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Ruj. Kami : FRIM (S).600-5/6/11 (22)
Tarikh : **27 FEB 2024**

SULIT

KA BINA CONSULTANCY GROUP SDN BHD,
Unit C1 & C2, Lot 886, Jalan Subang 9,
Taman Perindustrian Subang,
47500 Subang Jaya,
Selangor Darul Ehsan.
(u/p: En. Azrul Esfandy Razali)

Tuan,

**LAPORAN UJIAN KETAHANAN API UNTUK DINDING TAK BERBEBAN DAN
UJIAN HOSE STREAM NO: FPL2023122278**

Perkara diatas adalah dirujuk.

Sukacita dimaklumkan bahawa pihak FRIM telah pun menjalankan ujian ketahanan api berdasarkan Piawaian BS 476: Part 22: 1987: 'Method for determination of the fire resistance of non-load bearing element of construction' dan ASTM E2226-15b: 'Standard Practice for Application of Hose Stream' ke atas dinding tak berbeban syarikat tuan.

Sukacita dimaklumkan keputusan ujian tersebut adalah seperti berikut:

BS 476: Part 22: 1987: Integriti : 120 minit

Insulasi : 120 minit

ASTM E2226-15b: Lulus – Memenuhi kriteria piawaian.

Bersama-sama ini disertakan Laporan Ujian Ketahanan Api No. FPL2023122278 untuk simpanan tuan.

Sekian, terima kasih.

"MALAYSIA MADANI"

"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah,

.....
(KHAIRUL AZMI BIN JABAR)
Pegawai Penyelidik,
b.p Ketua Pengarah FRIM.

SULIT

FIRE RESISTANCE TEST REPORT

APPLICANT : KA BINA CONSULTANCY GROUP SDN. BHD.

REPORT NO. : FPL2023122278

TEST NO. : 2278



TEST REPORT

REPORT NO : FPL 2023122278

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Our Ref : FRIM (S).600-5/6/11 (22)

Issued by : Fire Protection Laboratory

Applicant & Manufacturer : KA BINA CONSULTANCY GROUP SDN BHD,
Unit C1 & C2, Lot 886, Jalan Subang 9,
Taman Perindustrian Subang,
47500 Subang Jaya,
Selangor Darul Ehsan.

(Attn: Mr. Azrul Esfandy Razali)

Product : Panel Wall

Trade Name : 3D Printed Wall

Reference Standard/Test Method : 1. BS 476 : Part 22 : 1987
Method for determination of the fire resistance of non-load bearing elements of construction. Clause 5 – Determination of fire resistance wall.
2. ASTM E2226-15b
Standard Practice for Application of Hose Stream.

Description of test item : The test specimen consisted of a non – load bearing wall concrete panel wall system was constructed with 5 nos of hollow cores concrete panels to the test frame. The wall panels were joined using concrete paste and cold joint bonding agent (Brand: Stella Crete BA888).

The actual overall dimensions of the concrete panel wall system was 2920 mm (l) x 3000 mm (h) x 200 mm (t).

A free edge clearance of approximately 80 mm wide filled with ceramic fibre wool was provided along one vertical side of the construction wall panel.

A full description of the test specimen and construction of the wall are detailed in Page 4 of this report.

Job No : FPL381223

Date received : 18/12/2023

Date of test : 23/01/2024

Issue date : 27 FEB 2024



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Applicant : KA BINA CONSULTANCY GROUP SDN BHD,
Unit C1 & C2, Lot 886, Jalan Subang 9,
Taman Perindustrian Subang,
47500 Subang Jaya,
Selangor Darul Ehsan.

Summary

A specimen of a non – load bearing wall system of a brand name '3D Printed Wall' has been subjected to a fire resistance test in accordance with BS 476: Part 22: 1987, Clause 5 to determine its fire resistance performance and ASTM E2226-15b, Standard Practice for Application of Hose Stream.

The wall's design and parameters was modelled in CAD software according to the sample requirements as outlined in BS 476: Part 22 before it was constructed with grade G30 concrete mix using a layered extrusion process with COBOD's BOD2 3D printer. Due to in-house printing limitations, the sample was constructed in 5 different parts with hollow cores and assembled at test site. The actual overall dimension of the wall system was 2920 mm (l) x 3000 mm (h) x 200 mm (t).

The description of products given above is as in Page 4 of this report and has been prepared from information provided by the applicant.

Inspection was carried out during the construction of wall assembly to verify on its dimension used in FPL laboratory only. No verification was done on the test specimen at the factory. The construction of the wall was arranged and carried out by the applicant

The specimen satisfied the performance requirement specified in Clause 5 of BS 476: Part 22, for non-load bearing wall for the following periods:

Integrity : 120 minutes

Insulation : 120 minutes

The test was terminated after the period of 120 minutes at the request of the applicant.

The specimen also satisfied the performance requirement specified in ASTM E2226-15b. Standard Practice for Application of Hose Stream for durations 2 minutes 30 seconds, the test specimen maintained its integrity with no development of hole, crack or other penetrating that allows the passage of water from the hose stream and wetting on the unexposed surface of the test assembly.

Date of test: 23/01/2024.



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PART ONE: FIRE RESISTANCE TEST

1.0 Purpose of Test

To determine the fire resistance of the concrete wall panel system when tested in accordance with BS 476: Part 22: 1987 `Method for determination of the fire resistance of non - load bearing elements of construction: Clause 5 – Determination of the fire resistance of partitions.

2.0 Test Specification

- 2.1 BS 476: Part 22: 1987 states that the fire resistance of the specimen is the time, expressed in minutes, to failure under the following criteria:

2.11 Integrity

In general, a failure of the test construction to maintain integrity shall be deemed to have occurred when collapse or sustained flaming for more than 10 seconds on the unexposed face.

