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PERFORMANCE TEST

OF

PARTITION WALL SYSTEM

USING

WELL & ABLE INTERNATIONAL
BESTA™ HOLLOWCORE PANELS OF 90MM THK.

TESTED WITH REFERENCE TO

BS 5234: Part 2: 1992 or SS 492: 2001

TESTED FOR:

Well & Able International Pte Ltd
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TÜV SÜD PSB

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The results reported herein have been performed in accordance with the laboratory's terms of accreditation under the Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme. Tests/Calibrations marked "Not SAC-SINGLAS Accredited" in this Report are not included in the SAC-SINGLAS Accreditation Schedule for our laboratory.

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SUMMARY

TESTED FOR	WELL & ABLE INTERNATIONAL PTE LTD
TEST DATE	31/03/2015 to 01/04/2015
TEST METHOD	Reference to BS 5234 Part 2 : 1992 or SS 492 : 2001
TEST DESCRIPTION	The purpose of the test is to determine the resistance to damage of partition system for use as internal walls of buildings.

Tests for grade compliance:

Severe Duty (SD) – Prone to vandalism and abnormally rough use.

a. Stiffness	Severe Duty - Load of 500N applied through an area of 150 mm diameter plate perpendicular to the partition surface. 10 mm maximum deflection allowable and 1 mm maximum residual deformation
b. Small hard body impact	Impact by a 50 mm diameter steel ball with a swinging arm of 600 mm long (Total weight, 3 kg) swing perpendicularly against the wall. Test on 11 positions (includes a corner). Criteria: no significant damage.
i. Surface damage	Severe Duty - Impact energy of 10 Nm (swing angle of 63.6 degree)
ii. Perforation	Severe Duty - Impact energy of 30 Nm (swing angle of 131.8 degree)
c. Large soft body impact	Impact by a 50 kg spheroconical bag of 600 mm X 400 mm diameter filled with hardened glass beads. Test on 3 positions (includes a corner). Criteria: no significant damage.
i. Resistance to damage	Severe Duty - Impact energy of 100 Nm (drop height of 204 mm). Single impact at two selected positions and one on corner.
ii. Resistance to structural damage	Severe Duty - Impact energy of 120 Nm (drop height of 245 mm). Three impacts at two selected positions.
d. Door slam	Severe Duty - Partition wall is being slammed 100 times with a 60 kg door leaf by a force of 15 kg. Door frame shall not be permanently displaced by 1mm.

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SUMMARY CONT'DS

Other tests:

e. Crowd pressure	A load of 3.0 kN/m is applied through a 2.5 m (± 10 mm) wooden beam at a height of 1.2 m. No damage or collapse that would render the partition dangerous is allowed.
f. Light weight anchorage	A static load is applied on the steel bracket fixed onto the partition wall by a specified type of anchorage. A shim plate supporting a 20 N weight is inserted in between the bracket and wall.
i. Pull out	The anchorage is to sustain a pull out load of 100 N (± 3 N) without releasing the shim plate.
ii. Pull down	The anchorage is to sustain a pull down load of 250 N (± 7.5 N) without releasing the shim plate. The bracket shall not move by more than 2 mm.
g. Heavy weight anchorage	An eccentric cyclic load is applied onto steel brackets fixed onto the partition by a specified type of anchorage. Shim plates supporting a 20 N (± 1N) weight are inserted in between the bracket and wall.
i. Wash basin	A load of 1500N is applied onto the wash basin steel bracket, without releasing either the shim plates, exceeding the deflection of 20 mm or residual deformation of 1 mm.
ii. Wall cupboard	Incremental load step of 500N up to 4000N is applied onto the wall cupboard steel bracket, without releasing either the shim plates, exceeding the deflection of 5 mm or residual deformation of 1 mm.

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SUMMARY OF TEST RESULTS:

Summary of strength and robustness tests reference to BS 5234 : Part 2 : 1992 or SS 492: 2001 (Details of partition specimen and test report are attached)	
Tests for grade compliance	
Requirements tested	Grade performance achieved
	Severe Duty (SD)
Stiffness	Passed
Surface damage by small hard body impact : [1]	Tested
Surface damage by large soft body impact:	Passed
Perforation by small hard body impact:	Passed
Resistance to structural damage by large soft body impact	Passed
Door slamming	Passed
Note: [1] - Indicates no specific criterion for acceptance is given because the impact damage will vary with different materials and forms of construction; some surface damage may be acceptable because it can be repaired. See test results photographs on page 13.	

Summary of other tests on partition specimen	
Requirement tested	Performance achieved
Crowd pressure	3 kN/m
Light weight anchorage – Pull out	100 N
Light weight anchorage – Pull down	250 N
Heavy weight anchorage – (Wash basin)	1500 N
Heavy weight anchorage – (Wall cupboard)	4000 N

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TABLE OF CONTENTS

1 INTRODUCTION

This document describes the test procedures and reports of the performance of Well & Able International BESTA™ Hollowcore panels of 90mm THK.

2 DESCRIPTION OF SAMPLE

Components used are as follow:

2.1) Panel Dimension: Length: 2760mm, Width: 600mm, Thickness: 90mm

2.2) Compound joint used: GX500 liquid mixed with GX500 powder

2.3) Non-shrink grouting used for infilling of hollow core:

Figure 1: Non shrink grout used for infilling hollow core

2.4) Screws used for light weight anchorage – pull out and pull down test

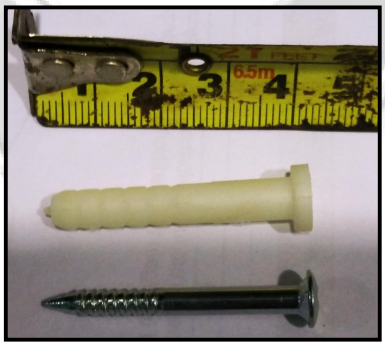

Figure 2: Screw with plastic anchor used for light weight anchorage tests

2.5) Screw use for heavyweight anchorage – wash basin and wall cupboard test

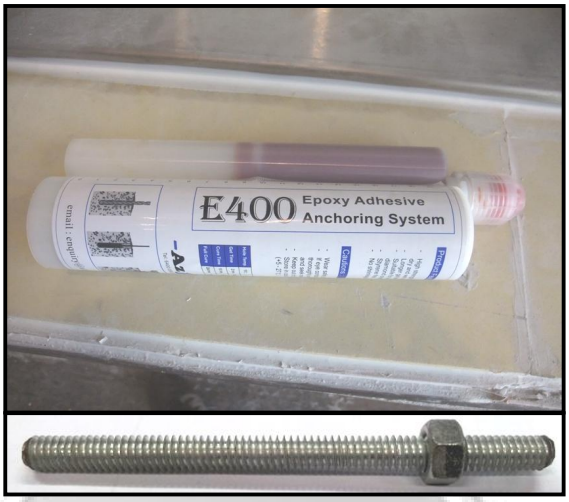

Figure 3: M10 bolt and epoxy used for heavy weight anchorage tests

3. TEST STANDARD

The test is tested with reference to BS 5234: 1992 “Partitions (including matching linings) Part 2: Specification for performance requirements for strength and robustness including methods of test”

SS 492: 2001 test method is equivalent to BS 5234 Part 2 : 1992

4. TEST SETUP

A mock-up test specimen 2760mm width X 4500mm height and a partition junction assembly of a right-angle corner with a return of 900mm was installed onto the test rig for the performance test. All hollow cores were infilled with non shrink grout. Total, 2 sheets of company’s drawings containing the details of the mock-up specimen.

