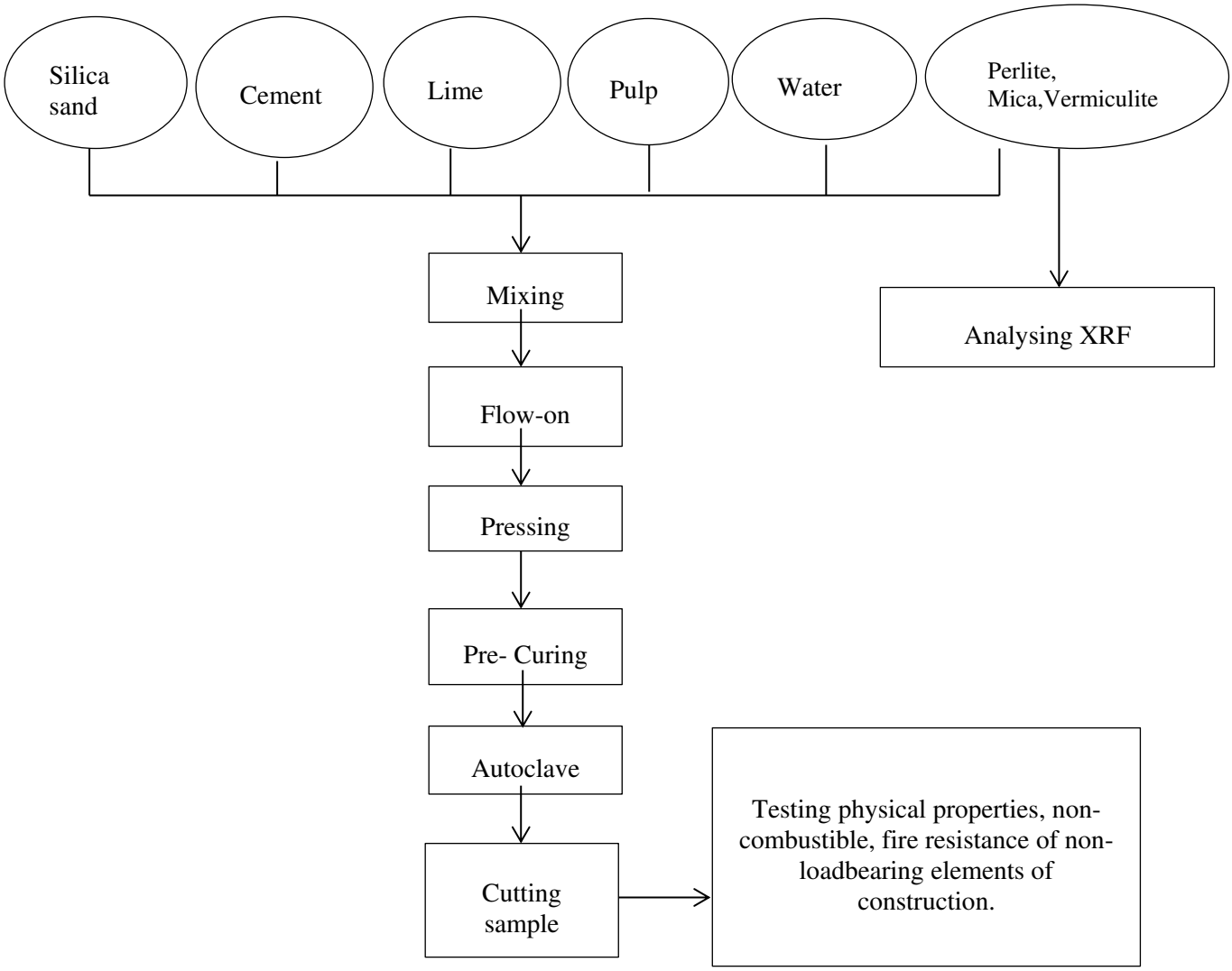


Figure 5: Production Process of Calcium silicate Fire Resistant Boards: Testing of raw materials and final product testing

3.3 Test results:

3.3.1 Physical properties test:

Physical properties test according ASTM C1185:2008[1] and satisfied ASTM C1186-08 type B[2], the results as following:

Physical properties	Results	Standard ASTM C1186-08 type B
Bending strength (MPa)	4.6	≥ 4
Density (g/cm^3)	0.9	NA
Moisture (%)	9.8	NA
Water absorption (%)	52.6	NA
Moisture movement (%)	0.04	NA

Table 3: Results physical properties test of Calcium silicate Fire Resistant (DURA Fire Stop)

3.3.2 Non Combustibility test ISO 1182 [3]:

Test results satisfied the classification of group non-combustion materials in QCVN06:2010/BXD, group A1 in EN 13501-1:2007 [4] (Figure 6).

VIỆN VẬT LIỆU XÂY DỰNG - BỘ XÂY DỰNG
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PHIẾU KẾT QUẢ THỬ NGHIỆM
TEST REPORT
Số *(No)*: ..410...../VLXD- VLHC

1. Cơ quan gửi mẫu *(Client)*: **Công ty cổ phần Hiệp Phú**
2. Loại mẫu *(Kind of sample)*: Tấm DURA FireStop
3. Số lượng *(Quantities)*: 01
4. Số phiếu Trung tâm (*Cen.No*): .../VLHC
5. Ngày nhận mẫu *(Date of received)*: 26/2/2016

KẾT QUẢ THỬ NGHIỆM
TEST RESULT

TT *(No)*	Tên chỉ tiêu *(Properties)*	Đơn vị *(Units)*	YCKT *(Specification)*		Kết quả *(Results)*	Phương pháp thử (Test method)
			QCVN 06 :2010	EN 13501-1 :2007 (nhóm A1)		
1	Nhiệt độ ban đầu của lò *(Furnace temperature)*	°C	750	750	750	ISO 1182:2010
2	Mức gia tăng nhiệt độ của lò đốt *(Temperature rise)*	°C	≤ 50	≤ 30	12	
3	Thời gian cháy thành ngọn lửa liên tục *(Duration of sustained flaming)*	s	≤ 10	0	0	
4	Tổn hao khối lượng *(Mass loss)*	%	≤ 50,0	≤ 50,0	16,7	

Kết luận (*Conclusion*):
- Kết quả thử nghiệm thỏa mãn phân loại vật liệu thuộc nhóm không cháy theo Quy chuẩn Kỹ thuật Quốc gia về an toàn cháy cho nhà và công trình QCVN 06:2010/BXD
(Test results satisfied the classification of group non-combustion materials in QCVN 06:2010/BXD)
- Kết quả thử nghiệm thỏa mãn phân loại vật liệu thuộc nhóm A1 theo tiêu chuẩn EN 13501-1:2007
(Test results satisfied the classification of group A1 in EN 13501-1:2007)

Figure 6: Non- Combustibility test of Calcium silicate Fire Resistant (DURA Fire Stop)

3.3.3 Fire resistant system for non-supporting structures BS 476-22 [5]:

3.3.3.1 Test Equipment and instrumentation:

- Vertical Testing furnace has specifications as followed:
- ✓ Manufacturer: Burwitz (Germany);
- ✓ Dimensions of furnace chamber: 3 m x 3 m x 1 . 5
- ✓ The maximum exposed area of specimen: 3 m x 3 m;
- ✓ Six plate thermometers in accordance with BS EN 1363-1:1999 Fire Resistance Test Part 1
- General Requirements were used to monitor and record the internal temperature of furnace during the test;
- ✓ The furnace was equipped with three 'T' sensors in accordance with BS EN 1363-1 : 1999 for recording and monitoring the internal pressure of furnace during the test;
- ✓ Other instrument, such as roving thermocouple, cotton pad, 6mm and 25mm gap gages were available and applied for investigating the temperature of and the occurrence of cracks, fissures on the unexposed surface of specimen, meeting the

needs of BS 476 Part 22 : 1987;

- ✓ Steel ruler was used to measure deformation of the unexposed face of the test specimen;
- ✓ A digital camera was used to record the behavior of specimen during the test.