Under criteria for impermeability, failure shall be deemed to have occurred when one or other of the following conditions prevail:

- a) Where cotton pad test is performed, flame and/or hot gases cause flaming and glowing of the cotton pad.
- b) Where the use of cotton pad is not suitable, failure shall be deemed to have occurred when either:
 - a through gap into the furnace exceeding 6 mm diameter in width and 150 mm in length exists or develops in the specimens or ;
 - a through gap into the furnace exceeding 25 mm diameter exists or develops in the specimen.

2.12 Insulation

Failure shall be deemed to have occurred when one of the following occurs:

- a) If the mean unexposed face temperature increases by more than 140 °C above its initial value.
- b) If the temperature recorded at any position on the unexposed face is in excess of 180 °C above the initial mean unexposed face temperature.
- c) When integrity failures as defined in 2.1 occur.

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3.0 Test Specimen

3.1 Product Description

The detailed drawings of the 3D Printed Wall system are shown in Figures 4 to 8 of this report. The sample was constructed in 5 different parts. At the interval of every 6th-layer, R6 bars was used as reinforce and anchor for the panel (see Figure 8). The nominal size of each panel as measured was 2920 mm (l) by 645 mm (w) by 200 mm (t) with hollow cavities size 2520 mm (l) by 645 mm (w) by 100 mm (t) and the density were 2200 kg/m³. The material composition as claimed to be manufactured is as below :

No.	Building Material	Mix Ratio (by weight or percentage)
1.	Cement	107 kg
2.	Sand	179.23 kg
3.	Water	25.314 kg
4.	Additive	2.51 kg
Other Information Claimed by Manufacturer		
1.	Density (air dry)	2240 kg/m ³
2.	Strength Test (Nm/kg)*	38.5 N/mm ²

The description of the specimen given above was from the information provided by the applicant.

*Strength Test Report No: 23101612 (BSEN Test Sdn. Bhd.)

3.2 Test Construction

The test specimen constructed in 5 different parts onto a test frame. The panel was laid horizontal and bonded together using concrete paste (mix with Etonis 3500 W) and cold joint bonding agent (Brand: Stella Crete BA888). Wall's cavity was filled with likewise concrete mix (M30 mix with Etonis 3500 W) and both ends of wall structure was reinforced with 4 nos tie-up Y12 reinforcement bars; later filled with non-shrink grouting mix (Sika Grout 215).

The overall size of the *3D Printed Wall* during the test was 2920 mm (l) x 3000 mm (h) x 200 mm (t) exclusive of an 80 mm wide vertical gap along one edge to provide no lateral restraint to the specimen. The gap was filled with ceramic fibre.

Inspection was carried out to verify on its design and dimension used in FPL laboratory only. No verification was done on the test specimen at the factory. The construction of the wall was arranged and carried out by the applicant.



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4.0 Conditioning of the test construction

Prior to test, the test construction was kept in the laboratory in ambient atmosphere for a period of 37 days.

5.0 Fire Resistance Test

5.1 Date of Testing:

The test was conducted on 23rd January 2024.

5.2 Witness of Test

The test was witness by:

- i. Mohd Azrul Esfandy Razali
- ii. Mohamed Khairul Azman Abdul Azeez
- iii. Mohamad Hannan Yusof

5.3 Test Method

- i. The test was conducted in accordance with the procedure specified in Clause 5 of BS 476: Part 22: 1987.
- ii. The ambient temperature at the beginning of the test was 26°C and on completion of test was 30°C. The temperature and pressure conditions were controlled to the limits defined in Clause 3.1 and 3.2 of BS 476: Part 22: 1987.
- iii. Throughout the test, observations were made on the exposed and unexposed faces of the test specimen. Gap gauges and cotton pad test were available to evaluate compliance with the requirements for imperviousness defined in BS 476: Part 22: 1987.

6.0 Test Result

- 6.1 The graph in Figure 1 shows the actual temperature/time curve of the furnace heating conditions in relation to the standard temperature/time curve.

Table 1 shows the actual mean furnace temperature, standard furnace temperature and the percentage difference between the areas under the standard curves and the areas under the actual curve compared with the percentage tolerance allowable within the standard as defined in Clause 3.1 of BS 476: Part 22: 1987.

- 6.2 The graph in Figure 2 shows the temperature rise recorded on the unexposed face of the test specimen as determined by the five thermocouples which are fixed approximately at the centre and the centre of the four quadrants of the specimen respectively (refer to Figure 3).

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Table 2 shows individual mean temperature and increase in mean temperature and maximum temperature rise at various intervals.

6.3 Table 3 shows the deflection of the wall panel system measured at middle-height.

6.4 Observations were made during the test on the general behaviour of the test specimen and these were given in Table 4 of this report.

6.5 Photographs of the test are shown in Plate 1 to 11 in this report.

7.0 Evaluation Against The Performance Criteria

The performance of the specimen was judged against the following criteria BS 476: Part 22: 1987.

7.1 Integrity

It is required that there is no collapse of the specimen, no sustained flaming on the unexposed surface and no loss of impermeability. **The requirements for integrity were satisfied for 120 minutes.**

7.2 Insulation

It is required that the mean temperature rise of the unexposed face shall not be greater than 140°C and the maximum temperature rise above initial mean temperature shall not be greater than 180°C.

At **120 minutes** of the test, the mean temperature rise and maximum temperature rise above initial mean temperature on the unexposed face of the test specimen were **21°C** and **30°C** respectively.

8.0 Conclusions for Fire Resistance

The specimen satisfied as requirements of BS 476: Part 22: 1987 for the following period:

Integrity : 120 minutes

Insulation : 120 minutes

The test was terminated after a period of 120 minutes at the requests of the applicant.