The test specimen includes a door set 900mm width X 2100mm height and a 600mm run of partition flanking at one side of the door set.
It was installed from 16 March 2015 to 18 March 2015. Conditioning of the specimen with reference to SS492:2001 was agreed to be 3 hours after installation was completed in the lab’s condition.

Figure 4: Test specimen mock-up

5. DESCRIPTION OF TESTS

The following tests were conducted with reference to 5234 Part 2 : 1992 or SS 492: 2001:

5.1 Partition stiffness

This test is to establish the ability of the partition to withstand people or ladder leaning against the partition wall without causing unacceptable cracking or movement.

A static horizontal load of 500 N (±15 N) was applied through a 150 mm (±1 mm) diameter steel plate with a contact rubber pad of 6 mm (±2 mm) thick. The load was applied to the partition at a height of 1500 mm (±10 mm) from the bottom of the setup. Deflection was taken on the load side at 125 mm above the centre point of load application. A pretest load of 100 N was applied and stabilised for 1 min before unloading. The load was then applied in steps of 100 N until 500 N before unloading. Each loading was maintained for about 2 minutes for stabilisation.

Deflection was taken at the end of the 2 minutes interval. The residual deflection was taken when it had fully stabilized or 1 hour after unloading whichever occurs first.

5.2 Small hard body impact

The test is to simulate impact caused by sharp or pointed objects such as trolleys and wheelchairs. A 3 kg / 50 mm diameter steel sphere impactor was used to simulate a hard body object. It was attached to a 600 mm (±1.0 mm) long swinging arm.

5.2.1 Surface damage

This test is to determine the resistance of the partition to damage from impacts by small, hard body objects.

10 positions on the main wall of the test setup were chosen for the test. Each position was subject to a 10 Nm impact energy. The swinging arm was raised by 0.33 m or an angle of 63.6 degree and released. The rebounce of the steel arm was withheld to prevent it from making a second impact.

The depth of indentation was taken after each impact for a position.

The test was repeated at a corner position 75 mm away from the corner edge.

5.2.2 Perforation

This test is to determine the resistance of the partition to perforation from impacts by small, hard objects.

10 positions on the main wall of the test setup were chosen for the test. Each position was subject to a 30 Nm impact energy. The swinging arm was raised by 1.0 m or 131.8 degree and released. The rebounce of the steel arm was withheld to prevent it from making a second impact. The partition was inspected for any damage or perforation.

The test was repeated at a corner position 75 mm away from the corner edge.

5.3 Large soft body impact

The test is to simulate impact caused by people falling against or any large soft body object such as a ball hitting the partition wall. The impactor is a spheroconical bag of 600 mm X 400 mm filled with hardened glass beads. It has a total weight of 50 kg (±5 kg).

5.3.1 Resistance to surface damage

Two positions on the partition wall were selected for the test. Each location was subject to a single swinging impact. A linear gauge was placed behind the impacted panel to measure the permanent deformation.

The impact energy was 100 Nm. The impactor was raised by 204 mm before releasing. Permanent deformation was taken after 5 minutes from the impact.

The test was repeated at a corner position 200 mm away from the corner edge.

5.3.2 Resistance to structural damage

Two positions on the partition wall were selected for the test. Each location was subject to three swinging impacts.

The impact energy was 120 Nm. The impactor was raised by 245 mm before releasing. The partition was inspected for any surface or structural damage.

5.4 Door slam

The test simulates a door being forcefully slammed by a person, wind or tensioned door closer.

A 60 kg (±0.5 kg) door leaf was slammed through an opening angle of 60 degrees (±1 degree) with a force of 15 kg (±50 g) for 100 times. Residual deflection was taken on the door frame at 1 m above the bottom of the door leaf after 5 minutes from the last slamming.

5.5 Crowd pressure

This test simulates a uniform band load such as a crowd leaning against the wall.

A test load of 3.0 kN/m was applied through a 2.5 m long wooden beam placed at a height of 1.2 m above the bottom of the wall. Deflection was taken at 125 mm above the beam. Residual deflection was taken after 5 minutes upon released of the load.

5.6 Light weight anchorage

The test determines whether the partition wall can withstand light weight fixtures such as those for wall picture, clothing hook and basic wall shelving. A U-shaped steel bracket was secured by the specified anchorage. A shim plate was placed in between the steel bracket and the wall. A load of 20 N (±1 N) was applied on the shim plate.

5.6.1 Pull out

A pull out load of 100 N (±3 N) perpendiculars to the wall was applied on the bracket. The load was held for 1 minute before releasing.

5.6.2 Pull down

A pull down load of 250 N (±7.5 N) parallel to the wall was applied on the bracket. The load was held for 1 minute before releasing.

5.7 Heavy weight anchorage - Wall cupboard

The test simulates loading on the partition wall arising from heavy weight fittings such as wash basin and wall cupboard.

5.7.1 Wash basin

A steel bracket identical to a standard wash basin was mounted at a height of 0.8 m (±10 mm). Four deflections were taken, two on each side of the wall, at a height of 1.2 m and 1.75 m from the base of the wall. Shim plates were inserted in between the bracket and wall and loaded with a force of 20 N.

Cyclic load of the following sequence was applied: 500, 750, 500,750, 500, 1000, 500, 1000, 500, 1250, 500, 1250, 500, 1500, 500, 1500 & 500 N. Residual deflections were taken after 5 minutes from unloading.

5.7.2 Wall cupboard

A steel bracket identical to a standard wall cupboard was mounted at a height of 1.5 m (±10 mm). Four deflections were taken, two on each side of the wall, at a height of 1.2 m and 1.75 m from the base of the wall. Shim plates were inserted in between the bracket and wall and loaded with a force of 20 N (±1 N).

Incremental load of the following sequence was applied: 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000 N. Residual deflections were taken after 5 minutes from unloading.

