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APPENDIX A : BASIC DETAILS OF BUILDING - A

A1. Eighteen storied residential apartment building

As the first case study, the selected building is a 18 storied reinforced concrete apartment building, which includes a ground floor and 17 above ground floors, where the ground floor up to fourth floor were used for parking purposes. Typical floor plan and a schematic cross section showing the dimension of the building in plan and elevation are given in Fig. A1 and A2 respectively. The total height of the building above the ground level is 71.2m and the plan dimension are29.49m x 19.38m

The main structural system consists of concrete frames and shear walls, whereas unreinforced masonry walls are used as partition walls.

At fifth floor level, the columns located at grid C1 and E1 on grid 1 have moved along grid 1 and the columns at grid A3, C1 and E1 on grid 8 have been shifted along grid 8 and also the columns grid H and K on grid 3 have been moved to grid 2. All the columns then continued up to roof level. Similarly, the shear walls located between grid E1 to H on grid 1 and C1 to J on grid 8 terminates at 5th floor level. Also the shear wall between grids D1 to F1 have been moved from grid 3 to 2 from the fifth floor onwards.

The structure has been designed with C30 concrete, except the columns from ground floor up to sixth floor slab level, where C40 concrete was used.

All analysis were performed with the ETABS software (CSI 2002 ETABS Integrated Building Design Software, Computers & Structures Inc. Berkeley) on a three dimensional (spatial) mathematical model.