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PART 2: HOSE STREAM TEST*

9.0 Purpose of Test

- 9.1 This practice is applicable to building elements required to be subjected to the impact, erosion and cooling effects of a hose stream as part of a fire-test-response standard. Building elements include, but are not limited to wall and partition assemblies, fire-resistive joint systems and doors.
- 9.2 Immediately after the Fire Resistance Test, the assembly frame was moved into position for the Hose Stream Test. The exposed surface of the test assembly was subjected to impact, erosion and cooling effects of a hose stream described in the ASTM Standard E2226-15b: Standard Practice for Application of Hose Stream.

10.0 Significance and Use

- 10.1 This practice is intended to standardize the apparatus used and the method or pattern of application of a standard hose stream to building elements as one part of the assessment and fire resistance rating of building elements.
- 10.2 This practise specifies the water pressure and duration of exposure or application of the hose stream to the test assembly.
- 10.3 This practice is intended to be used only after a test assembly has completed a prescribed standard fire-resistance test.
- 10.4 This practise exposes a test assembly to a standard hose stream under controlled laboratory conditions.
- 10.5 Any variation from tested conditions has the potential of substantially changing the performance characteristics by this practise.

11.0 Test Specification

- 11.1 The Hose Stream test utilising the test methodology given in ASTM Standard E2226-15b: Standard Practice for Application of Hose Stream. The water pressure and duration of application shall be as prescribed in Table 1 of ASTM E2226-15b. However the fire resistance test for concrete wall panel system was tested accordance to BS 476: Part 22: 1987.

12.0 Observation During the Hose Stream

- 12.1 Observed the unexposed surface for the test assembly during the application of the hose stream for the development of any hole, crack or other penetration that allows the passage of water from the hose stream.

*****Not SAMM Accredited*****

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- 12.2 Observe any fully developed stream, wetting of the unexposed surface, water rolling down the unexposed surface or water projected beyond the unexposed surface.

13.0 Hose Stream Results

- 13.1 A Hose Stream Test was conducted based on total assembly area of 8.5 m² at requires duration of 2 minutes and 30 seconds. The hose stream water pressure was 207 kPa (30psi).

The test specimen maintained its integrity with no development of hole, crack or other penetrating that allows the passage of water from the hose stream and wetting on the unexposed surface of the test assembly.

14.0 Conclusion for Hose Stream

- 14.1 In accordance with the definitions specified in ASTM Standard E2226-15b: Standard Practice for Application Hose Stream, the result shows that the wall system **FULLY COMPLIED** the requirements.

15.0 Limitations

- 15.1 The results only relate to the behaviour of the specimen of the element of construction under the particular conditions of test; they are not intended to be the sole criteria for assessing the potential fire performance of the element in use nor do they reflect the actual behaviour of fire.
- 15.2 The test results relate only to the specimen tested. Appendix A of BS 476: Part 22: Part 20: 1987 provides guidance information on the application of the fire resistance test and the interpretation of test data.

Application of the results to assemblies of difference or incorporating different components should be subjected to retest.

Approved by:



(KHAIRUL AZMI BIN JABAR)
Head of Laboratory
Fire Protection Laboratory
Forest Research Institute Malaysia

Date : **27 FEB 2024**

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TEST REPORT

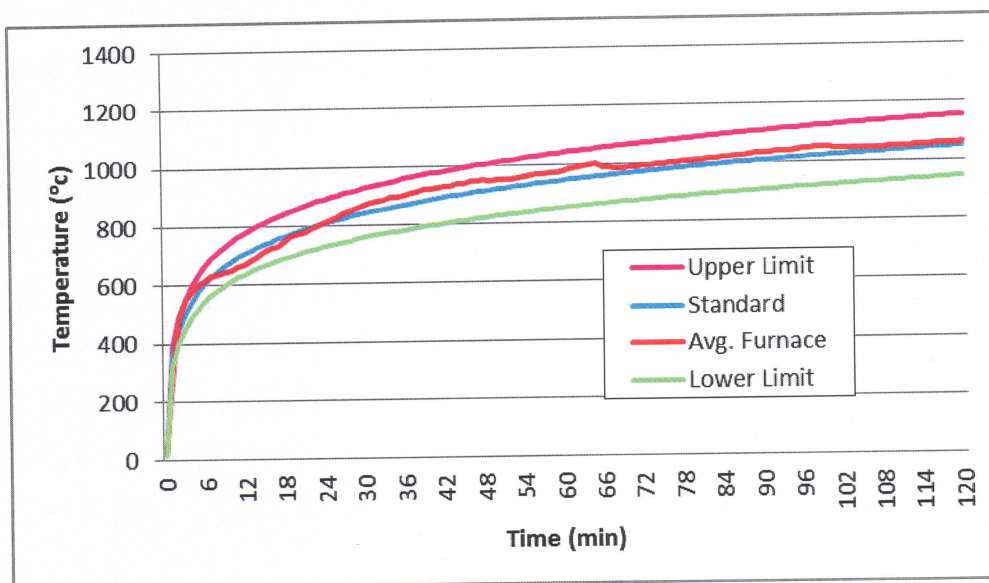
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Figure 1: Actual Furnace Average Temperature / Time Curve