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6. TEST RESULTS

6.1 Partition stiffness

Date of test: 31/04/2015
Lab temperature / Humidity: 28.6°C / 75%
Grade tested / load applied: Severe Duty / 500N ± 15 N

Load (N)	Duration (min)	Deflection (mm)	Residual Deflection (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
Pretest load of 100 N	1	-	-	Passed (No damage occurred)	1) There shall be no damage or detachment, loosening or dislodgement of partition wall's parts or fixing 2) The Maximum deflection and residual deformation shall not exceed 10 & 1 mm respectively.
100	2	-0.1	-		
200	2	-0.1	-		
300	2	-0.2	-		
400	2	-0.2	-		
500	2	-0.3	0.0		

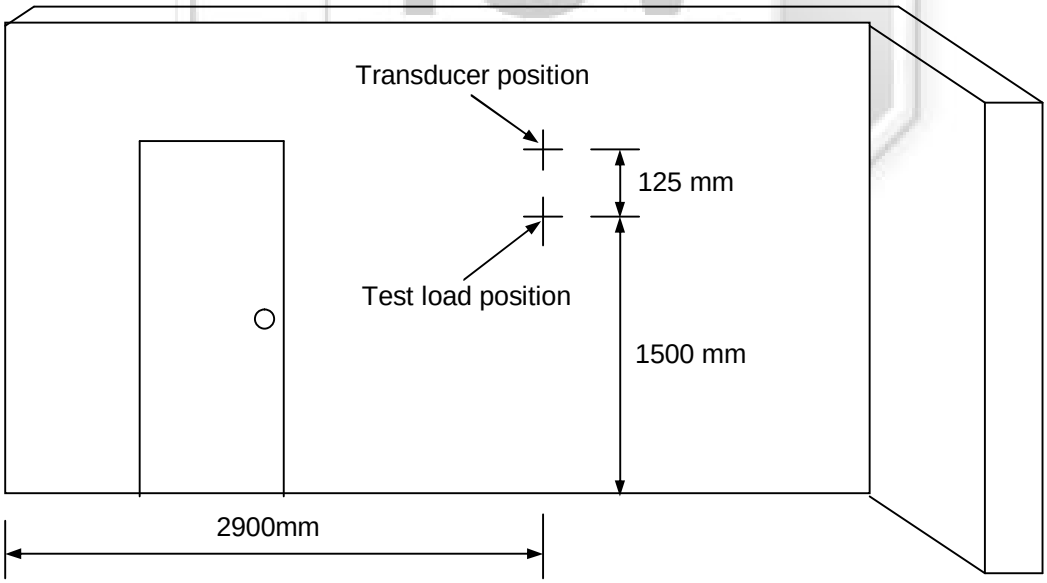

Figure 5: Location of applied load for partition stiffness test

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6.2 Small hard body impact

6.2.1 Surface damage

Date of test: 31/03/2015
Lab temperature / Humidity: 28.8°C / 78%
Grade tested / Impact Energy: Severe Duty / 10 Nm

Impact Position	X (mm)	Y (mm)	Depth of indentation (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
1	2480	390	0.7	Tested 1) No detachment, loosening or dislodgement of its parts or fixings occurred. 2) See Fig. 9 photos for closed-up view of surface damage.	1) No specific criterion for acceptance 2) Attached photographs of surface damages for the authority judgment to be made whether can be easily repaired for acceptance
2	2520	390	0.4		
3	2610	390	0.3		
4	2670	390	0.4		
5	2710	400	0.6		
6	2850	400	0.7		
7	2940	410	0.8		
8	3000	410	0.7		
9	3060	410	0.6		
10	3130	410	0.8		
**11	75	240	0.4		

**Note: Corner junction

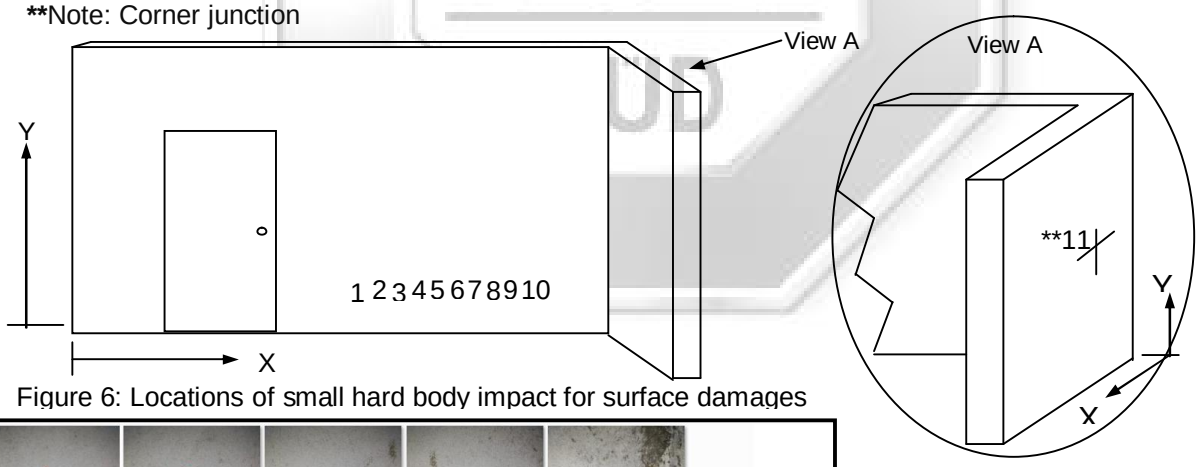

Figure 6: Locations of small hard body impact for surface damages

Figure 7: Surface damage by small hard body impact - closed up view of indentations

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6.2.2 Perforation

Date of test: 31/03/2015
Lab temperature / Humidity: 28.8°C / 78%
Grade tested / Impact energy: Severe Duty / 30 Nm

Impact Position	X (mm)	Y (mm)	Depth of indentation (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
1	2300	510	0.9	Tested 1) No detachment, loosening or dislodgement of its parts or fixings occurred. 2) See Fig. 9 photos for closed-up view of surface damage.	1) No specific criterion for acceptance 2) Attached photographs of surface damages for the authority judgment to be made whether can be easily repaired for acceptance
2	2400	510	1.0		
3	2500	510	0.7		
4	2590	510	0.8		
5	2640	510	0.8		
6	2745	510	1.0		
7	2820	510	1.2		
8	2910	510	1.6		
9	2990	510	1.5		
10	3080	510	1.2		
**11	75	370	0.8		