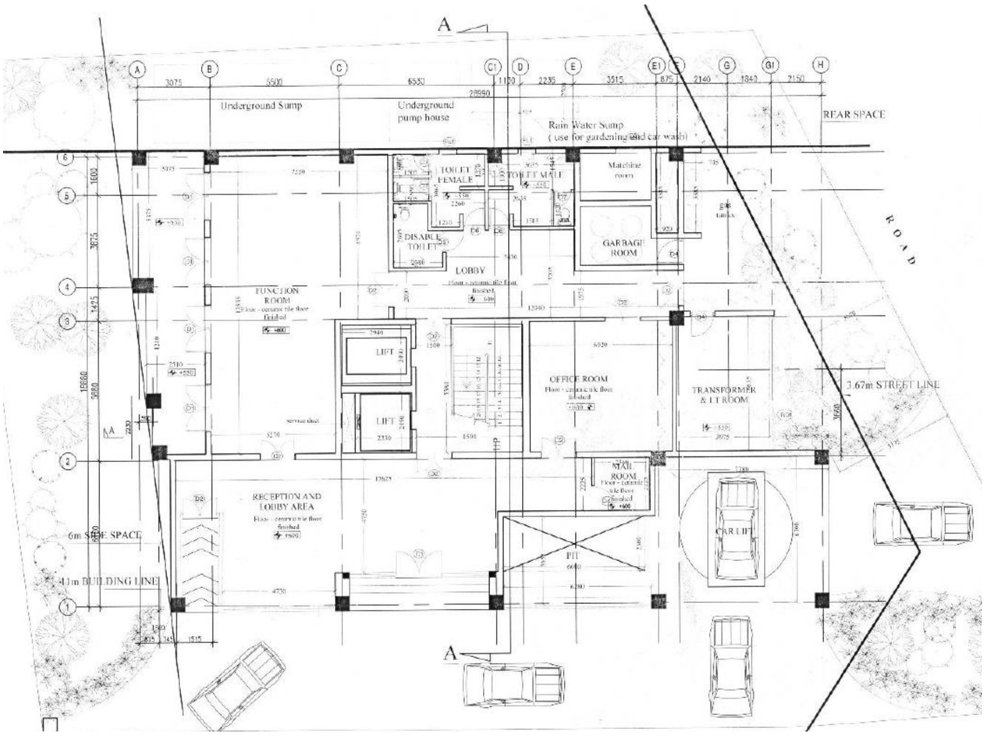

Figure A1: Plan View - Ground floor

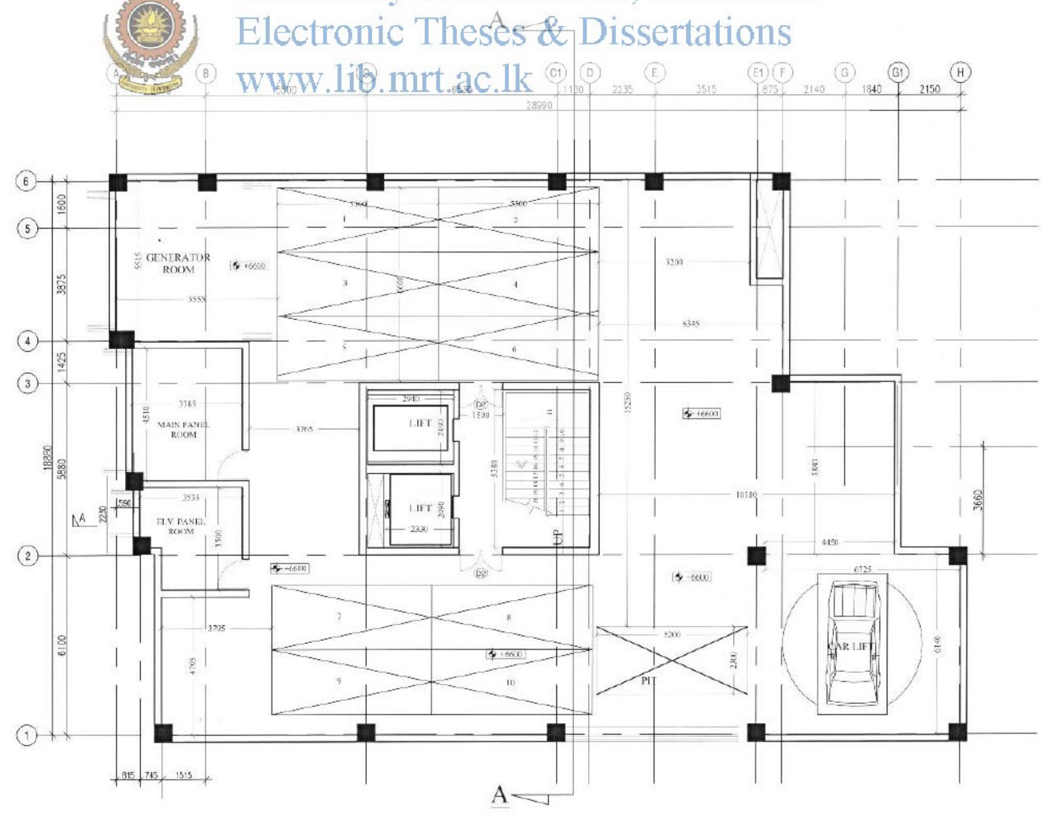

Figure A2: Plan View - First floor

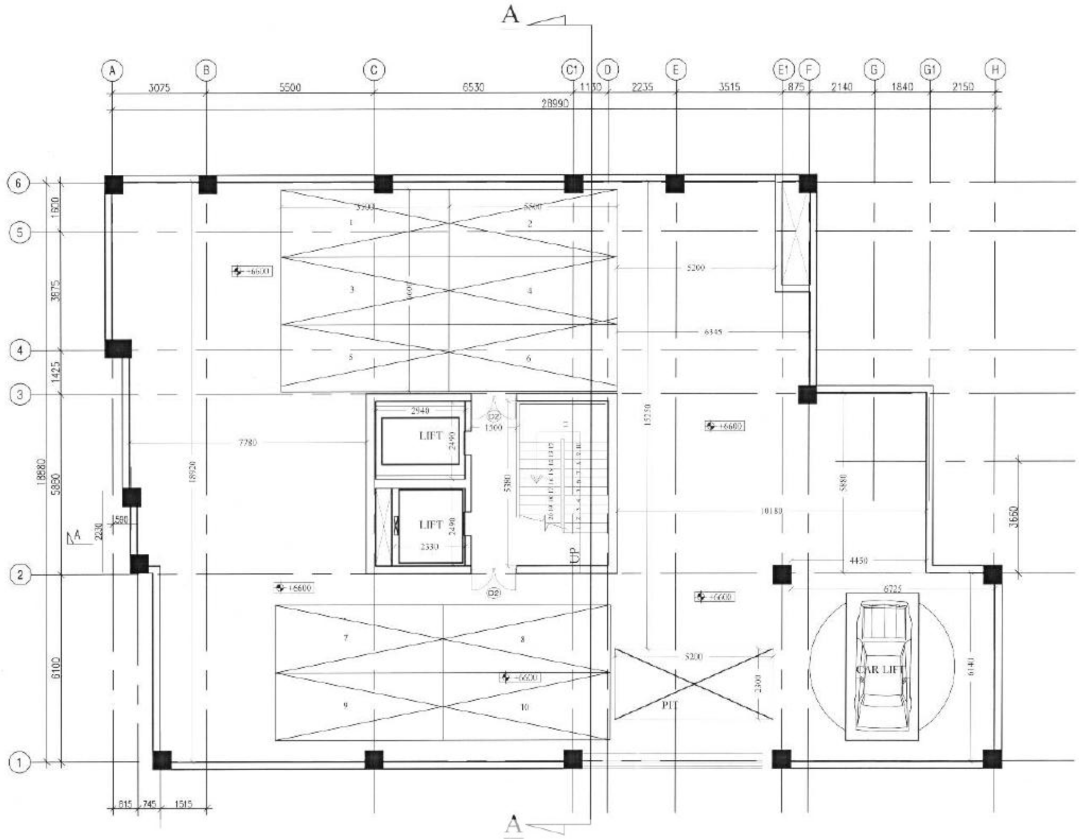

Figure A3: Plan View – 2nd to 4th floor

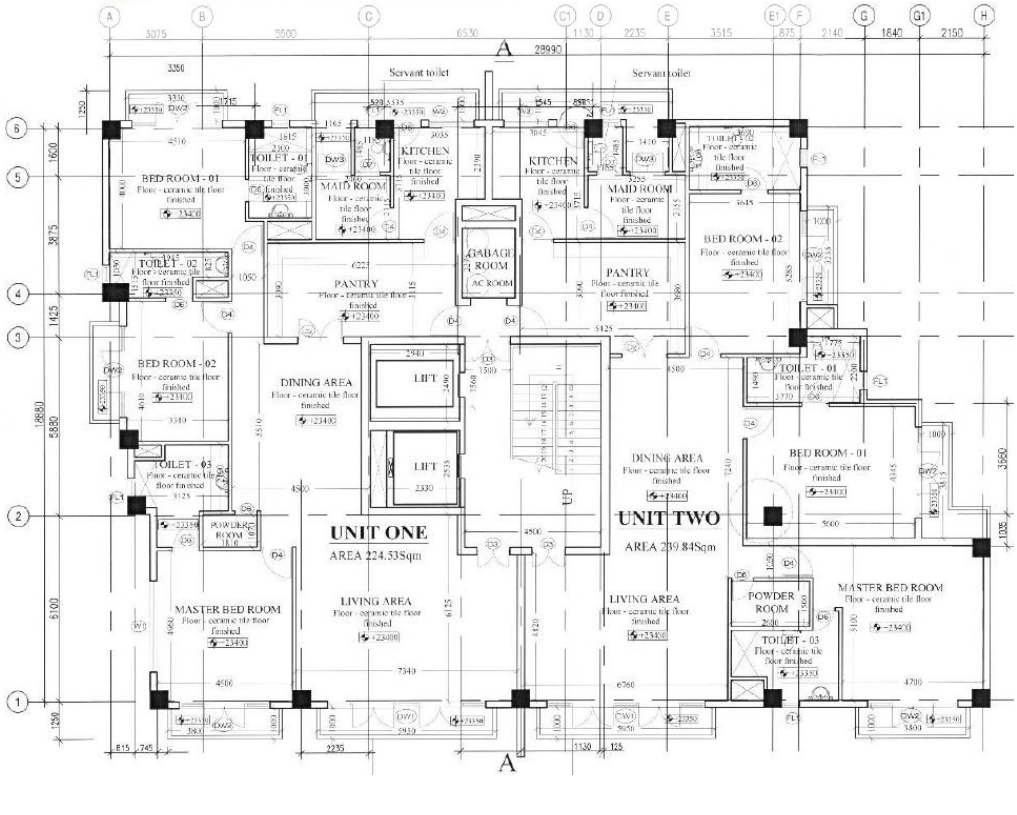

Figure A4: Plan View – 5th floor

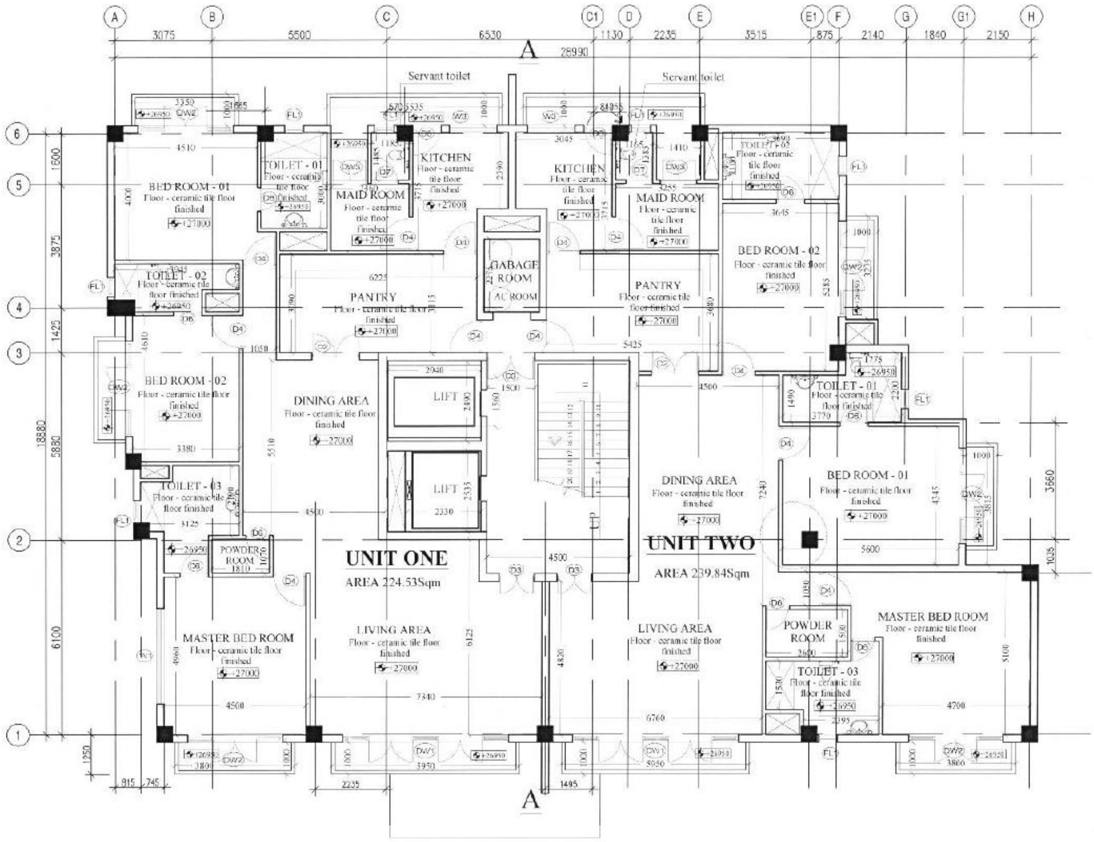

Figure A5: Plan View – 6^{th} to 16^{th} floor

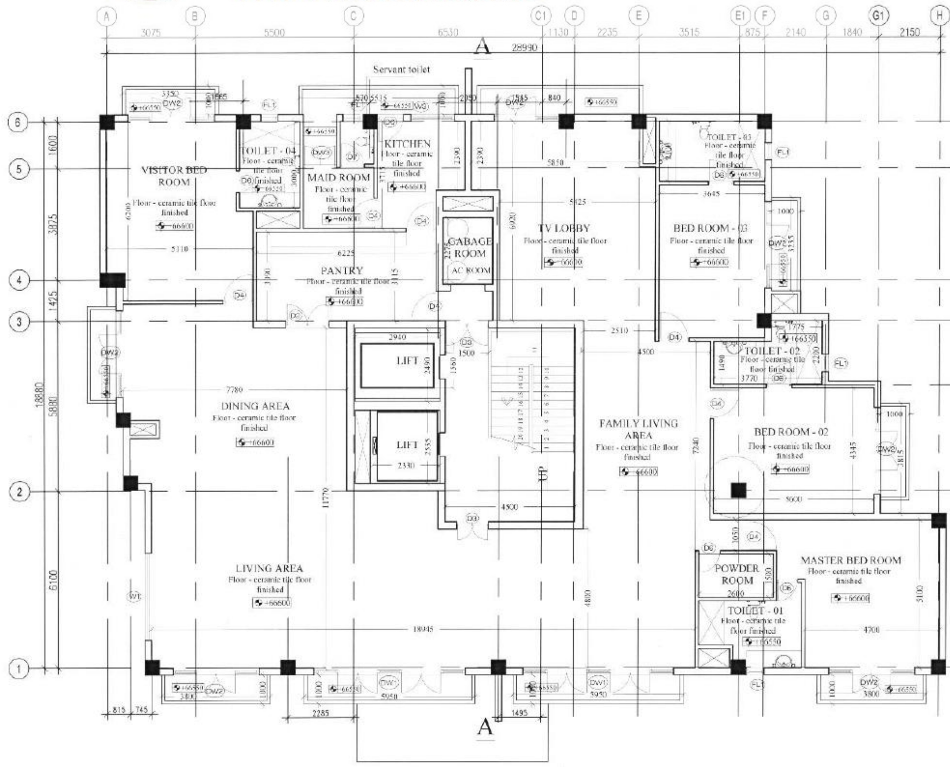

Figure A6: Plan View – 17^{th} floor

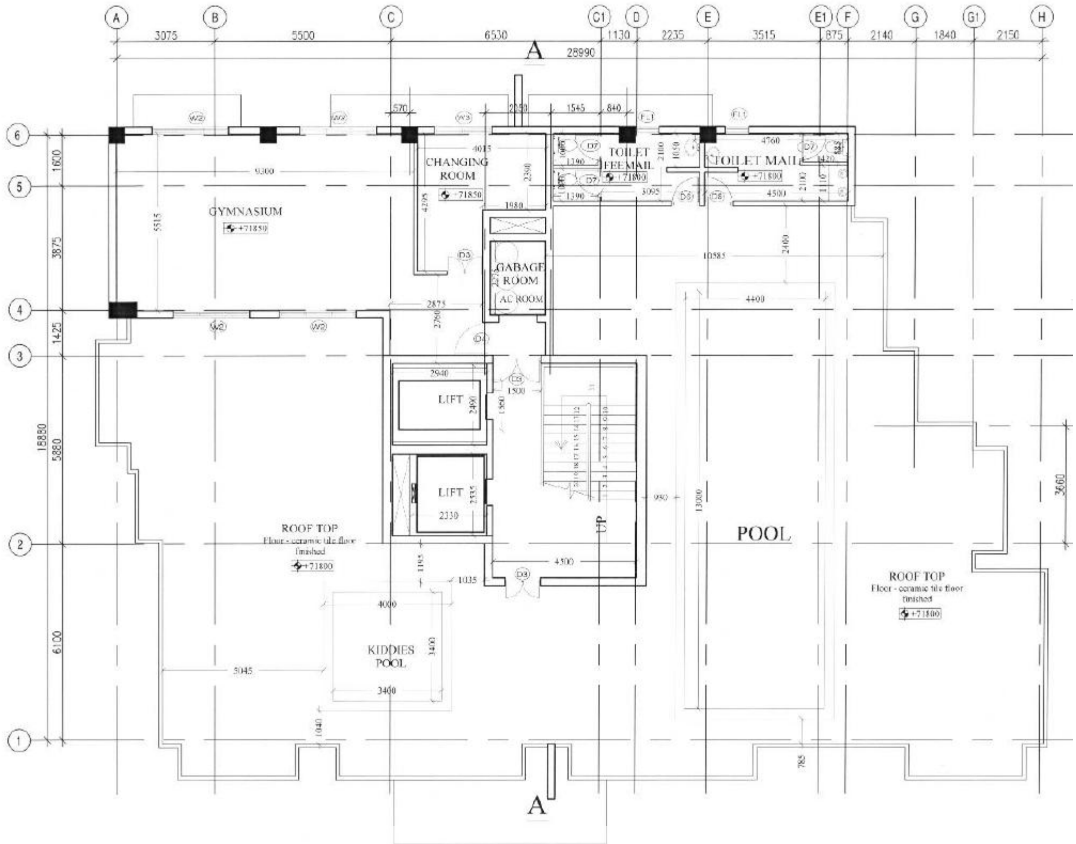

Figure A7: Plan View – Roof floor

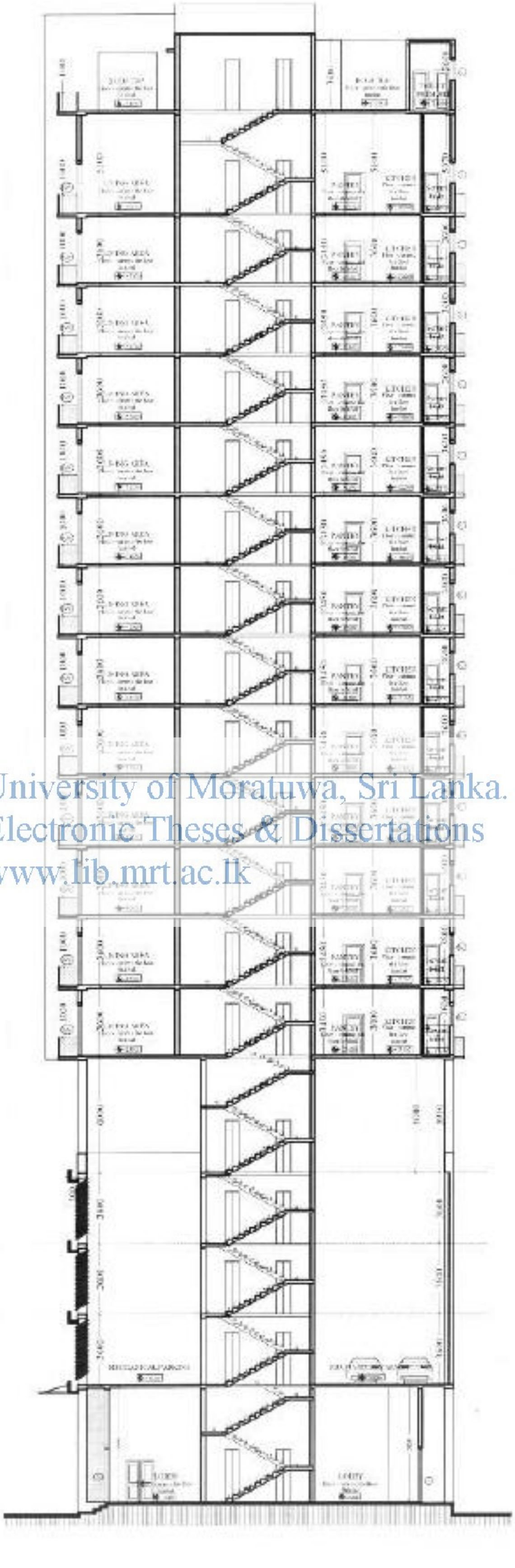

Figure A8: Cross section A-A of the buildings

Table A1 :Material properties used in the analysis

Material Properties			
Material	**Strength (N/mm^2)**	**Density (kN/m^3)**	**Modulus of elasticity (kN/mm^2)**
Concrete (C30)	30	24	26
Concrete (C40)	40	24	28
Steel	460	-	-
Masonry	-	22	-

Table A2 : Design loads used in the analysis

Live Load	
From first floor up to fourth floor	3.0 kN/m^2
From fifth floor up to roof floor	2.0 kN/m^2
Superimposed Dead Load	
Finishes -From first floor up to fourth floor	2.4 kN/m^2
Finishes -From fifth floor up to seventeenth floor	1.5 kN/m^2
Finishes –Roof floor	2.4 kN/m^2
Masonry walls-From first floor up to fourth floor	1.0 kN/m^2
Masonry walls-From fifth floor up to seventeenth floor	2.5 kN/m^2

