Tensile Pull Out test on Wire Loop (circular type)

Sample Ref.	Test Member	Fixing Type	Applied Tensile Load (kN)	Observation After Test
T1	PBU panel	Wire Loop (Circular Type)	37.7	Failure within the wire loop material
T2			39.5	

Further test was performed on the vertical connections between precast wall-wall, column-wall connections with a circular connection loop. The test sample was placed on the universal testing machine in a vertical position and tension load was applied gradually until failure. The maximum load was then recorded. A total of five samples were tested.

Result:

Table : Tension Load Test

Sample Reference	J Circular Connection Loop (JCCL) Ø6 X R60mm long Wire Rope				
	S1	S2	S3	S4	S5
Maximum Load (kN)	48.5	48.9	49.7	47.7	48.7
Position of Fracture	Drawn Out (See Photograph 2 attached)	Failure of wire (See Photograph 2 attached)		Drawn Out (See Photograph 2 attached)	Failure of wire (See Photograph 2 attached)

Further, cable loops pull out tension test results are as follows:

Cable Loop Anchorage pull out test				
Description 14 Day concrete strength	Jacking Force - kN		Design Force - kN	FOS– average value
	Sample 1	Sample 2		
Loop type (L-shape)	23.0	23.9	20	1.17
Circular type	37.7	39.5	20	1.93

Advantageously, the grout 48 has mechanical properties that binds (sandwich) each side wall 14b and 14c together as one composite wall to allow the embodiments to be able to withstand structural loads during use. Axial compression test show sample

loaded to ultimate load equal to 2 times working load. Additionally, sample did not fail at ultimate test load and there was no delamination observed at the concrete/grout interface. Therefore axial compression test showed that the, sample behaved in a composite manner under axial compression and it has performed satisfactorily beyond the design capacity as an integrated unit and the strength of the grout-interface performed as well as the strength of the concrete.

Compression Test – 3mx1.2m sample size			
Description	**Jacking Force kN**	**Design Force kN**	**Remarks**
1mm chequered plate finish - Compression	7200	4800	No failure, no delamination
1mm chequered plate finish - Compression with ecc	7200	4800	Fail at 7200kN

Further, bending test was performed on the sandwiched panels to verify flexural capacity of the panels and determine whether there is slipping issue between the precast panel and infill grout. The sample was loaded to failure and was found to fail by bending with flexural crack lines forming on surface. However, there was no delamination observed at the concrete/grout interface. Therefore bending test found that the sample behaved in a composite manner under bending.

Bending Test – 3mx1.2m sample size			
Description	**Jacking Force kN**	**Design Force kN**	**Remarks**
1mm chequered plate finish	260	173	Fail at 50% above design load

Further, direct and indirect shear test was performed on the sandwiched panels to verify shear bond capacity between the panels and the grout using different surfaces of concrete to find the best possible rough surface finish that will achieve a high shear bond capacity.

Direct Shear Test – 500mmx500mm sample size – 1mm chequered plate finish			
Sample No.	**Shear Stress-MPa**	**Design Shear Stress - MPa**	**Factor of Safety -FOS**
S1 (02.06.16)	1.45	0.44	3.29
S2 (02.06.16)	0.39	0.44	0.88
S3 (02.06.16)	0.48	0.44	1.09
S4 (02.06.16)	0.51	0.44	1.16
S1 (21.07.16)	1.44	0.44	3.27
S2 (21.07.16)	0.71	0.44	1.61
S3 (21.07.16)	0.60	0.44	1.36
S4 (21.07.16)	1.43	0.44	3.25
S5 (21.07.16)	1.22	0.44	2.77

Indirect Shear Test – 1100mmx270mm sample size				
Description	**Sample 1 Shear Stress-MPa**	**Sample 2 Shear Stress-MPa**	**Design Shear Stress - MPa**	**FOS–lowest value**
1mm chequered plate	3.59	1.71	0.44	3.88
1mm chequered plate w/ T10 bar groove	2.9	1.84	0.44	4.18
Broom brush finish	1.93	2.17	0.44	4.38
Exposed aggregates	2.40	2.21	0.44	5.02
3mm chequered plate w/ holes	1.38	1.08	0.44	2.45
5mm chequered plate	1.58	1.35	0.44	3.06
Wash aggregate	2.43	2.69	0.44	5.52
1mm chequered plate w/ 10mm groove @ 100mm	2.43	2.43	0.44	5.52

Further, pull out tension test was performed to verify the tension capacity between the panels and the grout using different surfaces of concrete to find the best possible rough surface finished that will achieve a high tension capacity.