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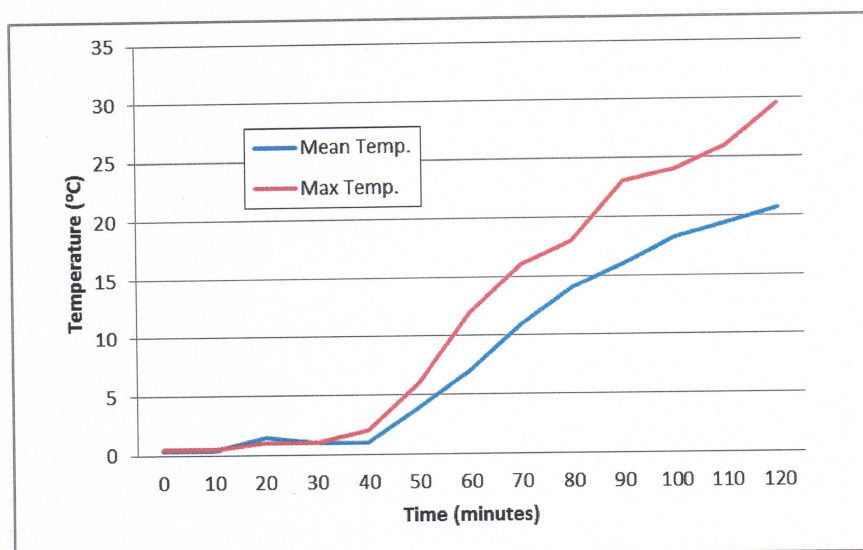
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Figure 2. Unexposed Face Temperature Curve Temperature
 Rise Above Initial Mean Temperature



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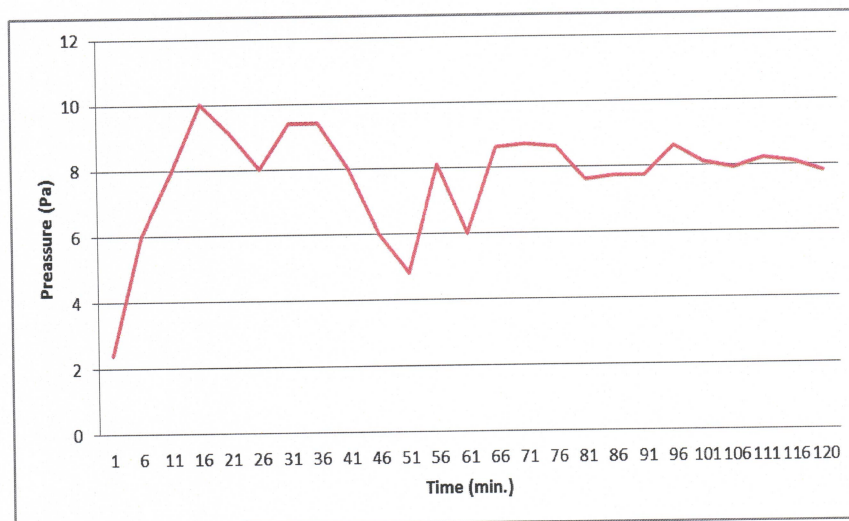
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Figure 3: Pressure reading for internal of furnace



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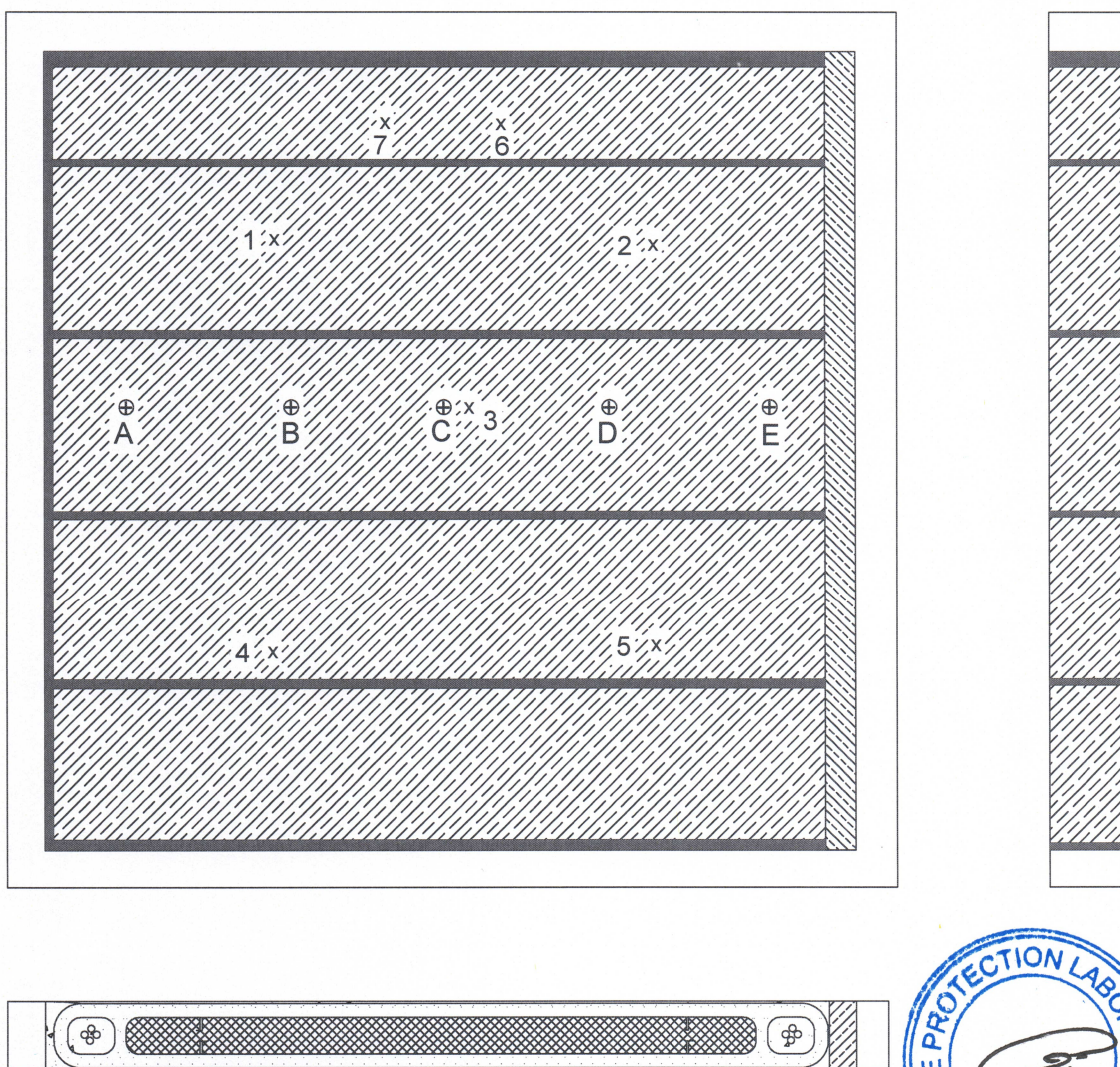
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X Thermocouple points on the unexposed.
 ⊕ Deflection points on the unexposed.