Table A3 : Approximate calculation of dead load on the test buildings

Storey	Element	Dimensions (in mm)	No of Elements	Density of (kN/m^3)	Weight (kN)	Total (kN)
Storey 1	Beam (X-dir)	500 x 300 x 78140	1	24	281	
	Beam (Y-dir)	500 x 300x 68320	1	24	246	
		500 x 250x 3320	1	24	10	
	Columns	600 x 600 x 4800	16	24	664	
		875 x 600 x 4800	1	24	60	
	Slab	13450 x 6000 x 125	1	24	242	
		14850 x 6000 x 150	1	24	321	
		25200 x 7000 x 165	1	24	699	
		13470 x 5000 x 175	1	24	283	
	Concrete Wall (X-direction)	3000 x 46920 x 250	1	24	845	
		1800 x 44820 x 250	1	24	484	
	Concrete Wall (Y-direction)	3000 x 30820 x 250	1	24	555	
		1800 x 27030 x 250	1	24	292	
	Finishes	18330 x 22300	1	2.4	981	
	Masonry Walls	18330 x 22300	1	1	409	6372
Storey (2-3)	Beam (X-dir)	500 x 300 x 735550	1	24	265	
		500 x 250 x 12070	1	24	43	
	Beam (Y-dir)	500 x 300x 75380	1	24	271	
		500 x 250x 3320	1	24	10	
	Columns	600 x 600 x 3600	16	24	498	
		875 x 600 x 3600	1	24	45	
	Slab	10980 x 6000 x 125	1	24	198	
		19760 x 6000 x 150	1	24	427	
		25200 x 7000 x 165	1	24	699	
		10550 x 5000 x 175	1	24	222	
	Concrete Wall (X-direction)	3600 x 44820 x 250	1	24	968	
	Concrete Wall (Y-direction)	3600 x 27030 x 250	1	24	584	
	Finishes	18330 x 22300	1	2.4	981	
	Masonry Walls	18330 x 22300	1	1	409	5620
Storey 4	Beam (X-dir)	500 x 300 x 735550	1	24	265	
		500 x 250 x 12070	1	24	43	
	Beam (Y-dir)	500 x 300x 75380	1	24	271	
		500 x 250x 3320	1	24	10	
	Columns	600 x 600 x 4800	16	24	664	
		875 x 600 x 4800	1	24	60	
	Slab	10980 x 6000 x 125	1	24	198	
		19760 x 6000 x 150	1	24	427	
		25200 x 7000 x 165	1	24	699	
		10550 x 5000 x 175	1	24	222	
	Concrete Wall (X-direction)	1800 x 44820 x 250	1	24	484	
		3000 x 42630 x 250	1	24	767	
	Concrete Wall (Y-direction)	1800 x 27030 x 250	1	24	292	
		3000 x 27030 x 250	1	24	487	
	Finishes	18330 x 22300	1	2.4	981	
	Masonry Walls	18330 x 22300	1	1	409	6279
Storey 5	Beam (X-dir)	500 x 300 x 57930	1	24	209	
		500 x 250x 1610	1	24	5	
		1500 x 600 x 18470	1	24	399	
		1800 x 600 x 20560	1	24	533	
	Beam (Y-dir)	500 x 300x 85000	1	24	306	
		500 x 250x 5540	1	24	17	
		1500 x 600 x 6350	1	24	137	
		1800 x 600 x 6350	1	24	165	
	Columns	600 x 600 x 4800	16	24	664	
		875 x 600 x 4800	1	24	60	
	Slab	16810 x 7100 x 125	1	24	358	
		27020 x 5000 x 150	1	24	486	
		14180 x 6350 x 165	1	24	357	
		7500 x 7030x 175	1	24	221	
	Concrete Wall (X-direction)	3000 x 42630 x 250	1	24	767	
		1800 x 44880 x 250	1	24	485	
	Concrete Wall (Y-direction)	3000 x 27030 x 250	1	24	487	
		1800 x 34680 x 250	1	24	375	
	Finishes	18330 x 22100	1	1.5	608	
	Masonry Walls	18330 x 22100	1	2.5	1013	7652

Table A3 : Approximate calculation of dead load on the test buildings (Contd.)

Storey	Element	Dimensions (in mm)	No of Elements	Density of (kN/m^3)	Weight (kN)	Total (kN)
Storey 6	Beam (X-dir)	500 x 300 x 101660	1	24	366	
		500 x 250x 1610	1	24	5	
	Beam (Y-dir)	500 x 300x 89740	1	24	323	
		500 x 250x 9120	1	24	27	
	Columns	600 x 600 x 1800	16	24	249	
		500 x 500 x 1800	16	24	173	
		875 x 600 x 1800	1	24	23	
		875 x 500 x 1800	1	24	19	
	Slab	9330 x 6900 x 125	1	24	193	
		41380 x 5000 x 150	1	24	745	
		13640 x 6350 x 165	1	24	343	
		7500 x 7200x 175	1	24	227	
	Concrete Wall (X-direction)	3600 x 44880 x 250	1	24	969	
	Concrete Wall (Y-direction)	3600 x 34680 x 250	1	24	749	
	Finishes	18330 x 22100	1	1.5	608	
	Masonry Walls	18330 x 22100	1	2.5	1013	6032
Storey (7-16)	Beam (X-dir)	500 x 300 x 101660	1	24	366	
		500 x 250x 1610	1	24	5	
	Beam (Y-dir)	500 x 300x 89740	1	24	323	
		500 x 250x 9120	1	24	27	
	Columns	500 x 500 x 3600	16	24	346	
		875 x 500 x 3600	1	24	38	
	Slab	9330 x 6900 x 125	1	24	193	
		41380 x 5000 x 150	1	24	745	
		13640 x 6350 x 165	1	24	343	
		7500 x 7200x 175	1	24	227	
	Concrete Wall (X-direction)	3600 x 44880 x 250	1	24	969	
	Concrete Wall (Y-direction)	3600 x 34680 x 250	1	24	749	
	Finishes	18330 x 22100	1	1.5	608	
	Masonry Walls	18330 x 22100	1	2.5	1013	5952
Storey 17	Beam (X-dir)	500 x 300 x 101660	1	24	366	
		500 x 250x 1610	1	24	5	
	Beam (Y-dir)	500 x 300x 89740	1	24	323	
		500 x 250x 9120	1	24	27	
	Columns	500 x 500 x 4400	16	24	422	
		875 x 500 x 4400	1	24	46	
	Slab	9330 x 6900 x 125	1	24	193	
		41380 x 5000 x 150	1	24	745	
		13640 x 6350 x 165	1	24	343	
		7500 x 7200x 175	1	24	227	
	Concrete Wall (X-direction)	4400 x 44880 x 250	1	24	1185	
	Concrete Wall (Y-direction)	1800 x 34680 x 250	1	24	375	
		2600 x 29620 x 250	1	24	462	
	Finishes	18330 x 22100	1	1.5	608	
	Masonry Walls	18330 x 22100	1	2.5	1013	6340
Roof	Beam (X-dir)	500 x 300 x 94520	1	24	340	
		500 x 250x 1610	1	24	5	
		1300 x 300x 6920	1	24	65	
	Beam (Y-dir)	500 x 300 x 66810	1	24	241	
		500 x 250x 2220	1	24	7	
		1300 x 300x 26340	1	24	247	
	Columns	500 x 500 x 2600	16	24	250	
		875 x 500 x 2600	1	24	27	
	Slab	43190 x 5000 x 150	1	24	777	
		23490 x 6350 x 165	1	24	591	
		7500 x 7200x 175	1	24	227	
	Concrete Wall (X-direction)	2600 x 44880 x 250	1	24	700	
	Concrete Wall (Y-direction)	2600 x 29620 x 250	1	24	462	
	Finishes	18330 x 22100	1	2.4	972	4911

Table A4 : Approximate calculation of imposed load on the test buildings

Imposed Load				
Storey	**Area (m^2)**	**Load (kN/m^2)**	**Weight (kN)**	**Total (kN)**
Roof	405.09	2	811	811
Storey 17	405.09	2	811	811
Storey 7-16	405.09	2	811	8110
Storey 6	405.09	2	811	811
Storey 5	405.09	2	811	811
Storey 4	408.76	3	1227	1227
Storey 2-3	408.76	3	1227	2454
Storey 1	408.76	3	1227	1227
	Total Imposed Load (kN)			16,262

Table A5 : Fundamental period of vibration obtained from modal analysis

Mode	**Fundamental period (T_1)**
Translation in y-dir	1.64 (s)
Translation in x-dir	1.32(s)

A2. Basic calculations according to EN 1998-1:2004

A2.1Structural regularity

A2.1.1Criteria for regularity in plan

EN 1998-1: 2004

Clause 4.2.3.2 **Criteria for regularity in plan**

- *With respect to lateral stiffness and mass distribution, the building structure shall be approximately symmetrical in plan with respect to two orthogonal axes.*

  The building is approximately symmetrical in plan with respect to the lateral stiffness and the mass distribution in both X and Y directions.

- *The plan configuration shall be compact*.

The rectangular plan shape of the building fulfills the criteria of compact plan configuration.

- *The in-plan stiffness of the building shall be sufficiently large in comparison with the lateral stiffness of the vertical structural elements*

  The in-situ concrete floor slab of thickness 125mm, 150mm, 165mm and 175mm, connected to the lateral load resisting system proves that the lateral stiffness of the building is large in comparison with the vertical stiffness of the test building.

- *The slenderness of the building ($\lambda = L_{max}/L_{min}$) shall not be higher than 4.0.*

  The slenderness of the building amounts to λ = 1.52 (29.49m/19.38m) which can be considered as satisfied.

- *The structural eccentricity*

$e_{0x} \leq 0.30 r_x$

$e_{0y} \leq 0.30 r_y$

Refer Table A6

- *The torsional radius shall be larger than the radius of the gyration of the floor mass in plan*

$r_x \geq l_x$

$r_y \geq l_y$

According to Table A6, the selected building does not fulfill this requirement. The building was considered as torsionally flexible.

Table A6 :Structural eccentricity, torsional radius and radii of gyration in each horizontal direction

Level	Direction X				Direction Y			
	$e_{o,x}$	$0.3r_x$	r_x	l_s	$e_{o,y}$	$0.3r_y$	r_y	l_s
Storey 1	0.0049	0.281	0.9368	10.19	0.2246	0.2231	0.7435	10.19
Storey 2	0.0109	0.4108	1.3692	10.19	0.2449	0.3097	1.0322	10.19
Storey 3	0.0195	0.5346	1.7819	10.19	0.2711	0.3934	1.3112	10.19
Storey 4	0.0409	0.7747	2.5822	10.19	0.4263	0.5606	1.8686	10.19
Storey 5	0.0619	0.8217	2.7389	10.19	0.3355	0.6007	2.0022	10.19
Storey 6	0.0605	0.9009	3.0029	10.19	0.3625	0.6894	2.2979	10.19
Storey 7	0.0574	0.9804	3.2681	10.19	0.3686	0.7841	2.6138	10.19
Storey 8	0.0559	1.0566	3.5219	10.19	0.3702	0.8745	2.915	10.19
Storey 9	0.0544	1.1294	3.7646	10.19	0.3734	0.9596	3.1988	10.19
Storey 10	0.0529	1.1989	3.9963	10.19	0.3757	1.0397	3.4658	10.19
Storey 11	0.0514	1.2652	4.2173	10.19	0.3778	1.1151	3.7169	10.19
Storey 12	0.05	1.3286	4.4285	10.19	0.3795	1.1859	3.9531	10.19
Storey 13	0.0486	1.389	4.6301	10.19	0.3809	1.2527	4.1755	10.19
Storey 14	0.0473	1.4469	4.8231	10.19	0.3819	1.3156	4.3853	10.19
Storey 15	0.0461	1.5024	5.0079	10.19	0.3828	1.375	4.5834	10.19
Storey 16	0.0449	1.5562	5.1872	10.19	0.3829	1.4318	4.7728	10.19
Storey 17	0.0579	1.8271	6.0903	10.19	0.4825	1.688	5.6265	10.19
Roof	0.0228	1.271	4.2365	10.19	0.2835	1.1818	3.9394	10.19

A2.1.1.1 Determining the structural eccentricities, torsional radii and radii of gyration

Structural eccentricities and torsional radii are calculated using the methods given in manual for the seismic design of steel and concrete buildings to Euro Code 8 [2]. Structural eccentricity (e_{0x} and e_{0y}) is the distance between the centre of mass and the centre of stiffness in two orthogonal axes X and Y. The torsional radii r_x (r_y) is defined as the square root of the ratio of the torsional stiffness to the lateral stiffness in Y (X) direction.

A2.1.1.1.1 Structural eccentricity

The structural eccentricity of level *i* is calculated using the equations;

$e_{ox,i}$ = (Rotation of the storey *i* about vertical axes due to static load ($F_{y,i}$) in Y direction) / (rotation of the floor due to torsional moment (M_i) about the vertical axis)

$e_{oy,i}$ = (Rotation of the storey *i* about vertical axes due to static load ($F_{x,i}$) in X direction) / (`rotation of the floor due to torsional moment (M_i) about the vertical axis)

In order to determine the structural eccentricity using the method above, computer analysis of the spatial model of the building is performed. In this analysis, static loads, F_{ix},F_{iy} and $M_i$of same magnitude are applied at the centre of mass of floor level i and the rotations of floors about vertical axis, $R_{z,i}$, due to each static load cases are obtained. The results obtained from the computer analysis for the test building including the eccentricities in both directions X and Y at tech floor level are shown in Table A2.