3.3.3.2 Test specimen:

a. General description*:*

- The test specimen has nominal dimension of 3m x 3m, each side consisting of two cladding layers including Calcium Silicate board (DURAflex) and Calcium Silicate Fire Resistance Board (DURA FireStop) on each sides of Vinh Tuong 75/76 steel studs framework.
- The steel frame combines Cstud profile and Utrack profile of thickness of 0.5 mm. The top and the bottom perimeter studs are u track profile of cross-section of 76x32x0.5 and fixed to supporting construction using M6x40 steel expansion bolts at nominal 600mm centre. Two vertical edges are C-profile of cross-section of 75x35x0.5mm, one of which is fixed to supporting construction using M6x40 steel expansion bolts at nominal 600mm centres and the other is kept by the top and the bottom tracks. The middle vertical C studs (04 studs) with the same profile dimension are inserted at both end to top and bottom tracks.
- DURAflex and DURA FireStop boards have nominal dimension of 1220mm x 2440mm and the thickness of 6mm and 10mm alternatively. The boards were fixed to framing using screw 3.5 x 25/40 (mm) at nominal 200mm pitch. All the screws were positioned roughly 12mm to 15mm from the edges of boards.
- The test specimen was fixed to standard supporting construction by top edge, bottom edge and one vertical edge. The conjunction of the three fixed edges and surrounding supporting construction was sealed by fire resistance sealant. A 20mm gap was made at the other vertical edge of the partition system to provide no lateral restraint to the specimen. This gap was sealed by using ceramic wool.

b. Detail configuration of element boards to form the partition system:

- The overall size of specimen is 3000mm (height) by 2980mm (width) and the overall thickness of the specimen system is 107mm.

- Detail configuration of element boards as followed:
  - ✓ The unexposed face:
  - ➢ The inner layer is 6mm-thickness DURAflex boards combined from 05 element boards as followed: (1) 2440mm x 1220mm (02 boards), (2) 2440mm x 560mm (01 board), (3) 1780mm x 560mm (01 board) and (4) 1220mm x 560mm (01 board).
  - ➢ The outer layer is 10mm-thickness DURA FireStop boards combined from 06 element boards as followed: (1) 2440mm x 1170mm (01 board), (2) 2440mm x 1220mm (01 board), (3) 2440mm x 610mm (01 board), (4) 2390mm x 560mm (01 board), và (5) 610mm x 610mm (01 board).
  - ✓ The exposed face*:*
  - ➢ The inner layer is 6mm-thick DURAflex boards combined from 05 element boards as followed: (1) 2440mm x 1220mm (01 board), (2) 2440mm x 1170mm (01 board), (3) 2440mm x 610mm (01 board), (4) 2390mm x 560mm (01 board), (5) 610mm x 560mm (01 board).
  - ➢ The outer layer is 10mm-thick DURA FireStop boards combined from 05 element boards as followed: (1) 2440mm x 1220mm (02 boards), (2) 2440mm x 560mm (1 board), (3) 1220mm x 560mm (01 board) and (4) 1780mm x 560mm (01 board).
  - ➢ The partition is insulated by a Rockwool layer that sandwiched in between of exposed and unexposed layers. All the as-built drawings are established based on the visual check and the examination of the delivered specimen product as well as the information supplied by the test sponsor.
  - ➢ A standard supporting construction conforming to the requirements of BS 476 Part 22 : 1987 Method for determination of fire resistance of non-load bearing elements of construction was built for installing the specimen product.

c. Observation during test:

- Ambient temperature. 14°C, Relative Humidity: 48%
- Atmosphere of testing furnace was controlled in accordance with the requirements of BS 476 Part 22 :1987 Method for determination of fire resistance of non-load bearing elements of construction.
- An air pressure of 0- (±3) Pa was maintained throughout the test in the testing furnace at level 500 mm from the furnace floor;
- Temperature and atmosphere of the testing furnace had been controlled throughout the duration of test and recorded every 1 minute since the commencement of test;
- Steel ruler was used to check deformation of the test specimen by measuring distances from points on the test surface to the steel wire that was bridged over

measuring points.

- The test was terminated by the request of Test sponsor after 155 minutes testing.
- The following table summarizes the behaviours of the tested specimens throughout the test that were visually recorded and by using a digital camera.