Pull out Tension Test Stage 1 – 500mmx800mm sample size					
Description	**Jacking Force - kN**			**Design Force - kN**	**FOS– average value**
	Sample 1	Sample 2	Sample 3		
1mm chequered plate	21.8	24.8	19.90	50	0.44
1mm chequered plate w/ T10 bar groove @ 150mm	70.50	64.50	47.70	50	1.22
1mm chequered plate w/ T10 bar groove @ 150mm + Studs @ 200mm	63.80	36.70	-	50	1.0
Wash aggregate + Stud @ 200mm	100.30	81.40	-	50	1.82

Pull out Tension Test Stage 2 ALL WASH AGGREGATE – 500mmx800mm sample size					
Description	**Jacking Force - kN**			**Design Force - kN**	**FOS– average value**
	Sample 1	Sample 2	Sample 3		
Normal recess w/o loops	128.90	94.20	179.60	50	2.68
Inverted key recess w/o loops	146.90	136.00	130.00	50	2.75
Normal recess + double loops	130.00	112.20	133.00	50	2.50
Inverted key recess + double loops	111.20	118.10	106.20	50	2.24
Normal recess + single loop + enhanced U-bar	272.80	207.30	206.30	50	4.58
Normal recess + H10 U-bar	159.70	173.60	-	50	3.33
Normal recess + double H10 U-bar	163.80	187.60	-	50	3.51

The tests conducted led to the conclusion that the sandwich wall system performs as a composite wall after grouting. The material used as grout 48 allows the overall system of binding or coupling of the two side walls 14b, 14c together to meet the structural capacity of concrete in terms of bending, axial compression and shear. The various shear and tension tests established the a suitable surface and mechanical connection for the system. The structural design requires for a rough surface according to SS EN 1992-1-1:2008. The test showed that a rough surface achieved by washed aggregate gives a higher shear resistance value compared to the other types of rough surface tested and as such, is preferable for multi-level buildings.

Concrete reference	Cube number	Compressive strength [MPa]
C1	1	82.7
C1	2	76.4
C1	3	85.2
C2	1	74.6
C2	2	78.4
C2	3	86.4
C3	1	92.3
C3	2	94.9
C3	3	91.9

The table below itemises the grout tension by flexion and compression for each grout batch by testing three grout prisms of dimensions 4 cm x 4 cm x 16 cm.

Concrete reference	Prism number	Flexural Tensile strength [MPa]	Compressive strength, 1 [MPa]	Compressive strength, 2 [MPa]
G1	1	7.10	62.8	59.3
G1	2	7.34	59.4	56.3
G1	3	8.59	60.0	58.8
G1	4	8.80	59.6	61.7
G1	5	7.06	68.7	61.7
G1	6	7.80	64.2	63.0
G2	1	6.95	72.2	68.2
G2	2	6.91	70.3	74.9
G2	3	6.73	71.8	73.5
G2	4	5.53	72.2	69.5
G2	5	6.18	70.3	66.2
G2	6	6.85	71.8	69.2
G2	7	6.02	68.1	64.9
G2	8	7.40	66.3	69.3
G2	9	5.75	68.1	64.8
G2	10	5.74	79.1	77.0
G2	11	6.73	79.0	73.5
G2	12	6.02	75.3	75.7
G3	1	7.71	70.0	72.8
G3	2	8.47	74.3	75.2
G3	3	7.07	69.6	71.0
G3	4	9.15	58.8	59.4
G3	5	7.69	58.1	53.2
G3	6	8.65	59.2	55.1
G4	1	8.1	62.1	61.0
G4	2	8.61	63.8	63.1
G4	3	8.39	62.8	60.1
G4	4	7.63	65.4	62.0
G4	5	6.04	68.3	65.1
G4	6	8.15	67.0	64.8

The table below itemises the tensile test results of the specimens with paraffin wax showing the maximum loads:

Specimen number	Date of test	Maximum load [kN]	Displacement corresponding to maximum load [mm]	Failure behaviour	Failure mechanism
P1	06/04/2017	40.2	3.48	Brittle	Anchorage of protruding reinforcement
P2	07/04/2017	36.1	4.37	Brittle	Anchorage of protruding reinforcement
P3	07/04/2017	43.6	3.54	Brittle	Anchorage of protruding reinforcement
P4	12/04/2017	40.0	4.38	Brittle	Anchorage of protruding reinforcement
P5	12/04/2017	40.3	4.11	Brittle	Anchorage of protruding reinforcement
P6	12/04/2017	37.7	3.45	Brittle	Anchorage of protruding reinforcement

The table below itemises the tensile test results of the specimens without paraffin wax showing the maximum loads:

Specimen number	Date of test	Maximum load [kN]	Displacement corresponding to maximum load [mm]	Failure behaviour	Failure mechanism
B1	06/04/2017	50.0	0.10	Brittle	Shear failure of concrete panel
B2	07/04/2017	56.4	0.03	Brittle	Shear failure of concrete panel
B3	07/04/2017	33.5	3.85	Brittle	Anchorage of protruding reinforcement
B4	12/04/2017	38.3	0.07	Brittle	Shear failure of concrete panel
B5	12/04/2017	47.4	0.06	Brittle	Shear failure of concrete panel
B6	12/04/2017	50.9	0.00	Brittle	Shear failure of concrete panel

Another Alternate Method of Constructing a Building

In the embodiment shown in Figures 11 to 13, the couplers 36 of the modules 12b, 12c are U-bars 50 that are used to couple side walls 14c and side wall 14b. In this embodiment, fastener 30 comprises chipping concrete 52 which is used to fill the fastening channel 32 between the mating surface 20 of module 14c and the mating surface 22 of module 14b. Advantageously, the distance between the mating surface