Table A7 :Structural eccentricity in each horizontal direction

Level	$F_{ix}=F_{iy}=M_i$	$R_{z,i}(F_x)$	$R_{z,i}(F_y)$	$R_{z,i}(M_i)$	$e_{o,y}$	$e_{o,x}$
Storey 1	10^6	1.294	0.0282	5.7613	0.2246	0.0049
Storey 2	10^6	1.4297	0.0634	5.8385	0.2449	0.0109
Storey 3	10^6	1.5862	0.114	5.8514	0.2711	0.0195
Storey 4	10^6	1.7486	0.1679	4.1018	0.4263	0.0409
Storey 5	10^6	1.9628	0.3624	5.8505	0.3355	0.0619
Storey 6	10^6	2.1578	0.35998	5.952	0.3625	0.0605
Storey 7	10^6	2.2066	0.3433	5.9857	0.3686	0.0574
Storey 8	10^6	2.2284	0.3366	6.0193	0.3702	0.0559
Storey 9	10^6	2.2589	0.3291	6.0502	0.3734	0.0544
Storey 10	10^6	2.2837	0.3213	6.0785	0.3757	0.0529
Storey 11	10^6	2.3063	0.3138	6.1041	0.3778	0.0514
Storey 12	10^6	2.3248	0.3062	6.1267	0.3795	0.05
Storey 13	10^6	2.3409	0.2988	6.1465	0.3809	0.0486
Storey 14	10^6	2.3538	0.2916	6.1633	0.3819	0.0473
Storey 15	10^6	2.3648	0.2845	6.1774	0.3828	0.0461
Storey 16	10^6	2.3682	0.2774	6.1844	0.3829	0.0449
Storey 17	10^6	2.3128	0.2774	4.7931	0.4825	0.0579
Roof	10^6	3.0682	0.2472	10.8244	0.2835	0.0228

A2.1.1.1.2 Torsional radius

The torsional radius r_x (r_y) is defined as the square root of the ratio of torsional stiffness (K_M) to the lateral stiffness in one direction K_y (K_x). It can be calculated from the computer analysis using the expression;

$$r_x\ (r_y) = \sqrt{\frac{\text{deflection at the centre of stiffness at each level due to static load in Y (X) direction}}{\text{rotation at each floor due to the moment applied at each floor level}}} \tag{A.3}$$

The values correspond to each parameter in the above expression obtained from the computer analysis are given in Table A1.3. The torsional radii, r_x and r_y are also given in the table.

Table A8 : Torsional radii in each horizontal direction

level	$F_{ix}=F_{iy}=M_i$	$U_{x,i}$	$U_{y,i}$	$R_{z,i}(M_i)$	r_x	r_y
Storey 1	10^6	3.1852	5.0556	5.7613	0.9368	0.7435
Storey 2	10^6	6.2204	10.9462	5.8385	1.3692	1.0322
Storey 3	10^6	10.0607	18.5799	5.8514	1.7819	1.3112
Storey 4	10^6	14.3227	27.3488	4.1018	2.5822	1.8686
Storey 5	10^6	23.4534	43.8868	5.8505	2.7389	2.0022
Storey 6	10^6	31.429	53.6723	5.952	3.0029	2.2979
Storey 7	10^6	40.8953	63.9312	5.9857	3.2681	2.6138
Storey 8	10^6	51.1469	74.6623	6.0193	3.5219	2.915
Storey 9	10^6	61.9073	85.7442	6.0502	3.7646	3.1988
Storey 10	10^6	73.0138	97.0741	6.0785	3.9963	3.4658
Storey 11	10^6	84.3298	108.567	6.1041	4.2173	3.7169
Storey 12	10^6	95.7432	120.153	6.1267	4.4285	3.9531
Storey 13	10^6	107.1642	131.77	6.1465	4.6301	4.1755
Storey 14	10^6	118.523	143.373	6.1633	4.8231	4.3853
Storey 15	10^6	129.7709	154.926	6.1774	5.0079	4.5834
Storey 16	10^6	140.8766	166.406	6.1844	5.1872	4.7728
Storey 17	10^6	151.7357	177.787	4.7931	6.0903	5.6265
Roof	10^6	167.9795	194.274	10.8244	4.2365	3.9394

A2.1.1.1.3. Radius of gyration of the floor mass in plan (l_x and l_y)

The radius of gyration is defined as the square root of the ratio of the polar moment of inertia to the mass, the polar moment of inertia being calculated about the centre of mass. The manual for the seismic design of steel and concrete building to Euro code 8 gives an expression for the radius of gyration (l_s) applied to a rectangular building of side lengths of *l* and *b*, and a uniform mass distribution as,

$$l_s = \sqrt{\frac{l^2 + b^2}{12}} \qquad (A.4)$$

For the test building, the radius of gyration is calculated as shown in Table A9.

Table A9 :Radius of gyration

Level	l (m)	b (m)	l_s
Storey 1	29.49	19.38	10.19
Storey 2	29.49	19.38	10.19
Storey 3	29.49	19.38	10.19
Storey 4	29.49	19.38	10.19
Storey 5	29.49	19.38	10.19
Storey 6	29.49	19.38	10.19
Storey 7	29.49	19.38	10.19
Storey 8	29.49	19.38	10.19
Storey 9	29.49	19.38	10.19
Storey 10	29.49	19.38	10.19
Storey 11	29.49	19.38	10.19
Storey 12	29.49	19.38	10.19
Storey 13	29.49	19.38	10.19
Storey 14	29.49	19.38	10.19
Storey 15	29.49	19.38	10.19
Storey 16	29.49	19.38	10.19
Storey 17	29.49	19.38	10.19
Roof	29.49	19.38	10.19

A2.1.2Criteria for regularity in elevation

EN 1998-1: 2004

Clause 4.2.3.3

In the case of investigated building, as mentioned under the description of the project, some of columns and shear walls terminates or shifts at fifth floor level. In order the building to be regular, all lateral load resisting system should run without interruption from foundation to the top. Since this requirement was not fulfilled, the building was considered as irregular in elevation.

Overall, the building was considered as torsionally fleixible

APPENDIX B : BASIC DETAILS OF BUILDING - B

B.1. Fourteen storied residential apartment building

The selected building is a 14 storied reinforced concrete apartment building, which includes the ground floor and 13 above ground floors. Typical floor plan and a schematic cross section showing the dimension of the building in plan and elevation are given in Fig. B1 and B2 respectively. The total height of the building above the ground level is 46.3m and the plan dimension are 44.3m x 20.6m

The main structural system consists of concrete frame with shear walls, whereas unreinforced masonry walls are used as partition walls.

At first floor level, the columns located at grid B'-1, B'-2, B, B'4 and B,-5 move on to grids B-1, B-2, B-4 and B-5 .

The structure has been designed with C30 concrete.

All analysis were performed with the ETABS software (CSI 2002 ETABS Integrated Building Design Software, Computers & Structures Inc. Berkeley) on a three dimensional (spatial) mathematical model.

