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APPENDIX A : BASIC DETAILS OF BUILDING - A

A1. Eighteen storied residential apartment building

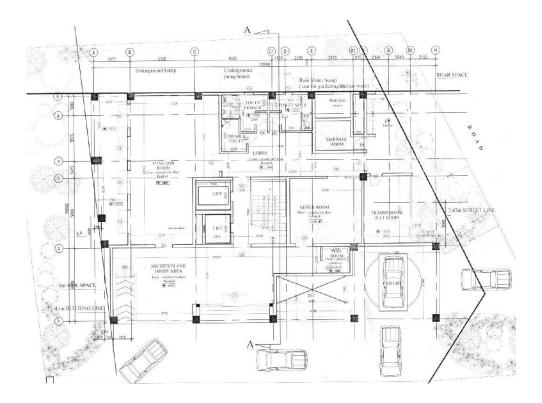
As the first case study, the selected building is a 18 storied reinforced concrete apartment building, which includes a ground floor and 17 above ground floors, where the ground floor up to fourth floor were used for parking purposes. Typical floor plan and a schematic cross section showing the dimension 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

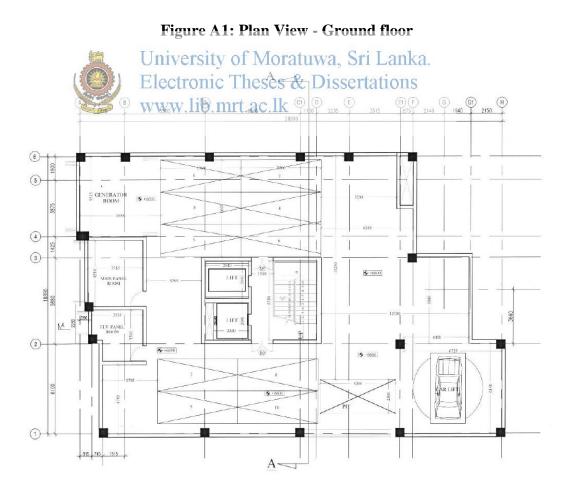
The main structural system consists of concrete frames and shear walls, whereas unreinforced masonry walls are used as partition walls.

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 in the proficiency singilarly the shear walls located between grid F1 to E1 ent grid to and C2 to C1 for level. Also the shear wall between grid 5 D1 C0 F1 have been moved from grid 3 to 2 from the fifth floor onwards.

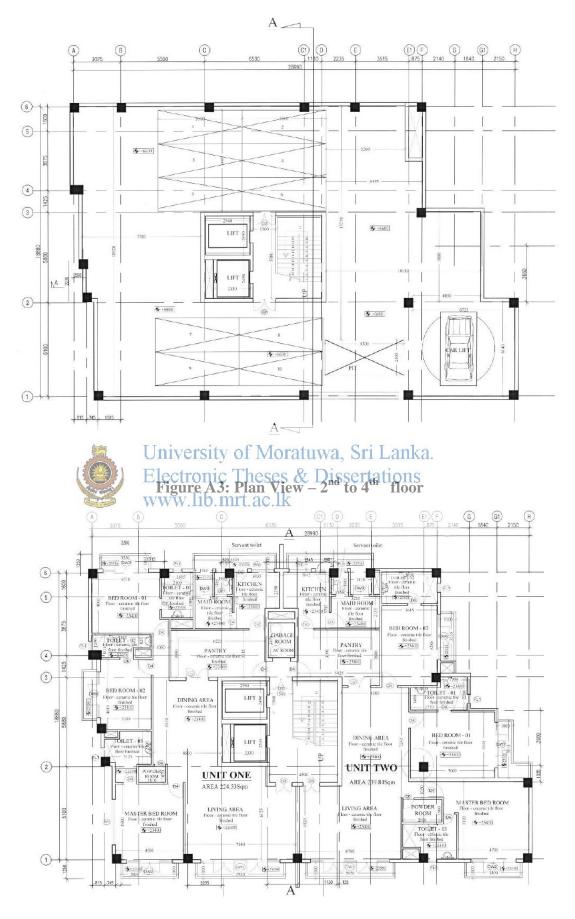
The structure has been designed with C30 concrete, except the columns from ground floor up to sixth floor slab level, where C40 concrete was used.

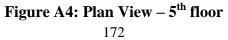
All analysis were performed with the ETABS software (CSI 2002 ETABS Integrated Building Design Software, Computers & Structures Inc. Berkeley) on a three dimensional (spatial) mathematical model.