Figure 4: General arrangement of thermocouple and deflection points on the unexposed surface of wall system.

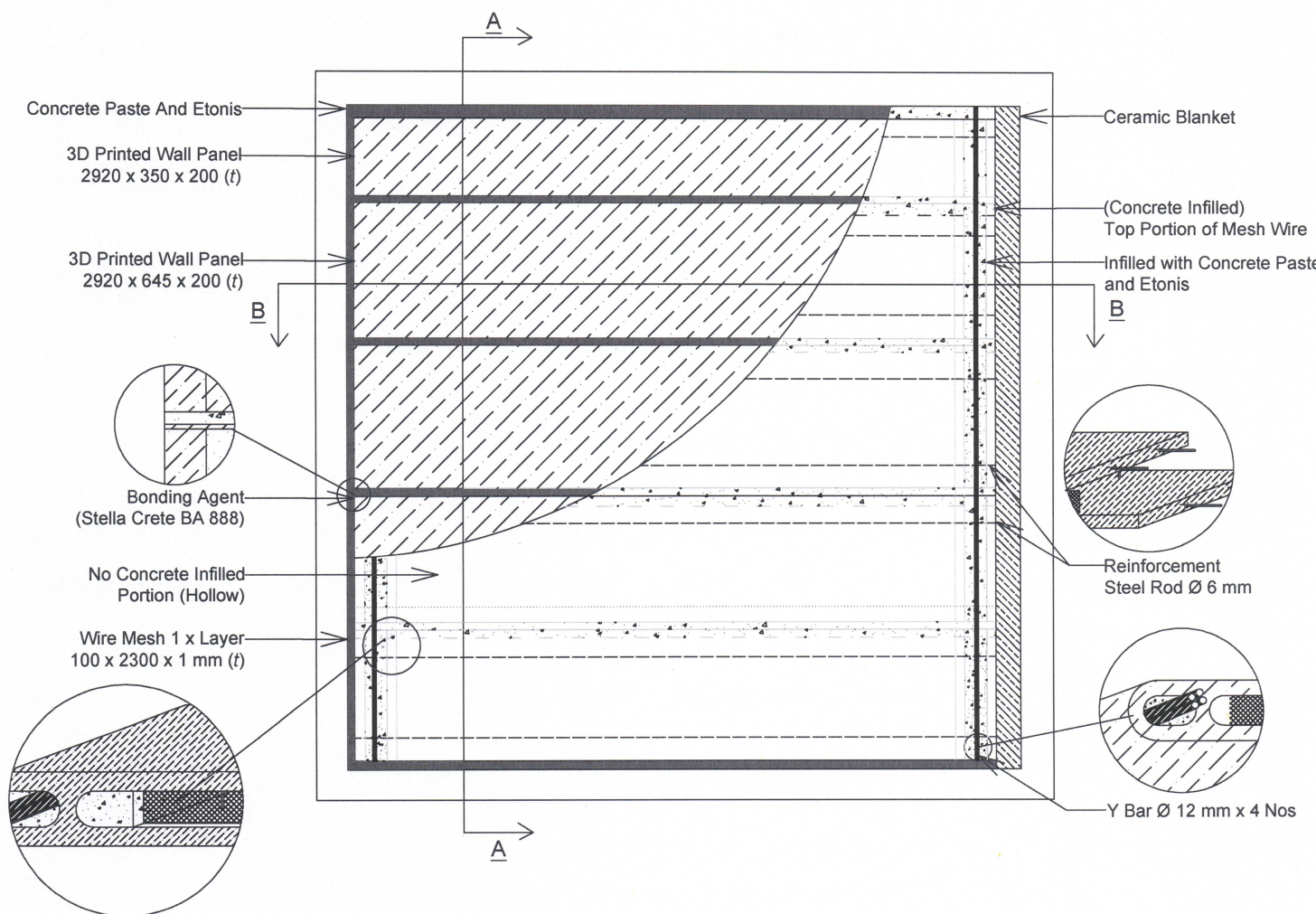
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Note:
1) All dimension are in mm.
2) Drawing not to scale.

Figure 5: General dimension of wall system.