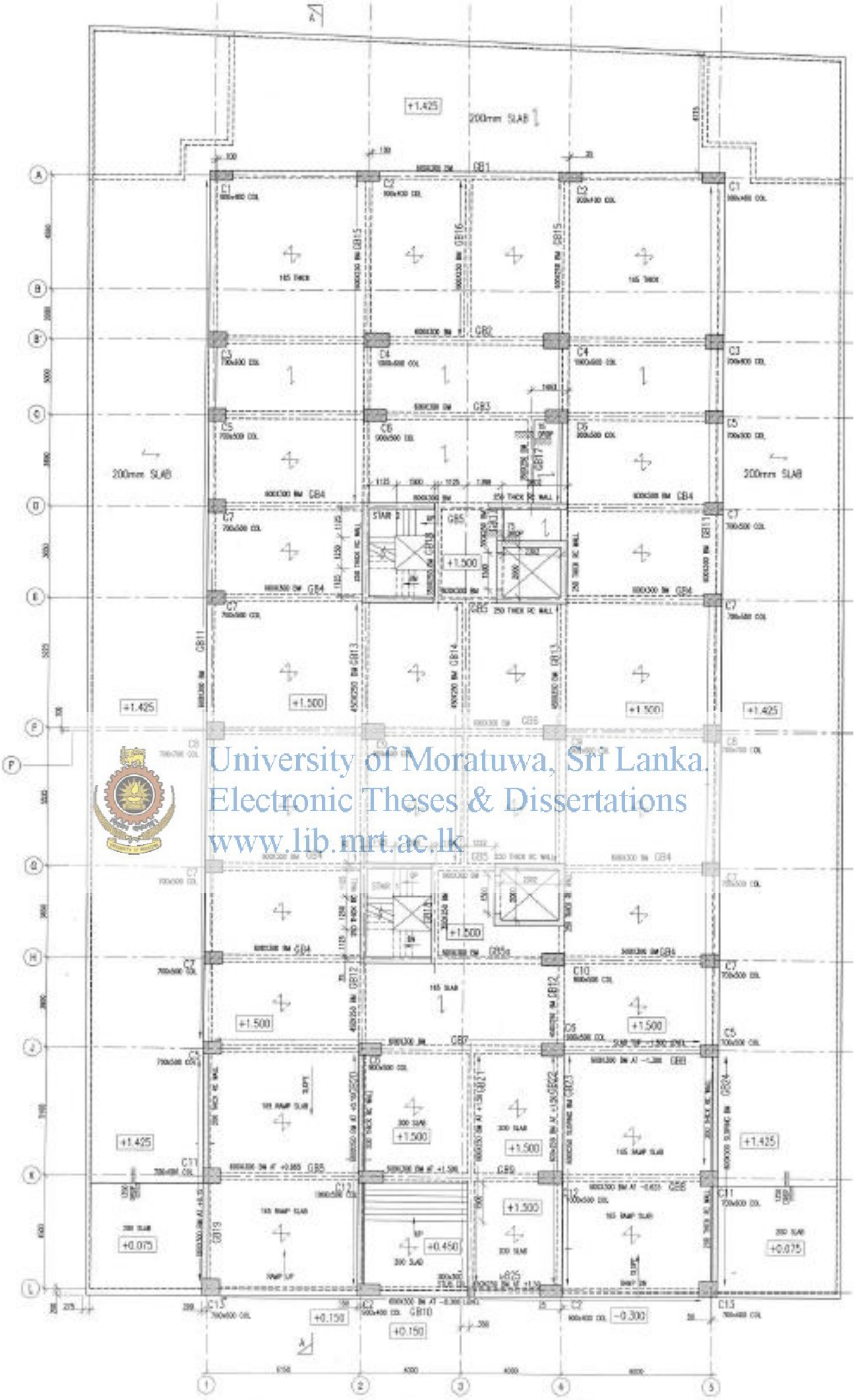

Figure B1: Plan View - Ground floor

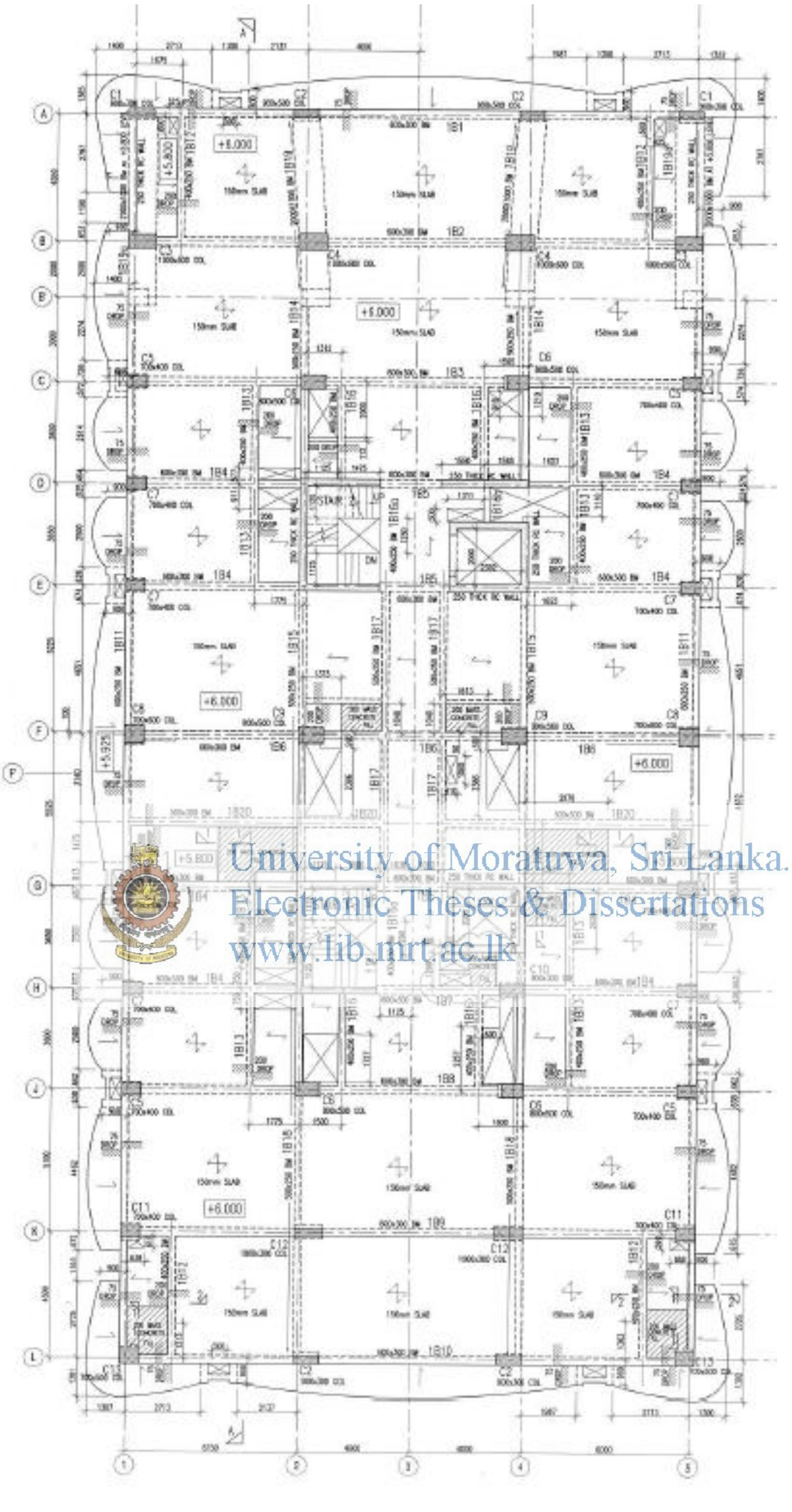

Figure B2 : Plan View - First floor

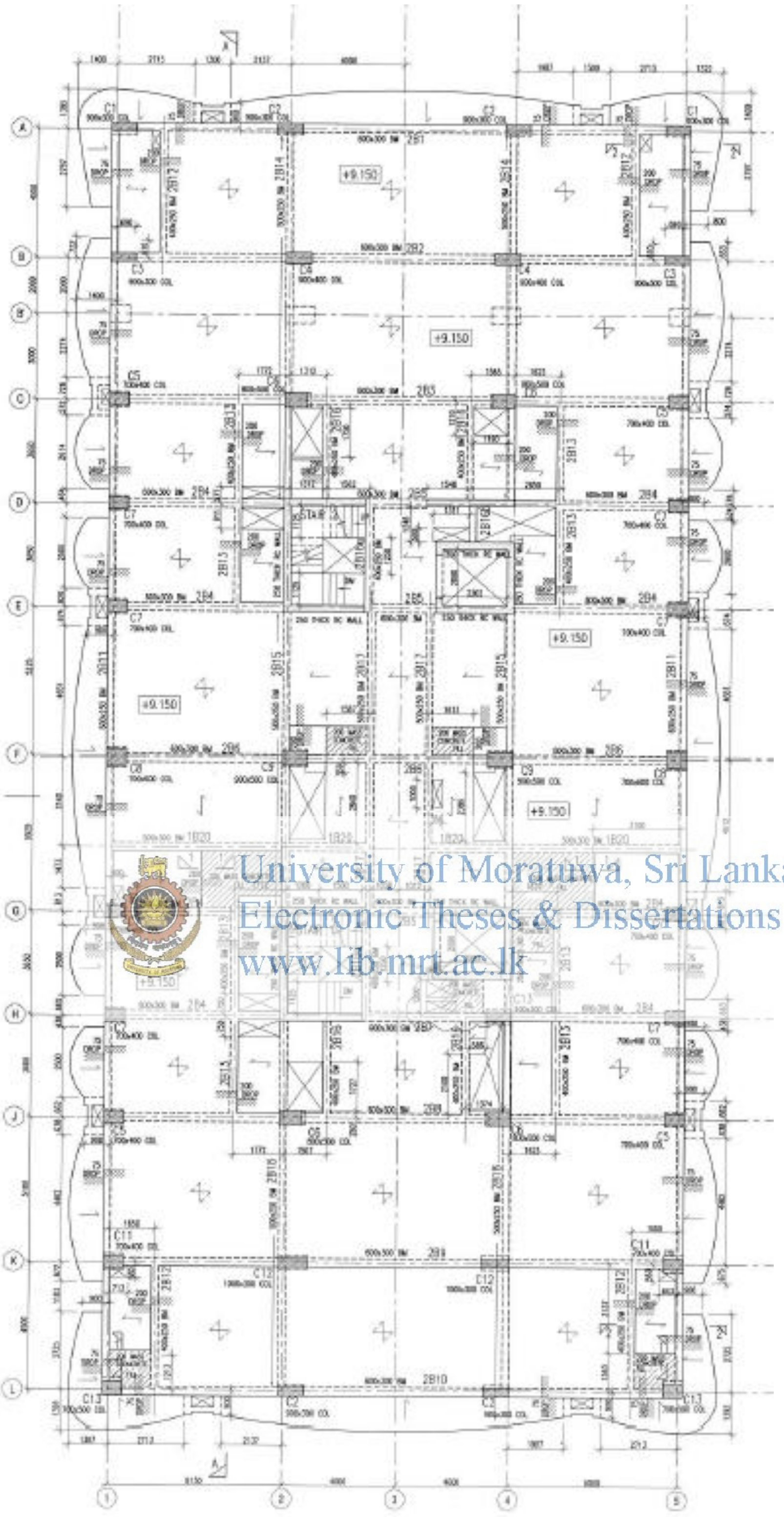

Figure B3 : Plan View – 2nd to 13th floor

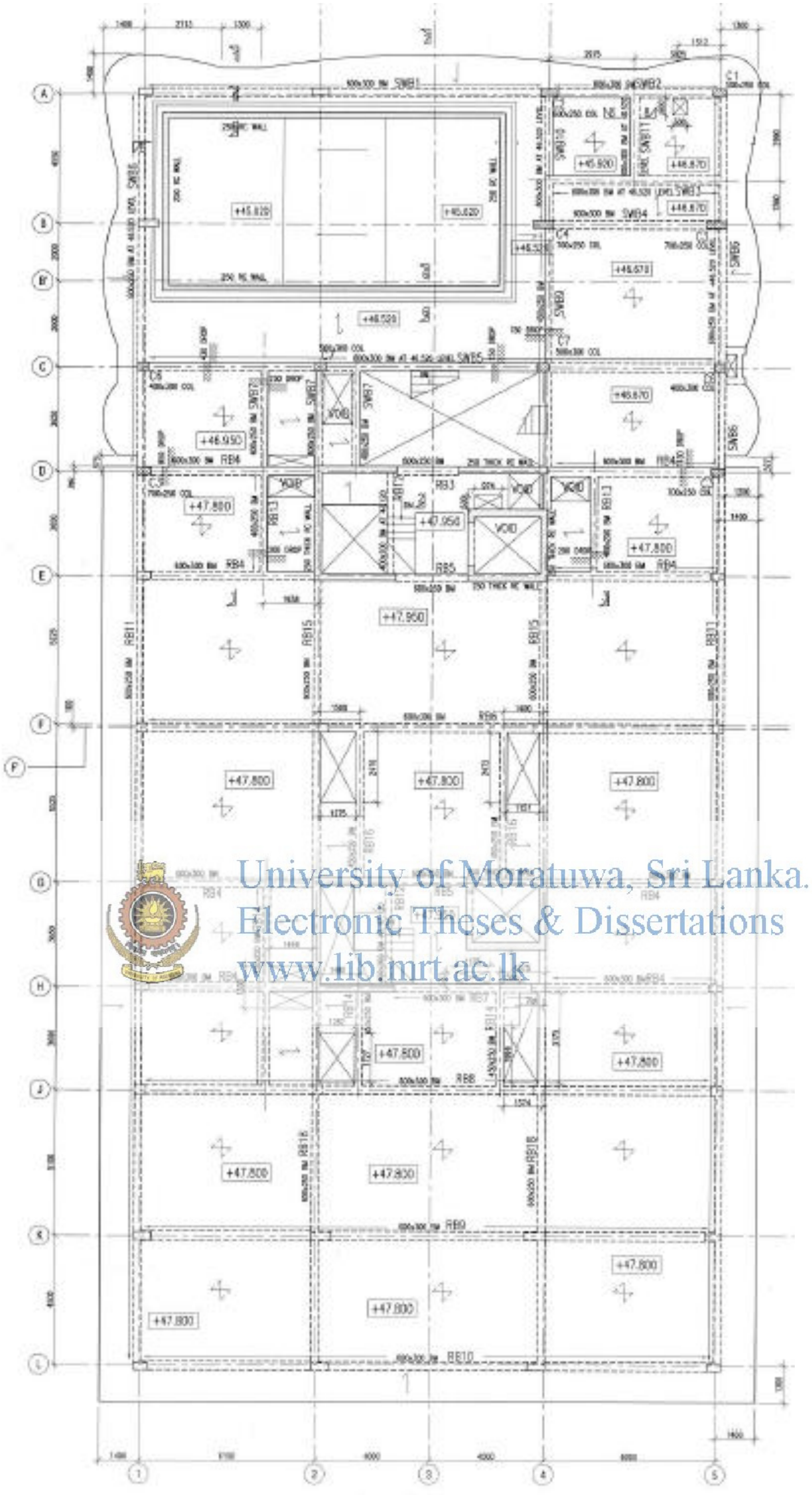

Figure B4 : Plan View – Roof floor

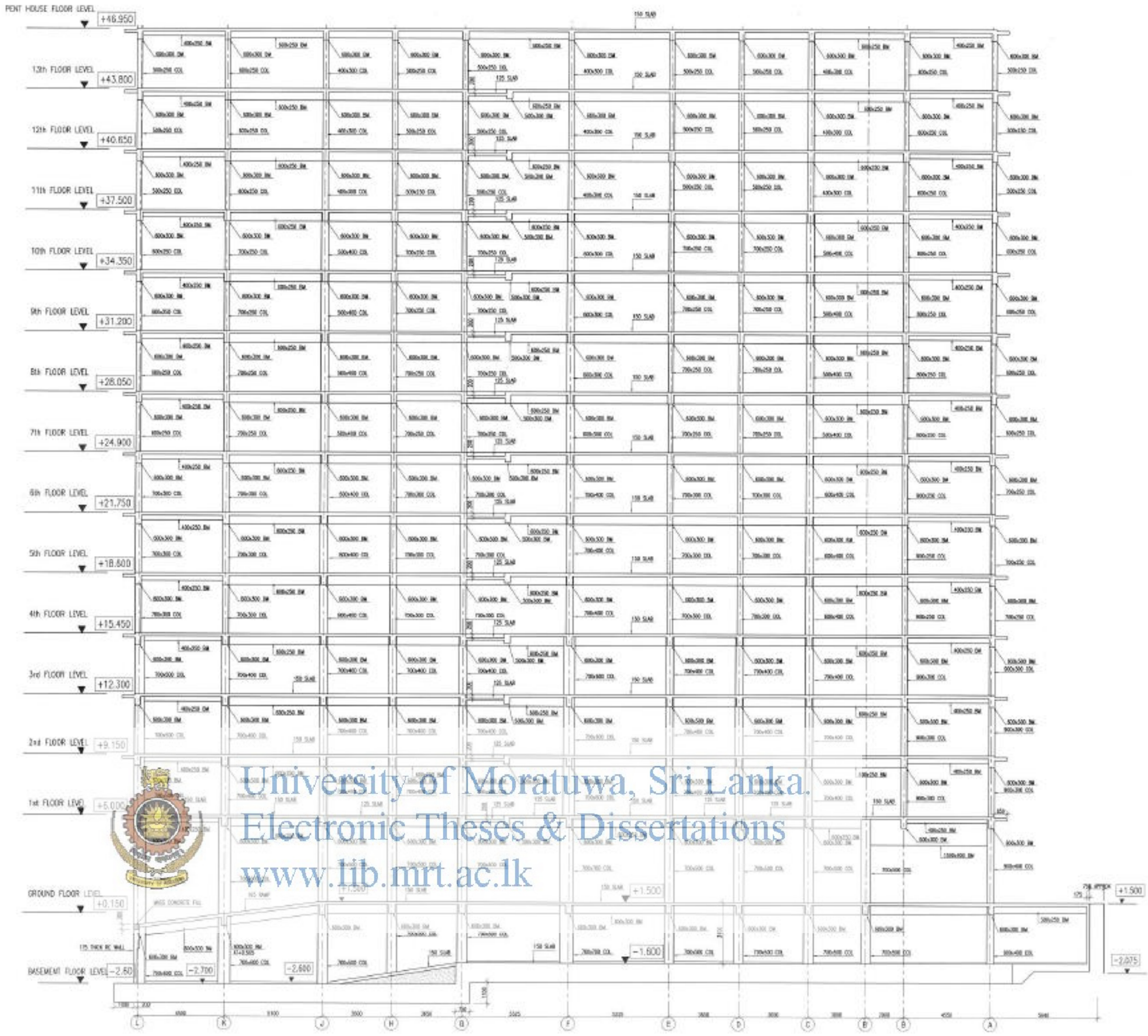

Figure B5 : Cross section A-A of the buildings

Table B1 : Material properties used in the analysis

Material Properties			
Material	**Strength (N/mm^2)**	**Density (kN/m^3)**	**Modulus of elasticity (kN/mm^2)**
Concrete (C30)	30	24	26
Concrete (C40)	40	24	28
Steel	460	-	-
Masonry	-	22	-