**Note: Corner junction

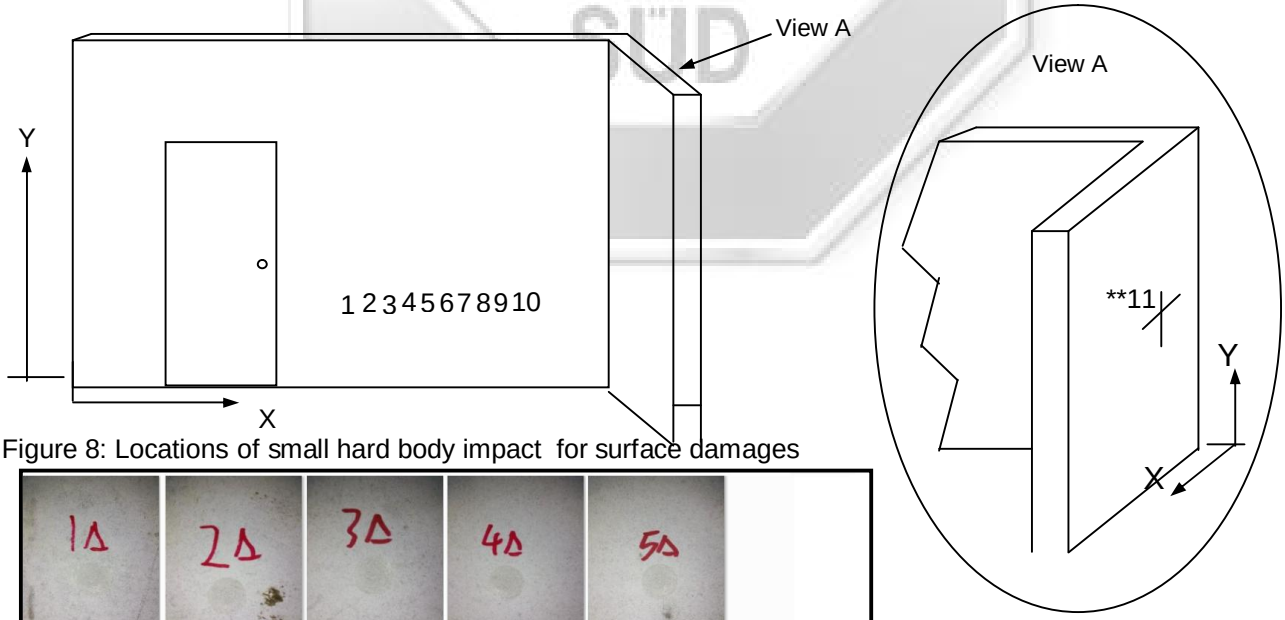

Figure 8: Locations of small hard body impact for surface damages

Figure 9: Perforation by small hard body impact - closed up view of indentations

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6.3 Large soft body impact

6.3.1 Resistance to damage

Date of test: 31/03/2015
Lab temperature / Humidity: 28.8°C / 78%
Grade tested / Impact Energy: Severe Duty / 100 Nm

Impact Position	X (mm)	Y(mm)	Residual deflection (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
1	2000	1300	0	Passed (No damage occurred)	The partition wall and a right angle junction shall be capable of withstanding the impact energies without sustaining either permanent deformation in excess of 2 mm or any damage.
2	3840	1300	0		
**3	200	1400	0.1		

**Note: Corner junction

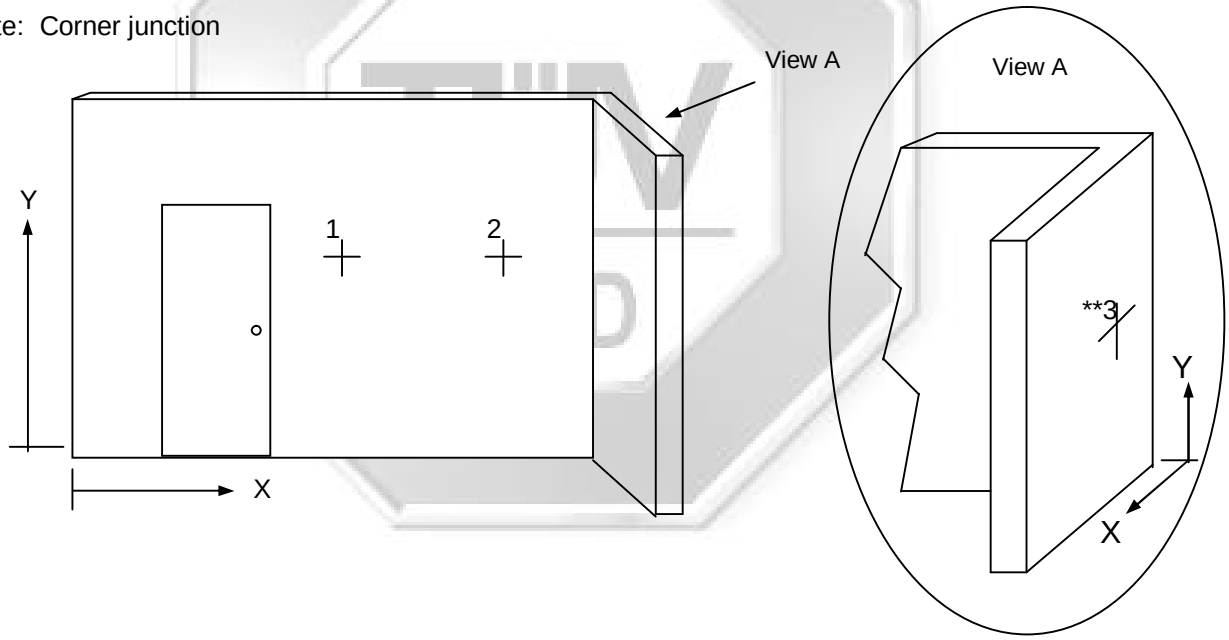

Figure 10: Locations of large soft body impact for resistance to damage

6.3.2 Resistance to structural damage by multiple impacts

Date of test : 31/03/2015
Lab temperature / Humidity: 28.8°C / 78%
Grade tested / Impact Energy: Severe Duty / 120 Nm

Impact Position	X (mm)	Y (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
1	2400	1300	Passed (No damage occurred)	The partition wall shall be capable of withstanding the impact energies, without collapsing or dislocating the partition wall or its fixings.
2	3000	1300		
**3	200	1300		

**Note: Corner junction

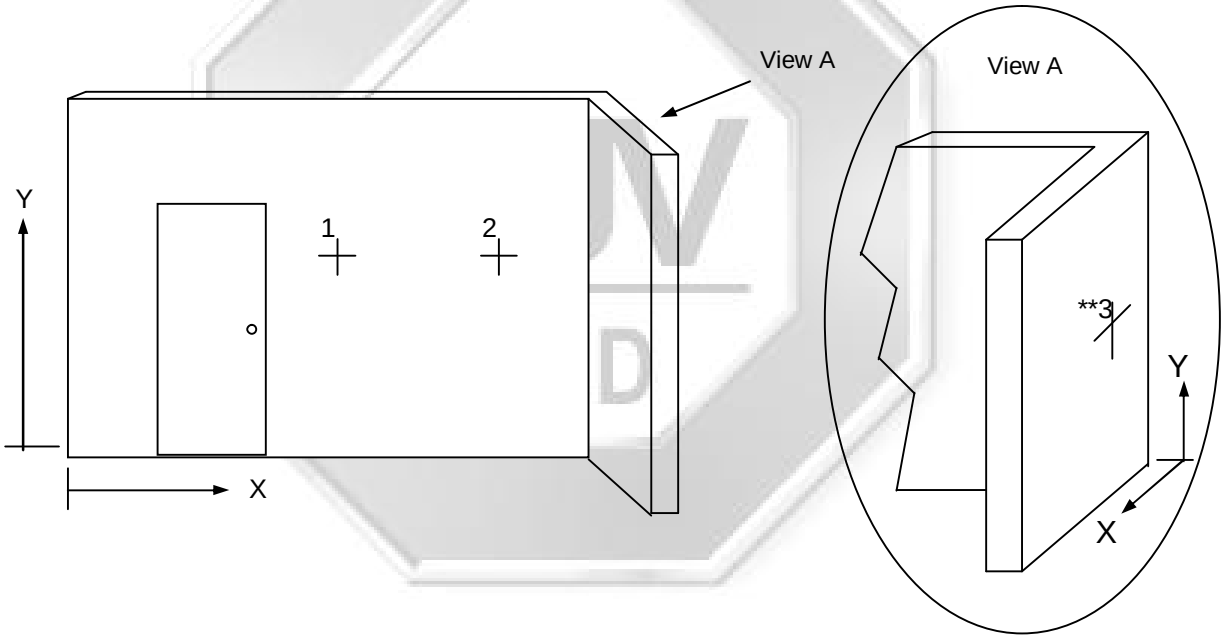

Figure 11: Locations of large soft body impact for resistance to structural damage