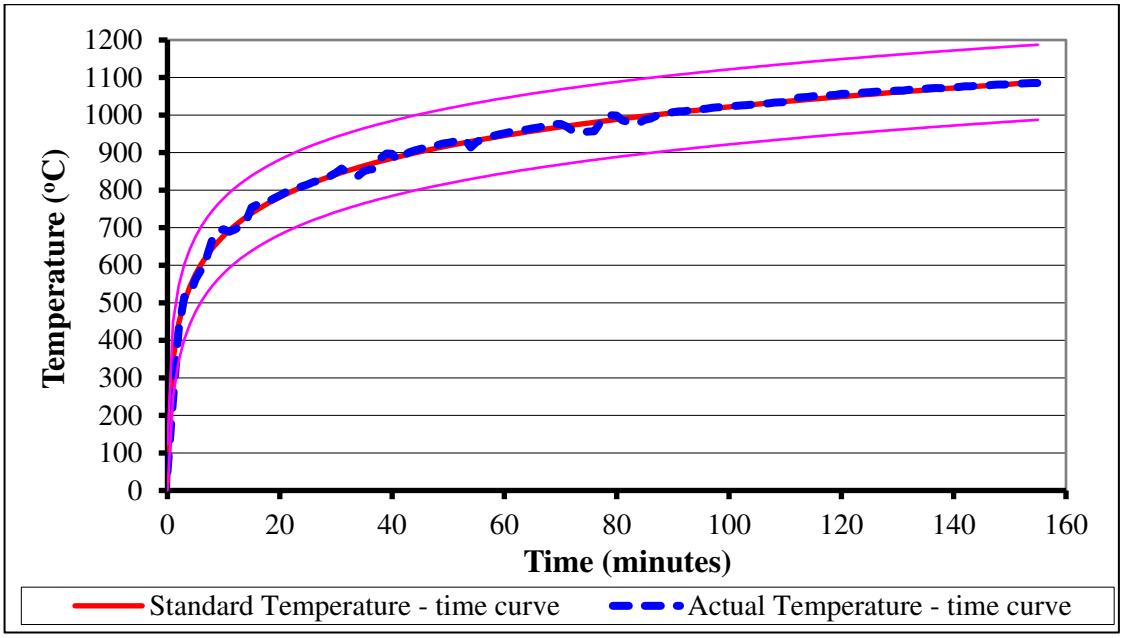

Diagram 1 - Monitoring temperature - time curves throughout the test

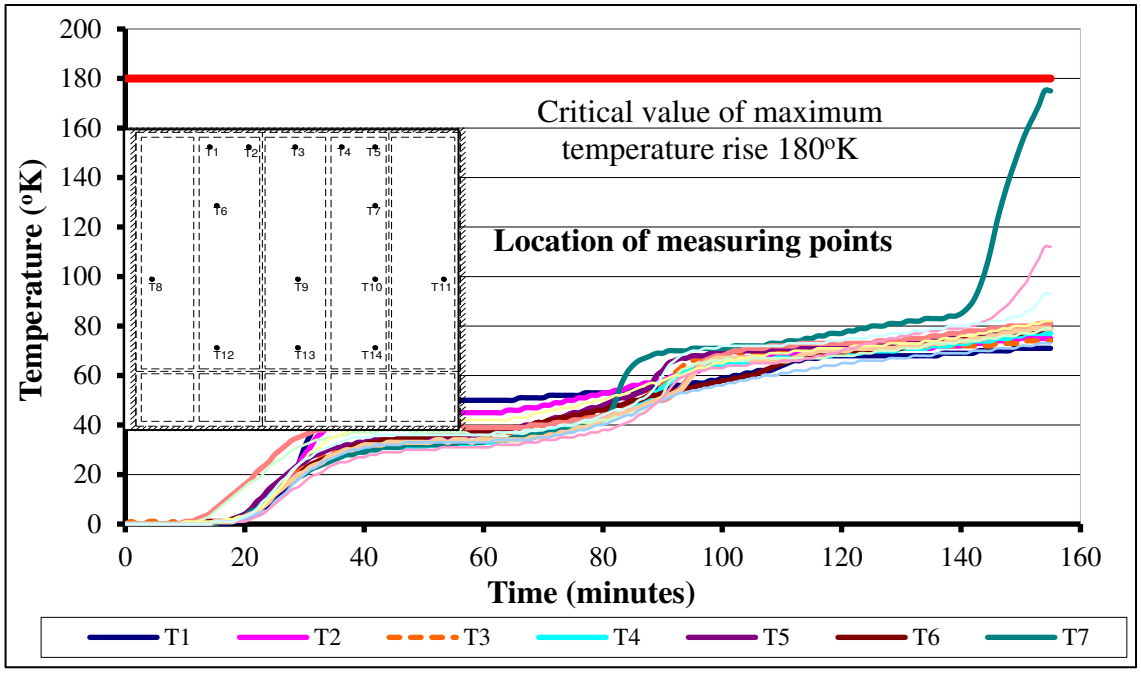

Diagram 2 - Temperature rise of the unexposed surface

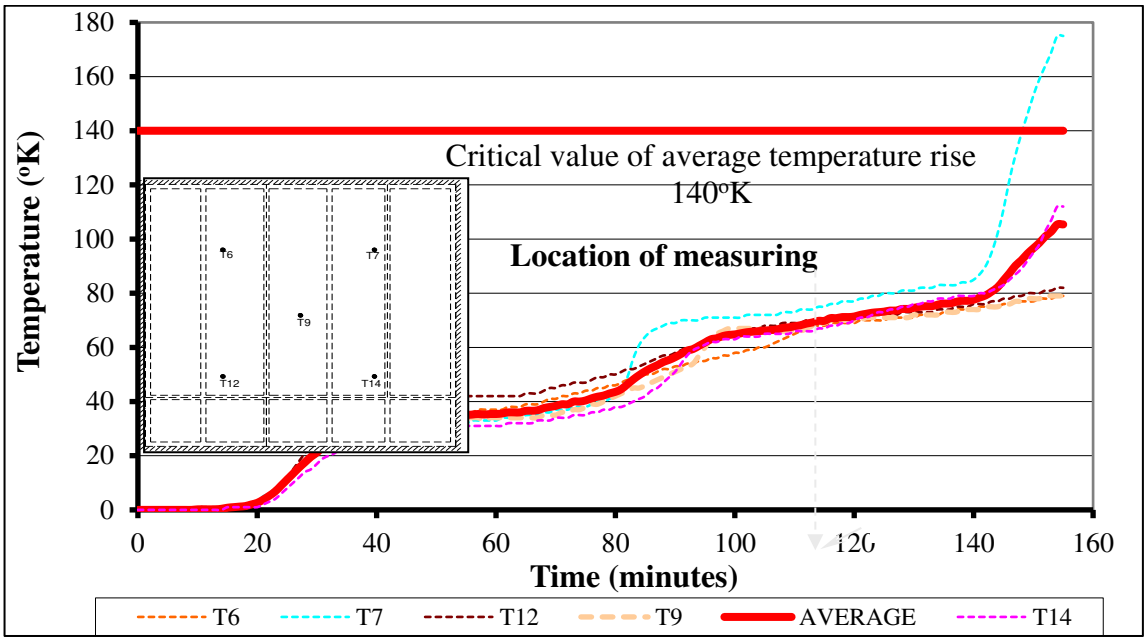

Diagram 3 - Average temperature rise of the unexposed surface

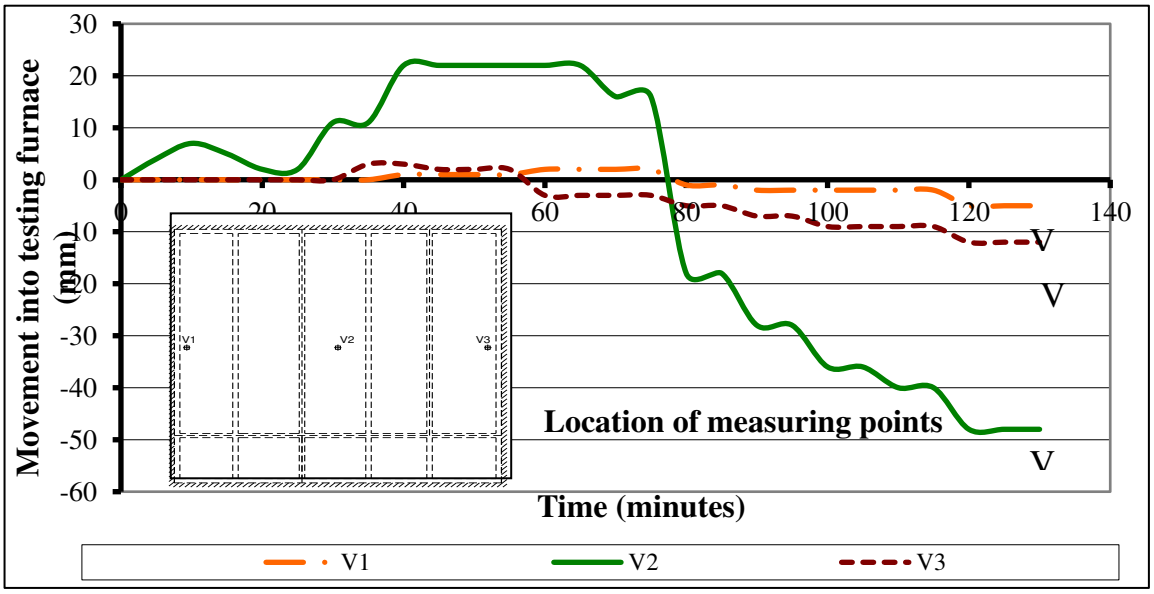

Diagram 4 - Deformation of the unexposed surface

Figure 7: Installation of the steel stud system of the specimen

Figure 8: Installation of DURA flex boards (inner layer-6mm)

on the exposed face of test

Figure 9: Installation of DURAflex boards (outer layer-10mm) on the exposed face of test specimen

Figure 10: Checking the test specimen before test

Figure 11: Specimen system after test (unexposed face)

4. EVALUATION AGAINST THE PERFORMANCE CRITERIA: TEST RESULTS

4.1 Integrity

The Integrity is evaluated by observation, the use of cotton pads and gap gauge;

Throughout the period of fire test, the result shows:

- The test specimen was not collapsed;