Table B2 : Design loads used in the analysis

Live Load	
From first floor up to roof floor	2.0 kN/m^2
Superimposed Dead Load	
Finishes -From first floor up to 13th floor	1.5 kN/m^2
Finishes –Roof floor	2.4 kN/m^2
Masonry walls-From first floor up to thirteenth floor	2.5 kN/m^2

Table B3 : Approximate calculation of dead load of the test building

Storey	Element	Dimensions (in mm)	No of Element	Density of (kN/m³)	Weight (kN)	Total (kN)
Storey 1	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 71800	1	24	216	
		400 x 250 x 70000	1	24	168	
		2000 x 1000 x 26200	1	24	1258	
	Columns	700 x 700 x 2250	2	24	53	
		700 x 600 x 2250	6	24	137	
		700 x 500 x 2250	12	24	227	
		900 x 400 x 2250	2	24	39	
		1000 x 600 x 2250	2	24	65	
		1000 x 500 x 2250	2	24	54	
		900 x 600 x 2250	2	24	59	
		900 x 500 x 2250	5	24	122	
		900 x 400 x 2250	4	24	78	
		700 x 600 x 1575	2	24	32	
		700 x 500 x 1575	2	24	27	
		700 x 400 x 1575	14	24	149	
		900 x 300 x 1575	2	24	21	
		900 x 300 x 1575	2	24	21	
		900 x 400 x 1575	2	24	28	
		1000 x 300 x 1575	2	24	23	
		900 x 500 x 1575	2	24	35	
		800 x 500 x 1575	4	24	61	
		900 x 300 x 1575	1	24	11	
		900 x 300 x 1575	4	24	41	
	Slab	109000 x 6000 x 150	1	24	2355	
		14000 x 13000 x 165	1	24	721	
		9500 x 7600 x 200	1	24	347	
	Concrete Wall	3825 x 24000 x 225	1	24	496	
	Concrete Wall	3825 x 16300 x 225	1	24	337	
	Finishes	44300 x 20600	1	2.4	2191	
	Masonry	44300 x 20600	1	1.5	1369	12023
Storey (2 -3)	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
	Columns	700 x 600 x 3150	2	24	64	
		700 x 500 x 3150	2	24	53	
		700 x 400 x 3150	14	24	297	
		900 x 300 x 3150	2	24	41	
		900 x 300 x 3150	2	24	41	
		900 x 400 x 3150	2	24	55	
		1000 x 300 x 3150	2	24	46	
		900 x 500 x 3150	2	24	69	
		800 x 500 x 3150	4	24	121	
		900 x 300 x 3150	1	24	21	
		900 x 300 x 3150	4	24	82	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3150 x 24000 x 225	1	24	409	
	Concrete Wall	3150 x 16300 x 225	1	24	278	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	10239

Table B3 : Approximate calculation of dead load of the test building (Contd.)

Storey	Element	Dimensions (in mm)	No of Element	Density of (kN/m^3)	Weight (kN)	Total (kN)
Storey 4	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
		700 x 600 x 1575	2	24	32	
		700 x 500 x 1575	2	24	27	
		700 x 400 x 1575	14	24	149	
		900 x 300 x 1575	2	24	21	
		900 x 300 x 1575	2	24	21	
		900 x 400 x 1575	2	24	28	
		1000 x 300 x 1575	2	24	23	
		900 x 500 x 1575	2	24	35	
		800 x 500 x 1575	4	24	61	
		900 x 300 x 1575	1	24	11	
		900 x 300 x 1575	4	24	41	
		700 x 400 x 1575	2	24	22	
		700 x 300 x 1575	2	24	16	
		700 x 300 x 1575	2	24	16	
		900 x 250 x 1575	2	24	18	
		600 x 400 x 1575	4	24	37	
		700 x 300 x 1575	8	24	64	
		700 x 250 x 1575	2	24	14	
		900 x 300 x 1575	2	24	21	
		900 x 300 x 1575	2	24	21	
		800 x 500 x 1575	2	24	31	
		700 x 400 x 1575	4	24	43	
		900 x 250 x 1575	1	24	9	
		900 x 250 x 1575	4	24	35	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3150 x 24000 x 225	1	24	409	
	Concrete Wall	3150 x 16300 x 225	1	24	278	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	10145
Storey (5-6)	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
	Columns	700 x 400 x 3150	2	24	43	
		700 x 300 x 3150	2	24	32	
		700 x 300 x 3150	2	24	32	
		900 x 250 x 3150	2	24	35	
		600 x 400 x 3150	4	24	73	
		700 x 300 x 3150	8	24	128	
		700 x 250 x 3150	2	24	27	
		900 x 300 x 3150	2	24	41	
		900 x 300 x 3150	2	24	41	
		800 x 500 x 3150	2	24	61	
		700 x 400 x 3150	4	24	85	
		900 x 250 x 3150	1	24	18	
		900 x 250 x 3150	4	24	69	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3150 x 24000 x 225	1	24	409	
	Concrete Wall	3150 x 16300 x 225	1	24	278	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	10034

Table B3 : Approximate calculation of dead load of the test building (Contd.)

Storey	Element	Dimensions (in mm)	No of Element	Density of (kN/m^3)	Weight (kN)	Total (kN)
Storey 7	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
	Columns	700 x 400 x 1575	2	24	22	
		700 x 300 x 1575	2	24	16	
		700 x 300 x 1575	2	24	16	
		900 x 250 x 1575	2	24	18	
		600 x 400 x 1575	4	24	37	
		700 x 300 x 1575	8	24	64	
		700 x 250 x 1575	2	24	14	
		900 x 300 x 3150	2	24	41	
		900 x 300 x 3150	2	24	41	
		800 x 500 x 3150	2	24	61	
		700 x 400 x 3150	4	24	85	
		900 x 250 x 3150	1	24	18	
		900 x 250 x 3150	4	24	69	
		600 x 300 x 1575	2	24	14	
		600 x 250 x 1575	2	24	12	
		700 x 250 x 1575	2	24	14	
		800 x 250 x 1575	2	24	16	
		500 x 400 x 1575	4	24	31	
		700 x 250 x 1575	8	24	53	
		600 x 250 x 1575	2	24	12	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3150 x 24000 x 225	1	24	409	
	Concrete Wall	3150 x 16300 x 225	1	24	278	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	10003
Storey (8-10)	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
	Columns	600 x 300 x 3150	2	24	28	
		600 x 250 x 3150	2	24	23	
		700 x 250 x 3150	2	24	27	
		800 x 250 x 3150	2	24	31	
		500 x 400 x 3150	4	24	61	
		700 x 250 x 3150	8	24	106	
		600 x 250 x 3150	2	24	23	
		900 x 300 x 3150	2	24	41	
		900 x 300 x 3150	2	24	41	
		800 x 500 x 3150	2	24	61	
		700 x 400 x 3150	4	24	85	
		900 x 250 x 3150	1	24	18	
		900 x 250 x 3150	4	24	69	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3150 x 24000 x 225	1	24	409	
	Concrete Wall	3150 x 16300 x 225	1	24	278	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	9963

Table B3 : Approximate calculation of dead load of the test building (Contd.)

Storey	Element	Dimensions (in mm)	No of Element	Density of (kN/m^3)	Weight (kN)	Total (kN)
Storey 11	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
	Columns	600 x 300 x 1575	2	24	14	
		600 x 250 x 1575	2	24	12	
		700 x 250 x 1575	2	24	14	
		800 x 250 x 1575	2	24	16	
		500 x 400 x 1575	4	24	31	
		700 x 250 x 1575	8	24	53	
		600 x 250 x 1575	2	24	12	
		900 x 300 x 1575	2	24	21	
		900 x 300 x 1575	2	24	21	
		800 x 500 x 1575	2	24	31	
		700 x 400 x 1575	4	24	43	
		900 x 250 x 1575	1	24	9	
		900 x 250 x 1575	4	24	35	
		400 x 300 x 1575	2	24	10	
		500 x 250 x 1575	2	24	10	
		600 x 250 x 1575	2	24	12	
		600 x 250 x 1575	2	24	12	
		400 x 300 x 1575	4	24	19	
		500 x 250 x 1575	8	24	38	
		500 x 250 x 1575	2	24	10	
		700 x 250 x 1575	2	24	14	
		700 x 250 x 1575	2	24	14	
		500 x 300 x 1575	2	24	12	
		400 x 300 x 1575	4	24	19	
		700 x 250 x 1575	1	24	7	
		600 x 250 x 1575	4	24	23	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3150 x 24000 x 225	1	24	409	
	Concrete Wall	3150 x 16300 x 225	1	`	278	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	9861
Storey 12	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
	Columns	400 x 300 x 3150	2	24	19	
		500 x 250 x 3150	2	24	19	
		600 x 250 x 3150	2	24	23	
		600 x 250 x 3150	2	24	23	
		400 x 300 x 3150	4	24	37	
		500 x 250 x 3150	8	24	76	
		500 x 250 x 3150	2	24	19	
		700 x 250 x 3150	2	24	27	
		700 x 250 x 3150	2	24	27	
		500 x 300 x 3150	2	24	23	
		400 x 300 x 3150	4	24	37	
		700 x 250 x 3150	1	24	14	
		600 x 250 x 3150	4	24	46	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3150 x 24000 x 225	1	24	409	
	Concrete Wall	3150 x 16300 x 225	1	24	278	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	9739

Table B3 : Approximate calculation of dead load of the test building (Contd.)