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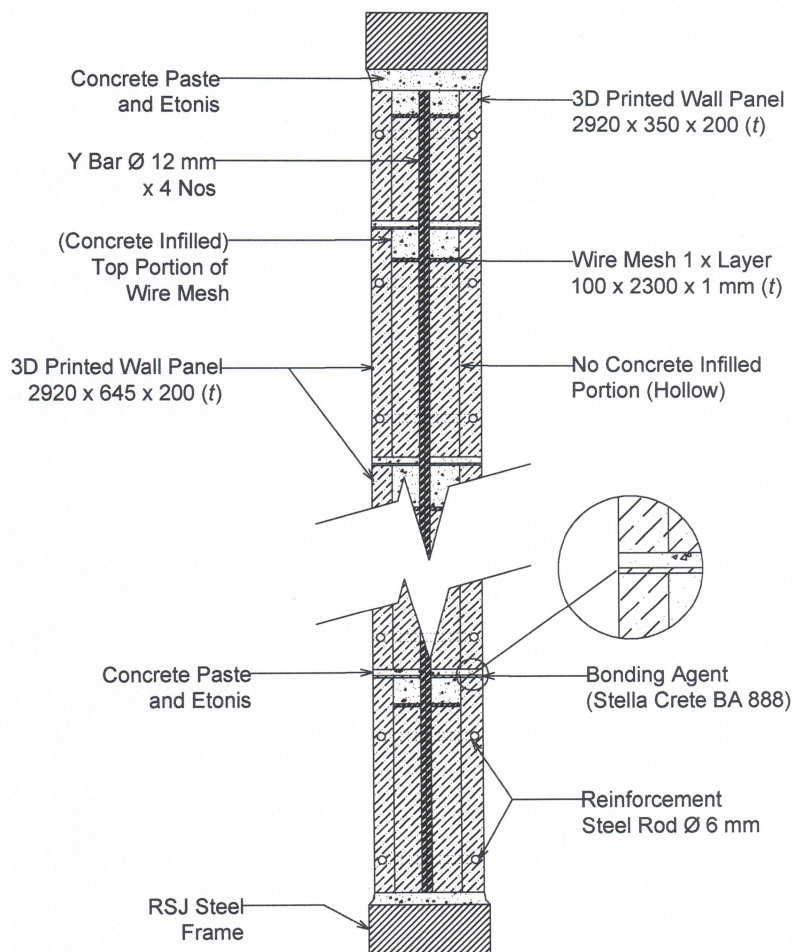


Figure 6: Cross-section A-A 3D Printed Wall Construction.



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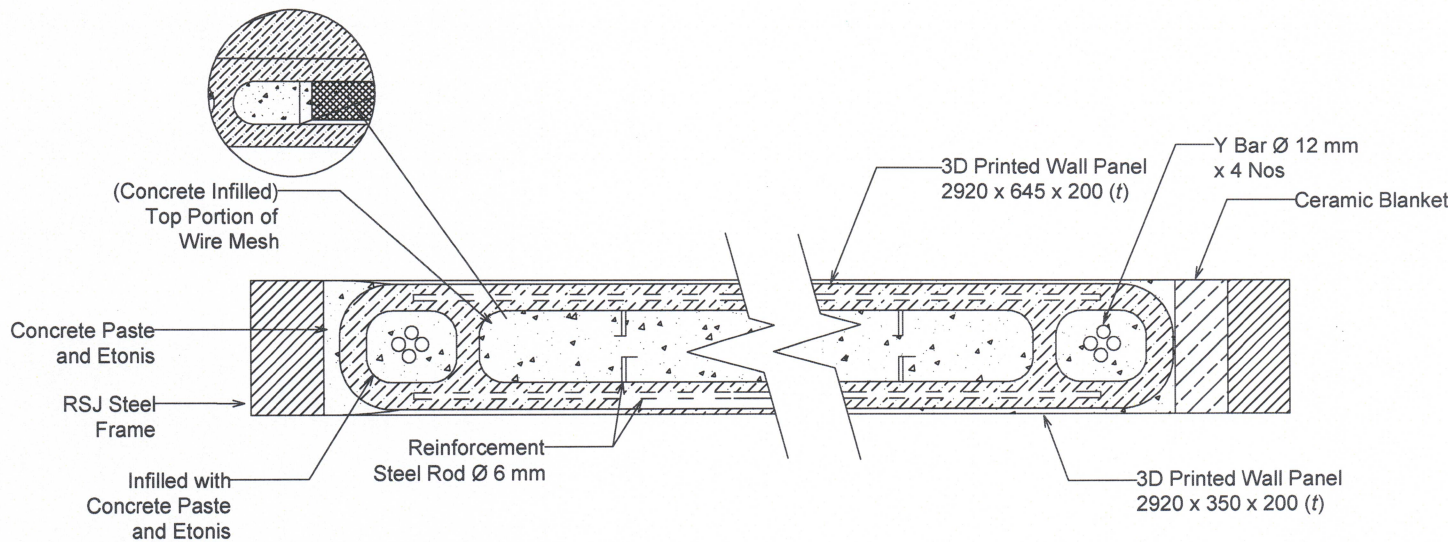


Figure 7: Cross-section B-B 3D Printed Wall Construction.