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6.4 Door Slamming

Date of test: 01/04/2015
Lab temperature / Humidity: 28.8°C / 78%
Grade tested: Severe Duty
Door weight: 60kg ± 0.5 kg

Number of slam (Open door to 60 ±10°)	Residual deflection (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
Pretest of 3	0	Passed (No damage Occurred)	1) The partition shall not be damaged, nor shall door frame fittings and architraves become detached or loose after the door leaf has been slammed. 2) The closing jamb of the door frame shall not be permanently displaced by more than 3mm as a result of the pre-slam test and by more than 1 mm as a result of the main slam test, from its position at the start of the test, measured at 1.0m above the bottom of the door leaf.
20	-0.4		
100	-0.6		

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6.5 Crowd Pressure

Date of test: 01/04/2015
Lab temperature / Humidity: 28.6°C / 75%
Load applied: 3.0 kN/m

Load	Duration (min)	Deflection(mm)	Residual Deflection (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
Pretest load of 200 (N)	1	-0.1	0	Passed (No damage occurred)	There shall be no collapse or damage that would render the partition wall dangerous, due to any of its parts becoming dislodged or shattered, in a manner that could cause injury.
3.0 kN/m	2	-3.16	-0.2		

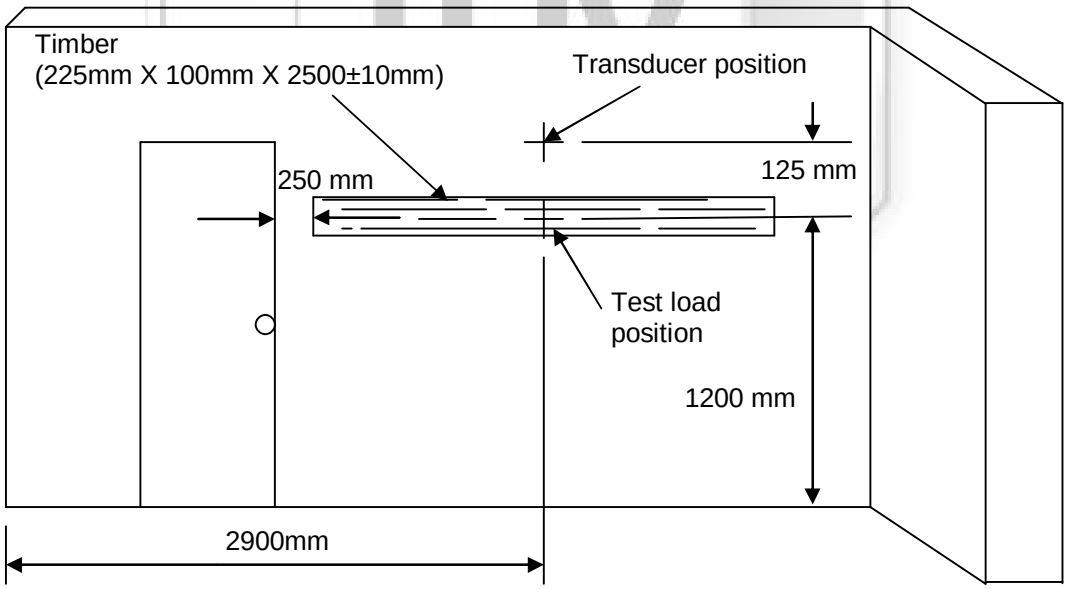

Figure 12: Locations of applied load for crowd pressure

6.6 Lightweight Anchorage

6.6.1 Pull-out test

Date of test: 01/04/2015
Lab temperature / Humidity: 28.8°C / 78%
Load applied: 100 N ± 3 N

Load (N)	Duration (min)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
100	1	Passed	The partition wall shall withstand the axial load without releasing the pull-up shim plate or damaging the partition other than superficial cracking

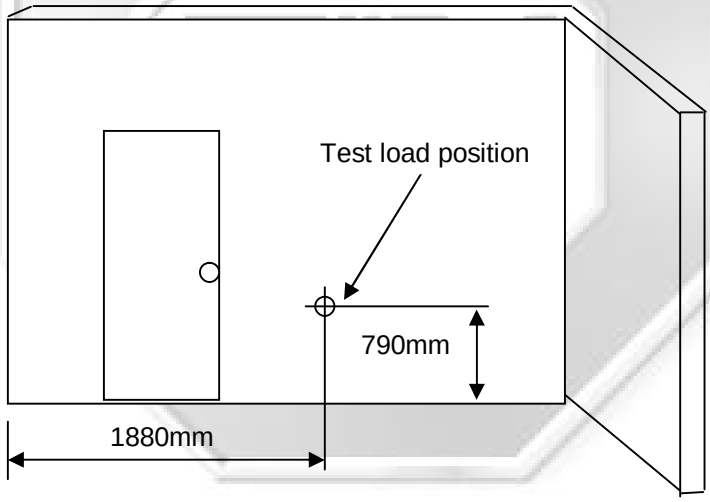

Figure 13: Locations of applied load for lightweight anchorage Pull-out test

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6.6.2 Pull-Down Test

Date of test: 01/04/2015
Lab temperature / Humidity: 28.8°C / 78%
Load applied: 250 N ±3 N

Load (N)	Duration (min)	Deflection (mm)	Condition of the specimen tested	BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements
250	1	0	Passed (No damage occurred)	1) The partition wall shall withstand the transverse load without releasing the pull-up shim plate or damaging the partition other than superficial cracking. 2) The maximum movement of the pull-down bracket shall not exceed 2mm.