Storey	Element	Dimensions (in mm)	No of Element	Density of (kN/m^3)	Weight (kN)	Total (kN)
Storey 13	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300	1	24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
	Columns	400 x 300 x 3575	2	24	21	
		500 x 250 x 3575	2	24	22	
		600 x 250 x 3575	2	24	26	
		600 x 250 x 3575	2	24	26	
		400 x 300 x 3575	4	24	42	
		500 x 250 x 3575	8	24	86	
		500 x 250 x 3575	2	24	22	
		700 x 250 x 3575	2	24	31	
		700 x 250 x 3575	2	24	31	
		500 x 300 x 3575	2	24	26	
		400 x 300 x 3575	4	24	42	
		700 x 250 x 3575	1	24	16	
		600 x 250 x 3575	4	24	52	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	3575 x 24000 x 225	1	24	464	
	Concrete Wall	3575 x 16300 x 225	1	24	315	
	Finishes	44300 x 20600	1	1.5	1369	
	Masonry	44300 x 20600	1	2.5	2282	9884
Roof	Beam (X-dir)	600 x 300 x 208000	1	24	899	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
		500 x 250 x 75000	1	24	225	
		400 x 250 x 7000	1	24	17	
	Columns	400 x 300 x 2000	2	24	12	
		500 x 250 x 2000	2	24	12	
		600 x 250 x 2000	2	24	15	
		600 x 250 x 2000	2	24	15	
		400 x 300 x 2000	4	24	24	
		500 x 250 x 2000	8	24	48	
		500 x 250 x 2000	2	24	12	
		700 x 250 x 2000	2	24	17	
		700 x 250 x 2000	2	24	17	
		500 x 300 x 2000	2	24	15	
		400 x 300 x 2000	4	24	24	
		700 x 250 x 2000	1	24	9	
		600 x 250 x 2000	4	24	29	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall	2000 x 24000 x 225	1	24	260	
	Concrete Wall	2000 x 16300 x 225	1	24	177	
	Finishes	44300 x 20600	1	2.4	2191	7602

Table B4 : Approximate calculation of imposed load of the test buildings

Storey	Area (m^2)	Load (kN/m^2)	Weight (kN)	Total (kN)
Roof	44.3 x 20.6	2	1826	1826
Storey 13	44.3 x 20.6	2	1826	1826
Storey 12	44.3 x 20.6	2	1826	1826
Storey 11	44.3 x 20.6	2	1826	1826
Storey 8-10	44.3 x 20.6	2	1826	5478
Storey 7	44.3 x 20.6	2	1826	1826
Storey 5-6	44.3 x 20.6	2	1826	3652
Storey 4	44.3 x 20.6	2	1826	1826
Storey 2-3	44.3 x 20.6	2	1826	3652
Storey 1	44.3 x 20.6	2	1826	1826
	Total Imposed Load (kN)			25,564

Table B5 : Fundamental period of vibration obtained from modal analysis

Mode	Fundamental period (T_1)
Translation in y-dir	1.59 (s)
Translation in x-dir	1.44(s)

B2. Basic calculations according to EN 1998-1:2004

B2.1Structural regularity

B2.1.1Criteria for regularity in plan

EN 1998-1: 2004

Clause 4.2.3.2 **Criteria for regularity in plan**

- *With respect to lateral stiffness and mass distribution, the building structure shall be approximately symmetrical in plan with respect to two orthogonal axes.*
  The building is approximately symmetrical in plan with respect to the lateral stiffness and the mass distribution in both X and Y directions.

- *The plan configuration shall be compact*.
  The rectangular plan shape of the building fulfills the criteria of compact plan configuration.

- *The in-plan stiffness of the building shall be sufficiently large in comparison with the lateral stiffness of the vertical structural elements*

The in-situ concrete floor slab of thickness 150mmconnected to the lateral load resisting system proves that the lateral stiffness of the building is large in comparison with the vertical stiffness of the test building.

- *The slenderness of the building ($\lambda = L_{max}/L_{min}$) shall not be higher than 4.0.*

  The slenderness of the building amounts to λ = 2.15 (44.3/20.6m) which can be considered as satisfied.

- *The structural eccentricity*

$e_{0x} \leq 0.30 r_x$

  $e_{0y} \leq 0.30 r_y$

  Refer Table B6

- *The torsional radius shall be larger than the radius of the gyration of the floor mass in plan*

$r_x \geq l_s$

$r_y \geq l_s$

According to Table B6, the selected building does not fulfill this requirement. The building was considered as torsionally flexible.

Table B6 : Structural eccentricity, torsional radius and radii of gyration in each horizontal direction

Level	Direction X				Direction Y			
	$e_{o,x}$	$0.3r_x$	r_x	l_s	$e_{o,y}$	$0.3r_y$	r_y	l_s
Storey 1	1.2912	4.9487	16.4955	14.1	0.2494	3.9207	13.0689	14.1
Storey 2	1.3322	4.8081	16.0271	14.1	0.2534	3.8673	12.891	14.1
Storey 3	1.3656	4.6968	15.656	14.1	0.2567	3.8257	12.7524	14.1
Storey 4	1.3994	4.5887	15.2957	14.1	0.2607	3.7866	12.622	14.1
Storey 5	1.4353	4.482	14.9401	14.1	0.2655	3.7474	12.4913	14.1
Storey 6	1.4707	4.3763	14.5875	14.1	0.2704	3.7085	12.3615	14.1
Storey 7	1.5059	4.2714	14.238	14.1	0.276	3.6701	12.2337	14.1
Storey 8	1.5393	4.1648	13.8826	14.1	0.2823	3.6302	12.1005	14.1
Storey 9	1.5731	4.0538	13.5127	14.1	0.2897	3.5852	11.9507	14.1
Storey 10	1.6056	3.9378	13.126	14.1	0.2974	3.535	11.7833	14.1
Storey 11	1.6352	3.8135	12.7115	14.1	0.3064	3.4748	11.5827	14.1
Storey 12	1.6712	3.6785	12.2615	14.1	0.3183	3.3899	11.2995	14.1
Storey 13	1.7019	3.5287	11.7623	14.1	0.3321	3.272	10.9068	14.1
Roof	1.7405	3.3389	11.1296	14.1	0.3435	3.0541	10.1802	14.1

B2.1.1.1 Determining the structural eccentricities, torsional radii and radii of gyration

Structural eccentricities and torsional radii are calculated using the same method as described in A2.1.1.1 under the building A. The results are tabulated as below.

Table B7 : Structural eccentricity in each horizontal direction

Level	$F_{ix}=F_{iy}=M_i$	$R_{z,i}(F_x)$	$R_{z,i}(F_y)$	$R_{z,i}(M_i)$	$e_{o,y}$	$e_{o,x}$
Roof	10^6	0.1163	0.6021	0.4663	0.2494	1.2912
Storey 13	10^6	0.1139	0.5987	0.4494	0.2534	1.3322
Storey 12	10^6	0.1113	0.592	0.4335	0.2567	1.3656
Storey 11	10^6	0.1079	0.5792	0.4139	0.2607	1.3994
Storey 10	10^6	0.1038	0.5612	0.3910	0.2655	1.4353
Storey 9	10^6	0.0984	0.5352	0.3639	0.2704	1.4707
Storey 8	10^6	0.0917	0.5004	0.3323	0.276	1.5059
Storey 7	10^6	0.0837	0.4564	0.2965	0.2823	1.5393
Storey 6	10^6	0.0745	0.4046	0.2572	0.2897	1.5731
Storey 5	10^6	0.0638	0.3444	0.2145	0.2974	1.6056
Storey 4	10^6	0.0519	0.277	0.1694	0.3064	1.6352
Storey 3	10^6	0.0395	0.2074	0.1241	0.3183	1.6712
Storey 2	10^6	0.0264	0.1353	0.0795	0.3321	1.7019
Storey 1	10^6	0.0135	0.0684	0.0393	0.3435	1.7405

Table B8 : Torsional radii in each horizontal direction

Level	$F_{ix}=F_{iy}=M_i$	$U_{x,i}$	$U_{y,i}$	$R_{z,i}(M_i)$	r_x	r_y
Roof	10^6	79.6421	126.8809	0.4663	16.4955	13.0689
Storey 13	10^6	74.6807	115.4358	0.4494	16.0271	12.891
Storey 12	10^6	70.4974	106.2549	0.4335	15.656	12.7524
Storey 11	10^6	65.9404	96.8351	0.4139	15.2957	12.622
Storey 10	10^6	61.0086	87.2732	0.3910	14.9401	12.4913
Storey 9	10^6	55.6067	77.4363	0.3639	14.5875	12.3615
Storey 8	10^6	49.7329	67.3638	0.3323	14.238	12.2337
Storey 7	10^6	43.4145	57.1436	0.2965	13.8826	12.1005
Storey 6	10^6	36.7331	46.9626	0.2572	13.5127	11.9507
Storey 5	10^6	29.7825	36.9567	0.2145	13.126	11.7833
Storey 4	10^6	22.7264	27.3721	0.1694	12.7115	11.5827
Storey 3	10^6	15.8448	18.6578	0.1241	12.2615	11.2995
Storey 2	10^6	9.4571	10.9989	0.0795	11.7623	10.9068
Storey 1	10^6	4.0729	4.8680	0.0393	11.1296	10.1802

Table B9 : Radius of gyration

Level	*l* (m)	*b* (m)	l_s
Roof	44.3	20.6	14.1
Storey 13	44.3	20.6	14.1
Storey 12	44.3	20.6	14.1
Storey 11	44.3	20.6	14.1
Storey 10	44.3	20.6	14.1
Storey 9	44.3	20.6	14.1
Storey 8	44.3	20.6	14.1
Storey 7	44.3	20.6	14.1
Storey 6	44.3	20.6	14.1
Storey 5	44.3	20.6	14.1
Storey 4	44.3	20.6	14.1
Storey 3	44.3	20.6	14.1
Storey 2	44.3	20.6	14.1
Storey 1	44.3	20.6	14.1

B2.1.2 Criteria for regularity in elevation

EN 1998-1: 2004

Clause 4.2.3.3

In the case of investigated building, as mentioned under the description of the project, some of columns discontinue at the first floor level. In order the building to be regular, all lateral load resisting system should run without interruption from foundation to the top. Since this requirement was not fulfilled, the building was considered as irregular in elevation.

Overall, the building was considered as torsionally flexible.

APPENDIX C : BASIC DETAILS OF BUILDING - C

C1. Ten storied residential apartment building

The selected building is a 10 storied reinforced concrete apartment building, which includes the ground floor and 9 above ground floors. Typical floor plan and a schematic cross section showing the dimension of the building in plan and elevation are given in Fig. C1 and C2 respectively. The total height of the building above the ground level is 31.46m and the plan dimensions are 41.3m x 25.6m

The main structural system consists of concrete frame shear walls, whereas unreinforced masonry walls are used as partition walls..

The structure has been designed with C25 concrete.

All analysis was performed with the ETABS software (CSI 2002 ETABS Integrated Building Design Software, Computers & Structures Inc. Berkeley) on a three dimensional (spatial) mathematical model.

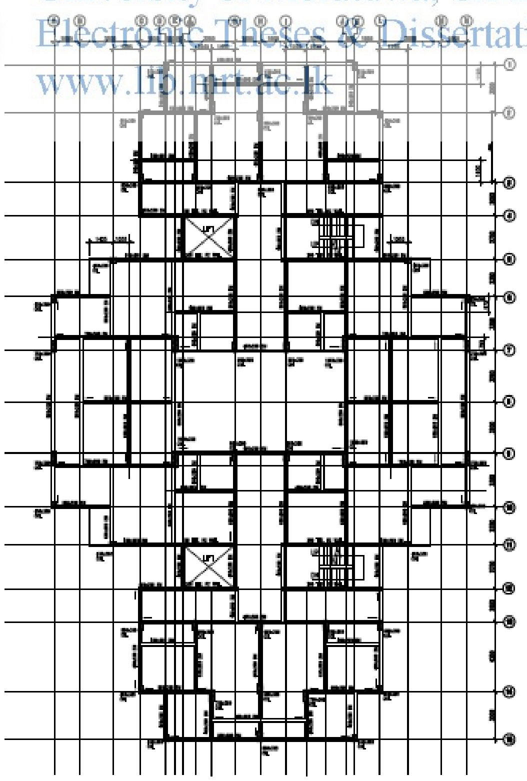

Figure C1: Plan View - First Floor

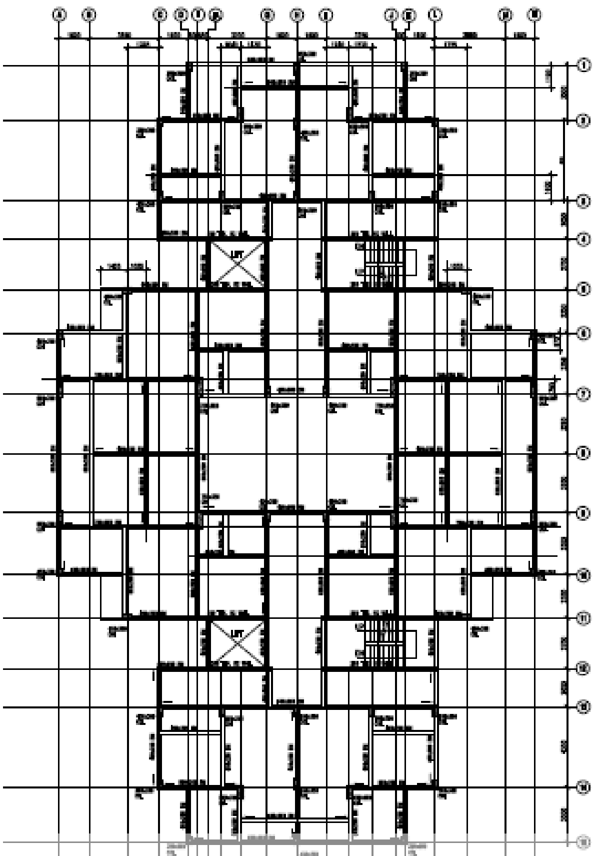

Figure C2: Plan View - Typical Floor

Table C1 :Material properties used in the analysis

Material	Strength (N/mm^2)	Density (kN/m^3)	Modulus of elasticity (kN/mm^2)
Concrete (C25)	25	24	24
Steel	460	-	-
Masonry	-	22	-