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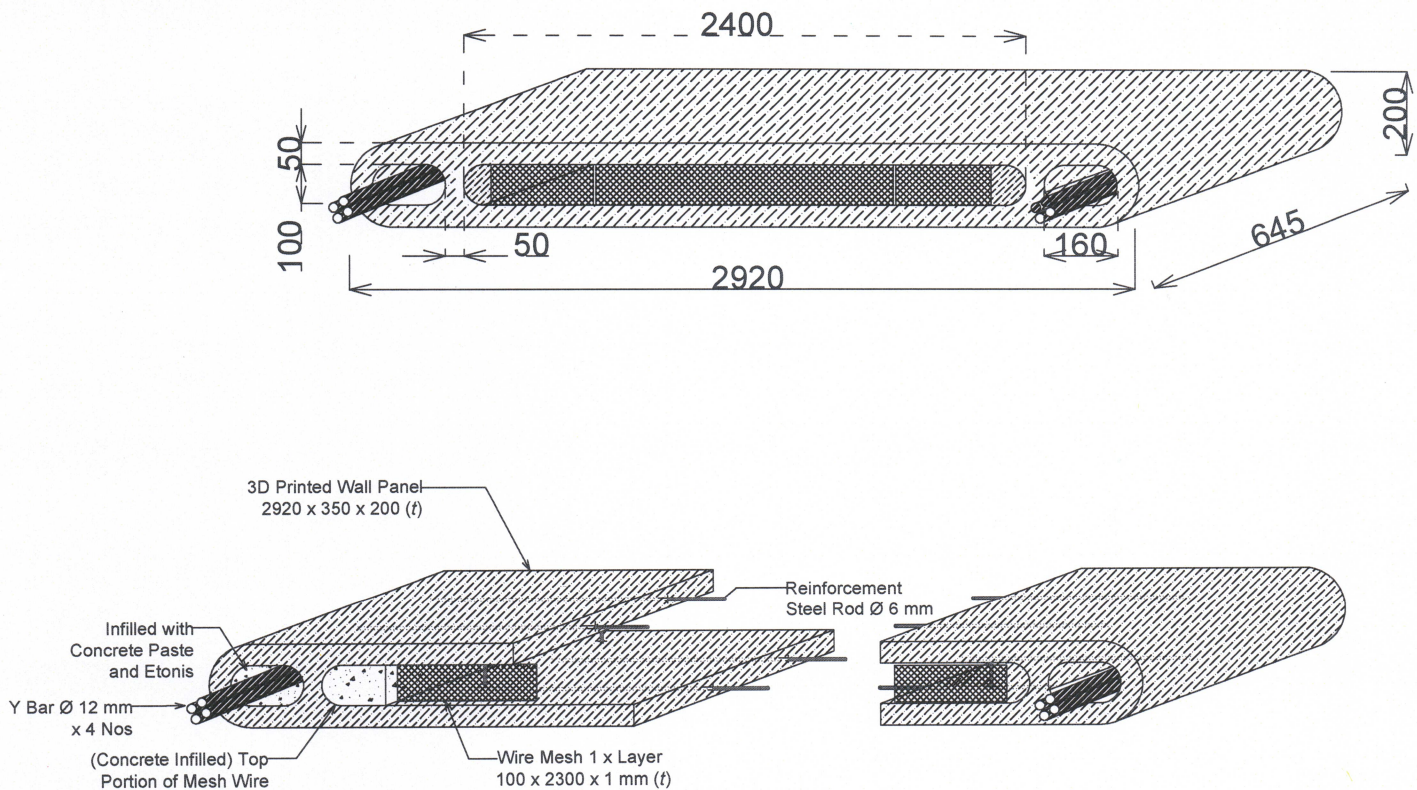


Figure 8: 3D Printed Wall Panel Construction.



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Table 1: Specified and actual recorded furnace temperature.

TIME (min)	STANDARD FURNACE TEMPERATURE (°C)	ACTUAL FURNACE TEMPERATURE (°C)	AREA UNDER STANDARD CURVE (°C min.)	AREA UNDER ACTUAL CURVE (°C min.)	PERCENTAGE DEVIATION	SPECIFIED PERCENTAGE TOLERANCE (+ or -)
0	20	26				
1	349	267				
2	445	479				
3	502	553				
4	544	576				
5	576	598				
6	603	613				
7	626	628				
8	646	635				
9	663	643				
10	678	649	5303	5330	-1	15
12	705	668				
14	728	697				
16	748	723				
18	766	747				
20	781	772				
22	796	789				
24	809	810				
26	821	830				
28	832	849				
30	842	867	15490	15285	1	10



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Table 1: Specified and actual recorded furnace temperature (cont.)

TIME (min)	STANDARD FURNACE TEMPERATURE (°C)	ACTUAL FURNACE TEMPERATURE (°C)	AREA UNDER STANDARD CURVE (°C min.)	AREA UNDER ACTUAL CURVE (°C min.)	PERCENTAGE DEVIATION	SPECIFIED PERCENTAGE TOLERANCE (+ or -)
35	865	894	87164	89395	-2.6	5
40	885	920				
45	902	938				
50	918	948				
55	932	960				
60	945	977				
65	957	999				
70	968	987				
75	979	997				
80	988	1009				
85	997	1019				
90	1006	1032				
95	1014	1042				
100	1022	1047				
105	1029	1043				
110	1036	1048				
115	1043	1055				
120	1049	1060				



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Table 2: Unexposed face temperature of the wall system.

Time (min)	Thermocouple Points (°C)							Mean Temp. (°C)	Temp. rise above mean temp. (°C)	
	TC1	TC2	TC3	TC4	TC5	TC6	TC7		Mean Temp.	Max Temp.
0	27	26	28	27	28	27	27	27	0	1
1	27	27	28	27	28	27	27	27	0	1
2	27	27	28	27	28	27	27	27	0	1
3	27	27	28	27	28	27	27	27	0	1
4	27	27	28	27	28	27	27	27	0	1
5	27	27	28	27	28	27	27	27	0	1
6	27	27	28	27	28	27	27	27	0	1
7	27	27	28	27	28	27	27	27	0	1
8	27	27	28	27	28	27	27	27	0	1
9	27	27	28	27	28	27	27	27	0	1
10	27	27	28	27	28	27	27	27	0	1
12	27	27	28	27	28	27	27	27	0	1
14	27	27	28	27	28	27	27	27	0	1
16	27	27	28	27	28	27	27	28	1	1
18	27	27	28	28	28	27	27	28	1	1
20	27	27	28	27	28	27	27	28	1	1
25	27	27	28	28	28	27	28	28	1	1
30	28	27	28	28	28	28	28	28	1	1
35	28	28	28	28	28	28	28	28	1	1
40	28	28	29	28	29	29	28	28	1	2
45	29	30	30	30	30	30	29	30	3	3
50	30	32	31	33	31	31	33	31	4	6
60	27	37	34	39	34	35	33	34	7	12
70	28	42	38	43	37	39	36	38	11	16
80	33	45	41	44	42	41	42	41	14	18
90	32	48	44	47	46	42	50	43	16	23
100	31	51	46	49	50	42	45	45	18	24
110	28	53	48	50	53	43	48	46	19	26
120	27	55	49	51	57	42	46	48	21	30



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Table 3: Deflection of the wall system measured at mid-height.