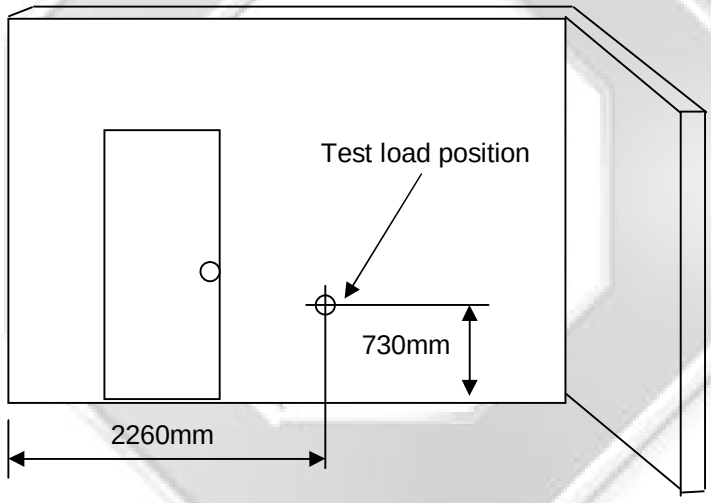

Figure 14: Locations of applied load for lightweight anchorage Pull-down test

6.7 Heavyweight Anchorage
6.7.1 Wash basin

Date of test: 01/04/2015
Lab temperature / Humidity: 28.8°C / 78%
Load applied: 1500 N

Load (N)	Time (min)	Deflection (mm)				Residual deflection (mm)				Condition of the specimen tested
		1	2	3	4	1	2	3	4	
Pretest load of 200	1	0	0	0	0	0.0	0.0	0.0	0.0	Passed (No damage occurred)
500	1	0.0	0.0	0.0	0.0	-	-	-	-	
750	1	0.0	0.0	0.0	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	-	-	-	-	
750	1	0.1	0.1	0.0	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	-	-	-	-	
1000	1	0.1	0.1	0.0	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	-	-	-	-	
1000	1	0.1	0.1	0.0	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	-	-	-	-	
1250	1	0.1	0.1	-0.1	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	-	-	-	-	
1250	1	0.1	0.1	-0.1	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	-	-	-	-	
1500	1	0.1	0.1	-0.1	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	-	-	-	-	
1500	1	0.1	0.2	-0.1	0.0	-	-	-	-	
500	1	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	

BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements	The anchorages shall be capable of withstanding the load selected applied to the 2 linked brackets without releasing either pull-up shim plate, exceeding 20 mm deflection or 1 mm residual deformation limits and without loosening, detaching or damaging the partition wall.

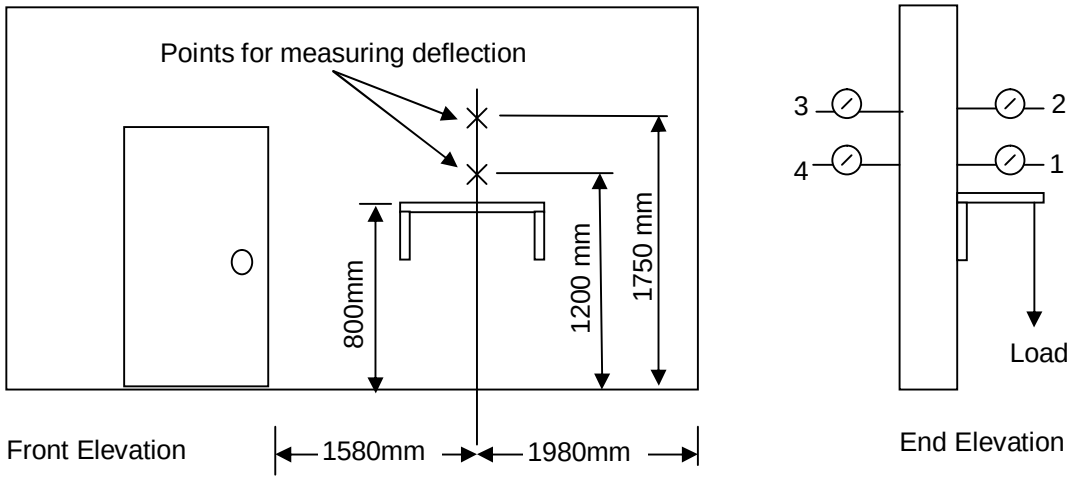

Figure 15: Locations of applied load for heavyweight anchorage (Wash basin) eccentric downward loading test test

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6.7.2 Wall cupboard

Date of test: 01/04/2015
Lab temperature / Humidity: 28.8°C / 78%
Load applied: 4000 N

Load (N)	Time (Min)	Deflection (mm)				Residual deflection (mm)				Condition of the specimen tested
		1	2	3	4	1	2	3	4	
Pretest load of 200	1	0	0	0	0	0	0	0	0	Passed (No damage occurred)
500	1	0.0	0.0	0.0	0.0	-	-	-	-	
1000	1	0.0	0.0	0.0	0.0	-	-	-	-	
1500	1	0.0	0.0	0.0	0.1	-	-	-	-	
2000	1	0.0	0.1	0.0	0.1	-	-	-	-	
2500	1	0.0	0.1	0.0	0.2	-	-	-	-	
3000	1	0.0	0.1	0.1	0.2	-	-	-	-	
3500	1	0.0	0.1	0.1	0.2	-	-	-	-	
4000	1	0.0	0.2	0.1	0.3	0.0	0.0	0.0	0.0	

BS 5234: Pt 2: 1992 or SS 492: 2001 Requirements	The anchorages shall be capable of withstanding the load selected applied to the 2 linked brackets without releasing either pull-up shim plate, exceeding 5 mm deflection or 1 mm residual deformation limits and without loosening, detaching or damaging the partition wall.

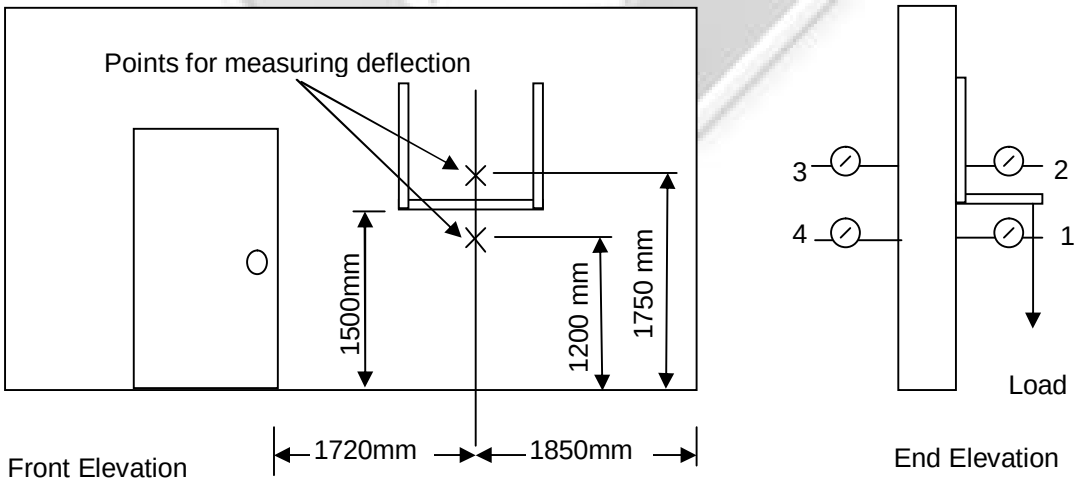


Figure 16: Locations of applied load for heavyweight anchorage
(High level wall cupboard) eccentric downward loading test