Table C2 : Design loads used in the analysis

Live Load	
From first floor up to roof floor	2.0 kN/m^2
Superimposed Dead Load	
Finishes -From first floor up to 9th floor	1.5 kN/m^2
Finishes –Roof floor	2.4 kN/m^2
Masonry walls-From first floor up to 9th floor	2.5 kN/m^2

Table C3 : Approximate calculation of dead load on the test building

Storey	Element	Dimensions (mm)	No of Elements	Density of Mat. (kN/m3) or	Weight (kN)	Total (kN)
Storey 1	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 131600	1.00	24.00	379	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	1000 x 350 x 3795	4.00	24.00	128	
		750 x 350 x 3795	8.00	24.00	191	
		600 x 300 x 3795	18.00	24.00	295	
		450 x 300 x 3795	16.00	24.00	197	
	Slab	29790 x 25600 x 125	1.00	24.00	2288	
	Concrete Wall	3795 x 43600 x 250	1.00	24.00	993	
	Finishes	29790 x 25600	1.00	1.50	1144	
	Masonry Walls	29790 x 25600	1.00	2.50	1907	8195
Storey 2	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 131600	1.00	24.00	379	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	1000 x 350 x 2985	4.00	24.00	100	
		750 x 350 x 2985	8.00	24.00	150	
		600 x 300 x 2985	18.00	24.00	232	
		450 x 300 x 2985	16.00	24.00	155	
	Slab	29790 x 25600 x 125	1.00	24.00	2288	
	Concrete Wall	2985 x 43600 x 250	1.00	24.00	781	
	Finishes	29790 x 25600	1.00	1.50	1144	
	Masonry Walls	29790 x 25600	1.00	2.50	1907	7809
Storey 3	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 131600	1.00	24.00	379	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	1000 x 350 x 1495	4.00	24.00	50	
		750 x 350 x 1495	8.00	24.00	75	
		600 x 300 x 1495	18.00	24.00	116	
		450 x 300 x 1495	16.00	24.00	78	
		750 x 350 x 1495	4.00	24.00	38	
		600 x 300 x 1495	12.00	24.00	78	
		450 x 300 x 1495	22.00	24.00	107	
		300 x 300 x 1495	8.00	24.00	26	
	Slab	29790 x 25600 x 125	1.00	24.00	2288	
	Concrete Wall	2985 x 43600 x 250	1.00	24.00	781	
	Finishes	29790 x 25600	1.00	1.50	1144	
	Masonry Walls	29790 x 25600	1.00	2.50	1907	7740
Storey 4-6	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 131600	1.00	24.00	379	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	750 x 350 x 2985	4.00	24.00	75	
		600 x 300 x 2985	12.00	24.00	155	
		450 x 300 x 2985	22.00	24.00	213	
		300 x 300 x 2985	8.00	24.00	52	
	Slab	29790 x 25600 x 125	1.00	24.00	2288	
	Concrete Wall	2985 x 43600 x 250	1.00	24.00	781	
	Finishes	29790 x 25600	1.00	1.50	1144	
	Masonry Walls	29790 x 25600	1.00	2.50	1907	7667

Table C3 : Approximate calculation of dead load on the test building (Contd.)

Storey	Element	Dimensions (mm)	No of Elements	Density of Mat. (kN/m3) or	Weight (kN)	Total (kN)
Storey 7	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 131600	1.00	24.00	379	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	750 x 350 x 1495	4.00	24.00	38	
		600 x 300 x 1495	12.00	24.00	78	
		450 x 300 x 1495	22.00	24.00	36	
		300 x 300 x 1495	8.00	24.00	26	
		600 x 350 x 1495	4.00	24.00	30	
		450 x 300 x 1495	4.00	24.00	19	
		300 x 300 x 1495	34.00	24.00	110	
	Slab	29790 x 25600 x 125	1.00	24.00	2288	
	Concrete Wall	2985 x 43600 x 250	1.00	24.00	781	
	Finishes	29790 x 25600	1.00	1.50	1144	
	Masonry Walls	29790 x 25600	1.00	2.50	1907	7509
Storey 8	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 117700	1.00	24.00	339	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	600 x 350 x 2985	4.00	24.00	60	
		450 x 300 x 2985	4.00	24.00	39	
		300 x 300 x 2985	34.00	24.00	219	
	Slab	29790 x 25600 x 125	1.00	24.00	2288	
	Concrete Wall	2985 x 43600 x 250	1.00	24.00	781	
	Finishes	29790 x 25600	1.00	1.50	1144	
	Masonry Walls	29790 x 25600	1.00	2.50	1907	7450
Storey 9	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 117700	1.00	24.00	339	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	600 x 350 x 2985	4.00	24.00	60	
		450 x 300 x 2985	4.00	24.00	39	
		300 x 300 x 2985	34.00	24.00	219	
	Slab	28500 x 25600 x 125	1.00	24.00	2189	
	Concrete Wall	2985 x 43600 x 250	1.00	24.00	781	
	Finishes	28500 x 25600	1.00	1.50	1094	
	Masonry Walls	28500 x 25600	1.00	2.50	1824	7218
Roof	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 117700	1.00	24.00	339	
	Beam (Y-dir)	400 x 200x 127400	1.00	24.00	245	
		600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
	Columns	600 x 350 x 1495	4.00	24.00	30	
		450 x 300 x 1495	4.00	24.00	19	
		300 x 300 x 1495	34.00	24.00	110	
	Slab	28500 x 25600 x 125	1.00	24.00	2189	
	Concrete Wall	1495 x 43600 x 250	1.00	24.00	391	
	Finishes	28500 x 25600	1.00	2.40	1751	5502

Table C4 : Approximate calculation of imposed load on the test buildings

Storey	Area (m^2)	Load (kN/m^2)	Weight (kN)	Total (kN)
Roof	729.6	2	1460	1460
Storey 9	729.6	2	1526	1526
Storey 8	762.68	2	1526	1526
Storey 7	762.68	2	1526	1526
Storey 4-6	762.68	2	1526	4578
Storey 3	762.68	2	1526	1526
Storey 2	762.68	2	1526	1526
Storey 1	762.68	2	1526	1526
	Total Imposed Load (kN)			15,194

Table C5 : Fundamental period of vibration obtained from modal analysis

Mode	Fundamental period (T_1)
Translation in X-dir	3.05 (s)
Translation in Y-dir	1.01 (s)

C2. Basic calculations according to EN 1998-1:2004

C2.1Structural regularity

C2.1.1Criteria for regularity in plan

EN 1998-1: 2004

Clause 4.2.3.2 **Criteria for regularity in plan**

- *With respect to lateral stiffness and mass distribution, the building structure shall be approximately symmetrical in plan with respect to two orthogonal axes.*

  The building is approximately symmetrical in plan with respect to the lateral stiffness and the mass distribution in both X and Y directions.

- *The plan configuration shall be compact*.

  The rectangular plan shape of the building fulfills the criteria of compact plan configuration.

- *The in-plan stiffness of the building shall be sufficiently large in comparison with the lateral stiffness of the vertical structural elements*

  The in-situ concrete floor slab of thickness 125mmconnected to the lateral load resisting system proves that the lateral stiffness of the building is large in comparison with the vertical stiffness of the test building.

- *The slenderness of the building ($\lambda = L_{max}/L_{min}$) shall not be higher than 4.0.*

  The slenderness of the building amounts to λ = 1.61 (41.3/25.6m) which can be considered as satisfied.

- *The structural eccentricity*

$e_{0x} \leq 0.30 r_x$

$e_{0y} \leq 0.30 r_y$

Refer Table C6

- *The torsional radius shall be larger than the radius of the gyration of the floor mass in plan*

$r_x \geq l_x$

$r_y \geq l_y$

According to Table C6, the selected building does not fulfill this requirement. The building was considered as torsionally fleixible

Table C6 :Structural eccentricity, torsional radius and radii of gyration in each horizontal direction

Level	Direction X				Direction Y			
	$e_{o,x}$	$0.3r_x$	r_x	l_s	$e_{o,y}$	$0.3r_y$	r_y	l_s
Roof	0.365	3.2948	10.9826	14.03	0.3146	8.7865	29.2882	14.03
Storey 9	0.3519	3.2876	10.9585	14.03	0.3146	9.2198	30.7326	14.03
Storey 8	0.3391	3.2785	10.9283	14.03	0.3135	9.6897	32.2989	14.03
Storey 7	0.3268	3.2691	10.8969	14.03	0.3119	10.2332	34.1106	14.03
Storey 6	0.3149	3.2571	10.8569	14.03	0.3093	10.9355	36.4518	14.03
Storey 5	0.3033	3.2458	10.8192	14.03	0.3072	11.8557	39.5191	14.03
Storey 4	0.292	3.2319	10.773	14.03	0.3046	13.1144	43.7145	14.03
Storey 3	0.2798	3.2191	10.7304	14.03	0.3045	14.9894	49.9648	14.03
Storey 2	0.2665	3.2006	10.6685	14.03	0.3061	18.1378	60.4592	14.03
Storey 1	0.2545	3.1743	10.581	14.03	0.2909	24.1001	80.3335	14.03

C2.1.1.1 Determining the structural eccentricities, torsional radii and radii of gyration

Structural eccentricities and torsional radii have been calculated using the same method as described in A2.1.1.1 under the building A. The results are tabulated as below.

Table C7 : Structural eccentricity in each horizontal direction

Level	$F_{ix}=F_{iy}=M_i$	$R_{z,i}(F_x)$	$R_{z,i}(F_y)$	$R_{z,i}(M_i)$	$e_{o,y}$	$e_{o,x}$
Roof	10^6	0.0916	0.1063	0.2912	0.3146	0.365
Storey 9	10^6	0.0817	0.0914	0.2597	0.3146	0.3519
Storey 8	10^6	0.0713	0.0771	0.2274	0.3135	0.3391
Storey 7	10^6	0.0606	0.0635	0.1943	0.3119	0.3268
Storey 6	10^6	0.0498	0.0507	0.1610	0.3093	0.3149
Storey 5	10^6	0.0392	0.0387	0.1276	0.3072	0.3033
Storey 4	10^6	0.029	0.0278	0.0952	0.3046	0.292
Storey 3	10^6	0.0197	0.0181	0.0647	0.3045	0.2798
Storey 2	10^6	0.0116	0.0101	0.0379	0.3061	0.2665
Storey 1	10^6	0.0048	0.0042	0.0165	0.2909	0.2545

Table C8 : Torsional radii in each horizontal direction

Level	$F_{ix}=F_{iy}=M_i$	$U_{x,i}$	$U_{y,i}$	$R_{z,i}(M_i)$	r_x	r_y
Roof	10^6	249.7916	35.1237	0.2912	10.9826	29.2882
Storey 9	10^6	245.2849	31.1870	0.2597	10.9585	30.7326
Storey 8	10^6	237.2274	27.1578	0.2274	10.9283	32.2989
Storey 7	10^6	226.075	23.0716	0.1943	10.8969	34.1106
Storey 6	10^6	213.9256	18.9773	0.1610	10.8569	36.4518
Storey 5	10^6	199.2801	14.9361	0.1276	10.8192	39.5191
Storey 4	10^6	181.923	11.0487	0.0952	10.773	43.7145
Storey 3	10^6	161.5221	7.4497	0.0647	10.7304	49.9648
Storey 2	10^6	138.5365	4.3137	0.0379	10.6685	60.4592
Storey 1	10^6	106.4824	1.8473	0.0165	10.581	80.3335

Table C9 : Radius of gyration

Level	***l*** **(m)**	***b*** **(m)**	l_s
Roof	41.3	25.6	14.03
Storey 9	41.3	25.6	14.03
Storey 8	41.3	25.6	14.03
Storey 7	41.3	25.6	14.03
Storey 6	41.3	25.6	14.03
Storey 5	41.3	25.6	14.03
Storey 4	41.3	25.6	14.03
Storey 3	41.3	25.6	14.03
Storey 2	41.3	25.6	14.03
Storey 1	41.3	25.6	14.03

C2.1.2 Criteria for regularity in elevation

EN 1998-1: 2004

Clause 4.2.3.3

In this building, all the lateral load resisting system run without interruption from foundation to the top. Also both the lateral stiffness and the mass of the individual storeys remain constant or reduced gradually. Further, the ratio of the actual storey resistance to the resistance required by the analysis do not vary disproportionately between adjacent storeys. Since these requirements have been fulfilled in the case of investigated building, the building was considered as regular in elevation.

Overall, the building was considered as torsionally fleixible.