Time (min)	Measuring Points				
	A (mm)	B (mm)	C (mm)	D (mm)	E (mm)
10	5	7	11	10	6
20	6	12	16	15	9
30	8	16	22	18	12
40	9	17	22	20	12
50	9	17	23	20	13
60	10	21	26	23	14
70	10	22	28	24	13
80	10	23	31	26	12
90	10	24	33	24	13
100	11	26	33	27	12
110	11	26	31	27	12

Notes : + ve values denotes movement towards furnace
- ve values denotes movement away from furnace



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Table 4: Observation made during the test

Time (min)	Test Face	Observation
0	–	Test commenced
15	U	Hairline crack appear at the top left corner
17	U	Water spot from concrete appear from wall panel joint
23	U	More water drop appear from wall panel joint
25	E	Pop sound heard
39	U	Hot water vapor start to appear from small gap hole between panel layer
46	U	Top side wall start to dry out, water drop still continue at lower side
70	U	Wall still maintain its integrity and insulation
105	U	No significant changes
120	–	Test discontinued.

Hose Stream Test

After the Fire Resistance test has completed, the Hose Stream Test was conducted immediately for **2 minutes 30 seconds**. The hose stream water pressure was **207 kPa (30 psi)**.

The wall brick system maintained its integrity with no development of any hole, crack or other penetrating that allows the passage of water from the hose stream and wetting on the unexposed surface of the test assembly.



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Plate 1. Construction of the 3D Printed Wall.



Plate 2. Before the fire resistance test (exposed face).



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Plate 3. Before the fire resistance test (Time taken: 0 minutes).



Plate 4. During fire resistance test (Time taken: 30 minutes).



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Plate 5. During fire resistance test (Time taken: 60 minutes).

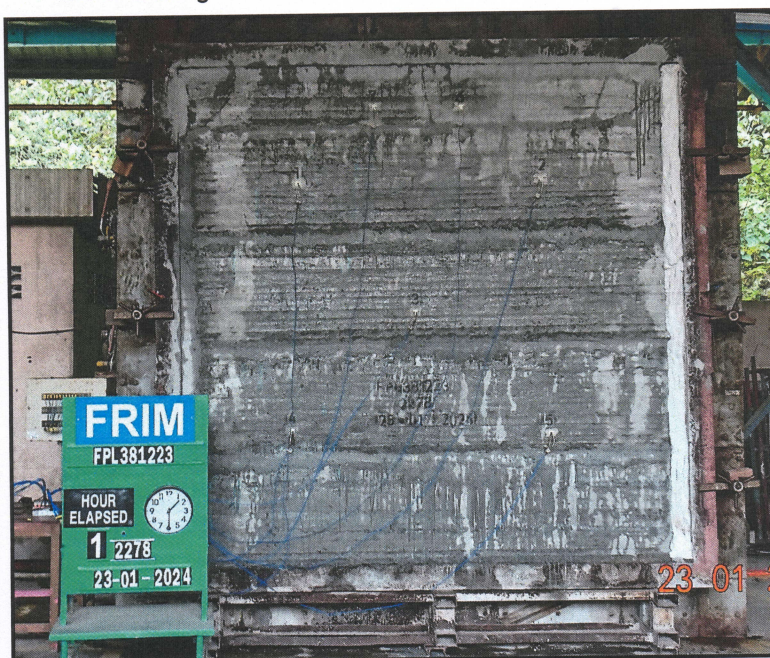


Plate 6. During the fire resistance test (Time taken: 90 minutes).



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Plate 7. During the fire resistance test (Time taken: 120 minutes).



Plate 8. Exposed face after the fire test (Time taken: 120 minutes).



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Plate 9. After the Hose Stream test (Un-exposed face)

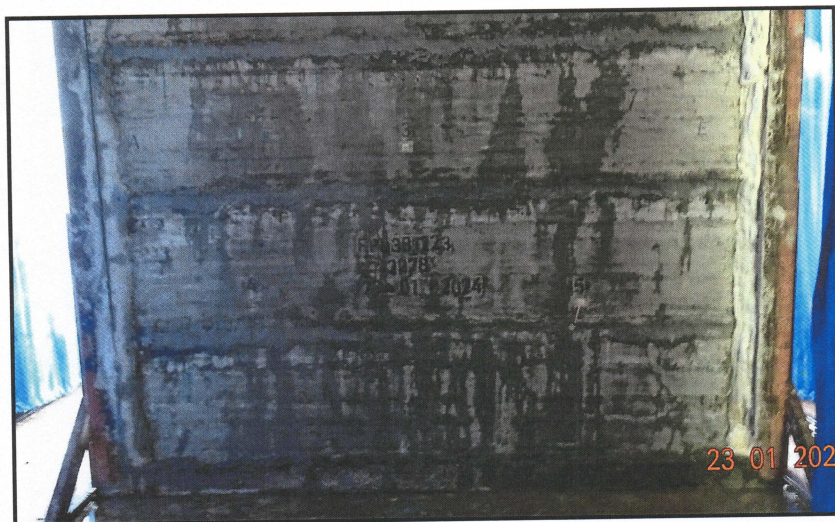


Plate 10. After the Hose Stream test (Un-exposed face)



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Plate 11. After the Hose Stream test for 2 minutes and 30 seconds (Exposed face).



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