CONCLUSION

All test results meets the **SEVERE DUTY** grade requirements of BS 5234 Part 2: 1992 or SS 492:2001

Well & Able International BESTA™ hollowcore panels of 90mm THK has also achieved the following performance;

Crowd pressure	:	3.0 kN/m
Light weight anchorage – pull out	:	100 N
Light weight anchorage – pull down	:	250 N
Heavy weight anchorage – wash basin	:	1500 N
Heavy weight anchorage – wall cupboard	:	4000 N

Ng Yui Xiong
Higher Associate Engineer

Wong Mun Hong
Product Manager
Building Group
Mechanical Centre

PSB Singapore

APPENDIX: TEST SET-UP

Figure17: Lightweight anchorage- pull-down test

Figure 18 : Lightweight anchorage- pull-out test

Figure 19: Heavy weight anchorage wash basin

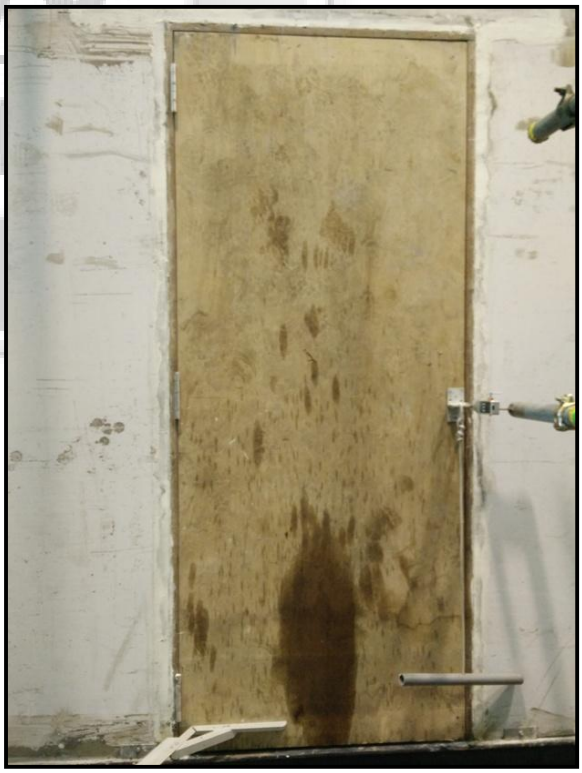


Figure 20: Door Slam