- No gaps and holes exceed the Standard limit;
- No sustained flame occurred on the unexposed face of the test specimen.

4.2 Insulation:

The Insulation is evaluated through the mean and the maximum temperature rise recorded at the positions as criteria of the standard specifies. The maximum temperature rise is also measured by a roving thermocouple at other suspect positions during the test. The result shows: temperature rise on the unexposed face of the test specimen did not exceed the allowed value regulated by testing standard.

5. CONCLUSION

- The sample product installed, is a non-load bearing, partition made from steel studs framing and cladding each side by 2 layers, including DURAflex and DURA FireStop boards. The specimen was mounted into a standard supporting construction and tested for fire resistance in accordance with BS 476 Part 22 : 1987 Method for determination of fire resistance of non-load bearing elements of construction.
- The tested specimen has passed the requirements of BS 476 Part 22: 1987 Method for determination of fire resistance of non-load bearing elements of construction as follows:
- Integrity: $\geq$ 150 minutes. The test terminated upon Request of the Test Sponsor.
- Insulation: $\geq$ 150 minutes
- Physical property tests according to ASTM C1186-08 type B were conducted and all test results were positive.

REFERENCES

[1] ASTM C1185: 08 Standard Test Methods for Sampling and Testing Non-Asbestos Fiber-Cement Flat Sheet, Roofing and Siding Shingles, and Clapboards.

[2] ASTM C1186: 08 Standard Specification for Flat Fiber-Cement Sheets.

[3] ISO 1182: 2010 Reaction to Fire Test For Products-Non- Combustibility test .

[4] BS EN 13501-1:2007 Fire classification of construction products and building elements. Classification using test data from reaction to fire tests

[5] BS 476-22:1987 Fire tests on building materials and structures. Method for determination of the fire resistance of non-loadbearing elements of construction.