PSB Singapore

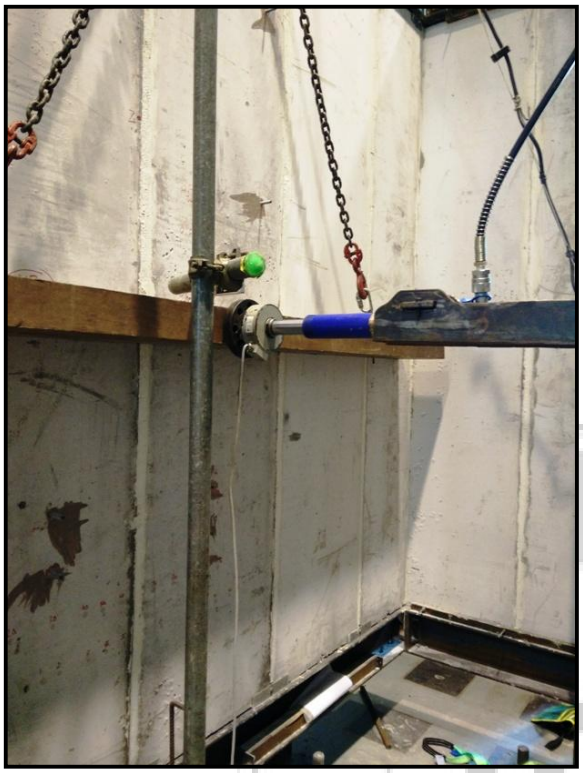


Figure 21: Crowd Pressure test

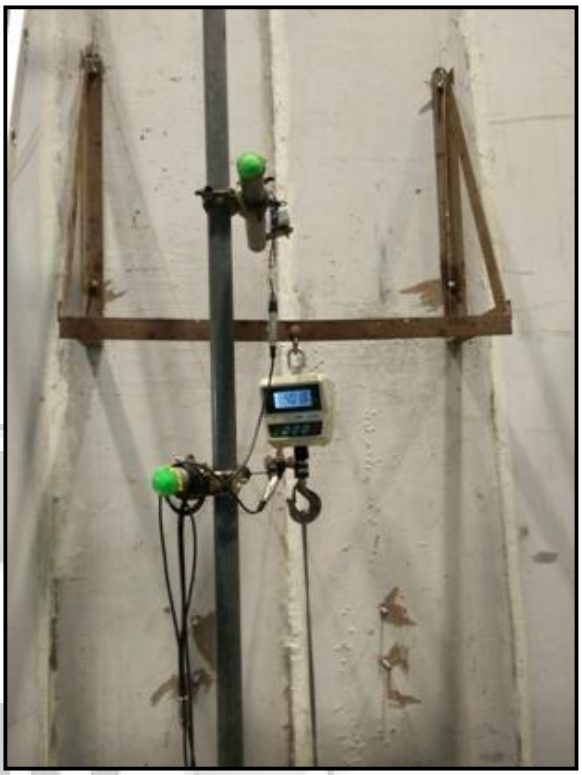
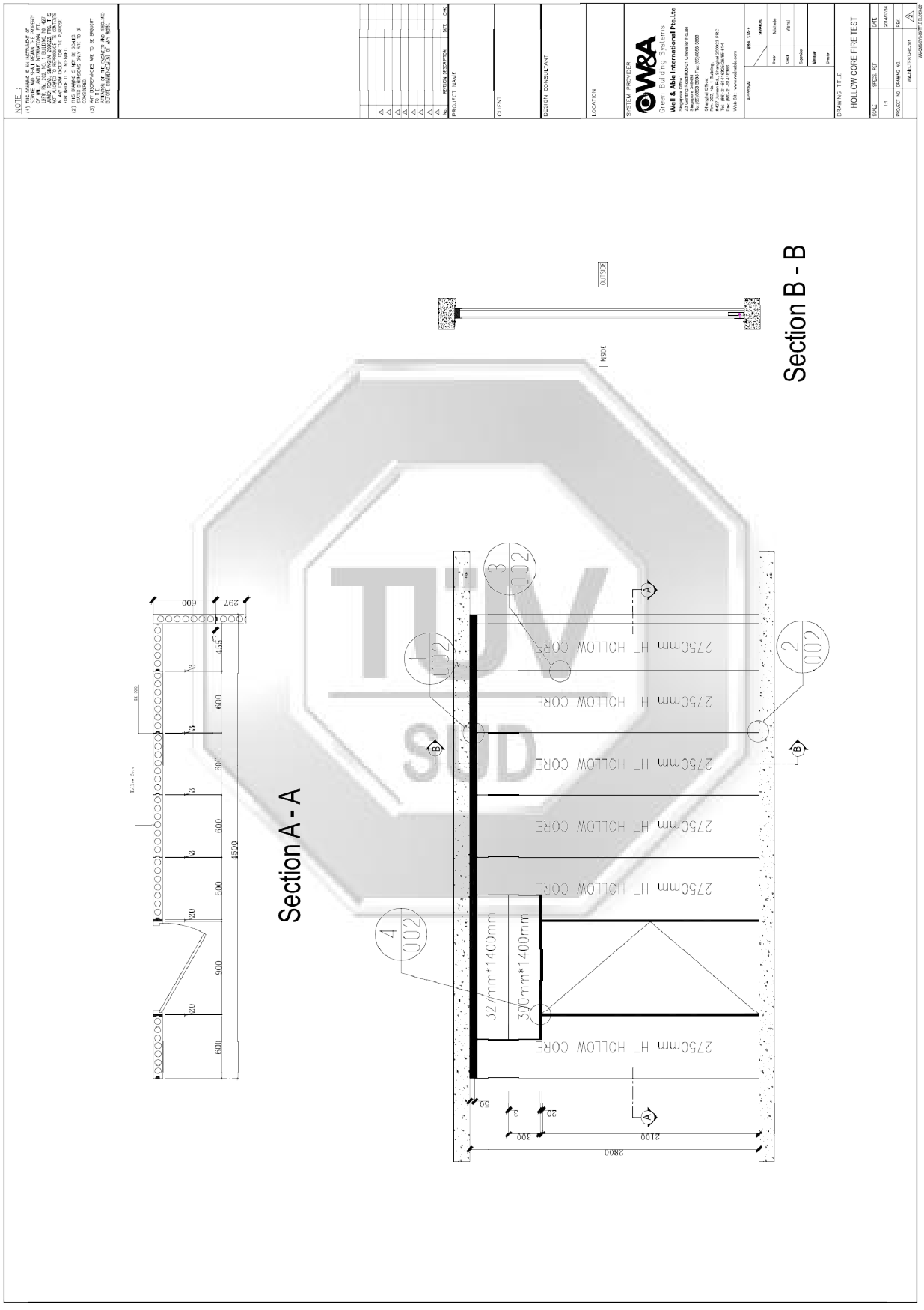
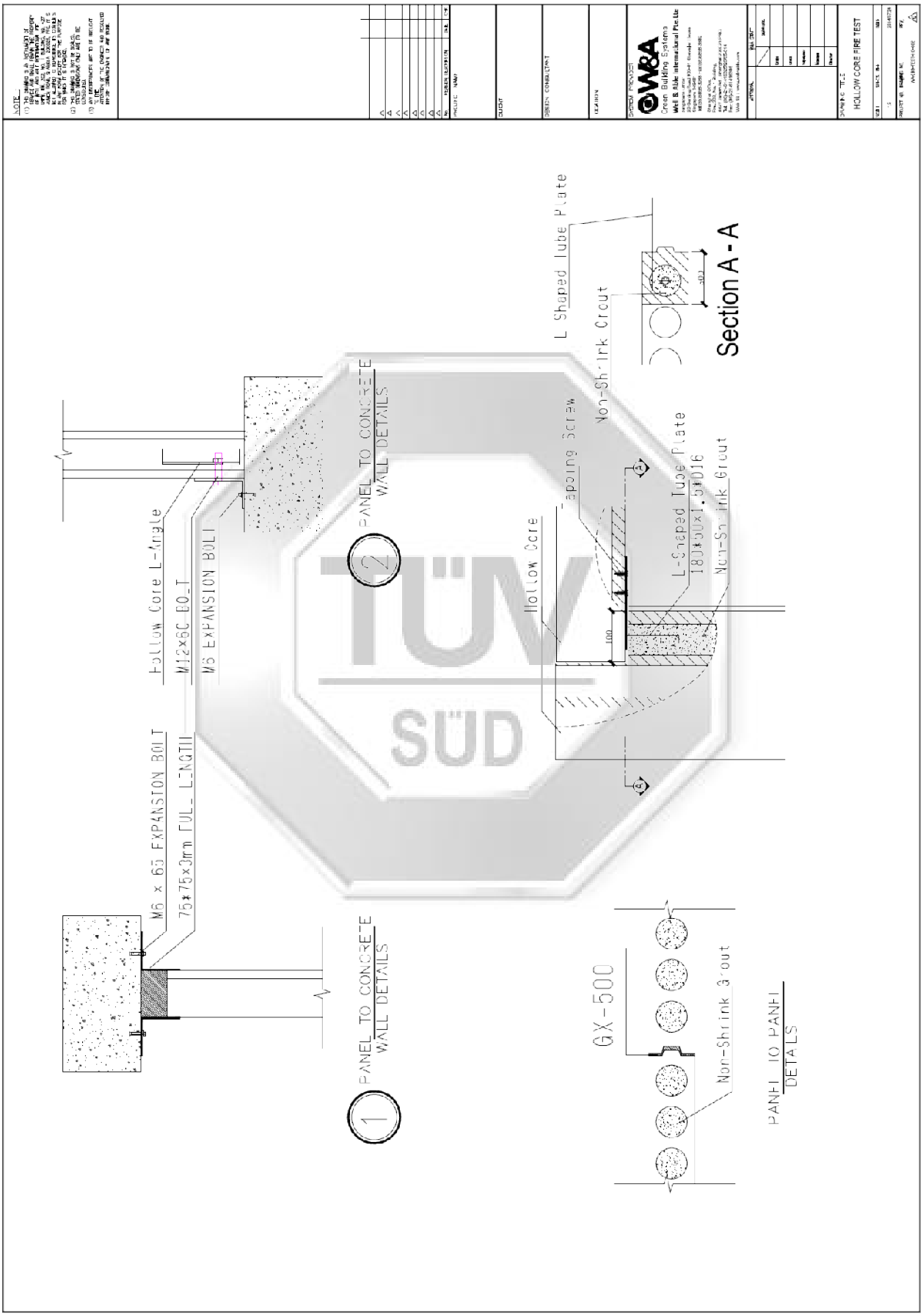


Figure 22: Heavy weight anchorage wall cupboard


Section A - A
Section B - B
275mm HT HOLLOW CORE
327mm*1400mm
390mm*1400mm
2800
2100
1500


Section A - A
L Shaped Tube Plate
Non-Shrink Grout
Hollow Core
Tapping Screw
L-Shaped Tube Plate
180*90x1.5*016
Non-Shrink Grout
Hollow Core L-Angle
M12x60 EQ_T
M6 EXPANSION BOLT
M6 x 65 EXPANSION BOLT
75*75x3mm FULL LENGTH
1 PANEL TO CONCRETE WALL DETAILS
2 PANEL TO CONCRETE WALL DETAILS
GX-500
Non-Shrink Grout
PANEL TO PANEL DETAILS
HOLLOW CORE FIRE TEST

PSB Singapore

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