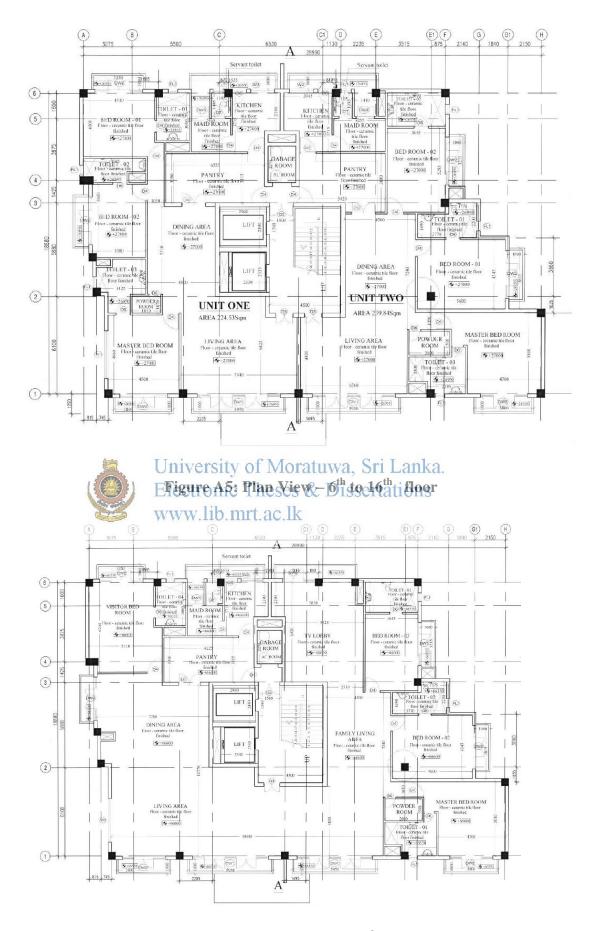
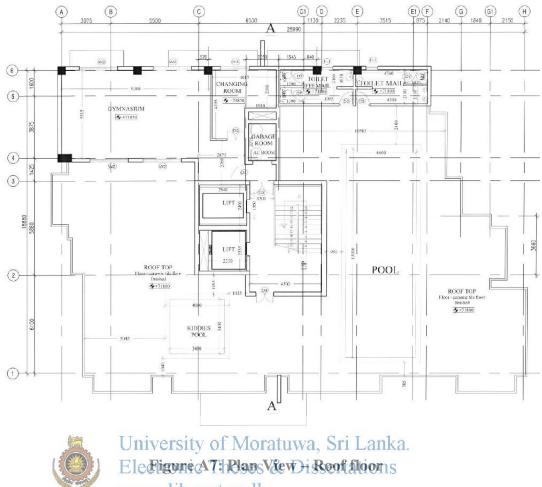


Figure A6: Plan View – 17th floor



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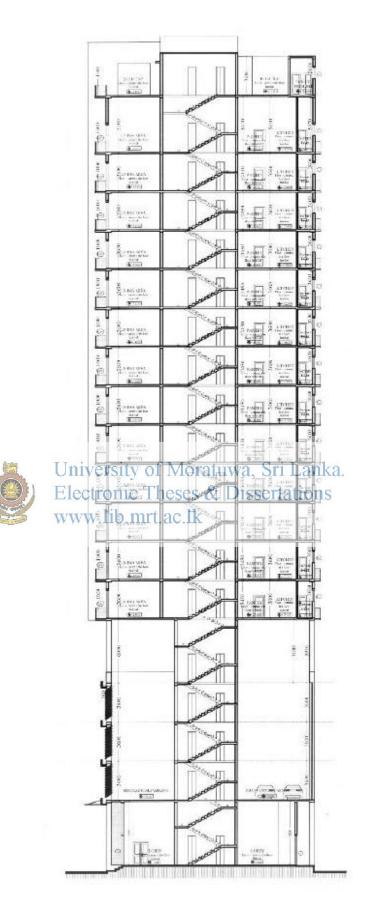


Figure A8: Cross section A-A of the buildings

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 of Moratuwa,	Sri Lanka. ^{1.0 kN/m²}					
Masonry walls From fifth floor up to seventeenth floor Preses & Diss	sertations ^{2.5 kN/m²}					
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Storey	Element	Dimensions	No of	Density of	Weight	Total
storey	Element	(in mm)	Elements	(kN/m ³)	(kN)	(kN)
	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 24	60 242	
		13450 x 6000 x 125 14850 x 6000 x 150	1	24	321	
Storey 1	Slab	25200 x 7000 x 165	1	24	699	
5		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	(370
	Masonry Walls	18330 x 22300	1	1 24	409 265	6372
	Beam (X-dir)	500 x 300 x 735550 500 x 250 x 12070	1	24	43	
		500 x 300x 75380	1	24	271	
	Beam (Y-dir)	500 x 250x 3320	1	24	10	
	Columns	600 x 600 x 3600	16	24	498	
	Columns	875 x 600 x 3600	1	24	45	
Storey		10980 x 6000 x 125	1	24	198	
(2-3)	Slab	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) Concrete Wall (Y-direction)	3600 x 44820 x 250	1	24 24	968	
	Finishes	3600 x 27030 x 250		24	584 981	
	Masonry Walls TSILy	of 18590 x122300 a,	Sri Lai	$1ka_{.1}^{2.4}$	409	5620
		T 500 x 300 x 735550 c	ertation		265	5020
0	Beam (Xedit)ron1C	500 x 250 x 12070	enquo	24	43	
	Bearly With lib.m	1 500 x 300x 75380	1	24	271	
	Beain (Fruin). 110.111	500 x 250x 3320	1	24	10	
	Columns	600 x 600 x 4800	16	24	664	
		875 x 600 x 4800	1	24	60	
Storey		10980 x 6000 x 125 19760 x 6000 x 150		24 24	198	
4	Slab	25200 x 7000 x 165	1	24	427 699	
-		10550 x 5000 x 175	1	24	222	
		1800 x 44820 x 250	1	24	484	
	Concrete Wall (X-direction)	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	409	6279
		500 x 300 x 57930	1	24	209	
	Beam (X-dir)	500 x 250x 1610 1500 x 600 x 18470	1	24 24	5 399	
		1800 x 600 x 20560	1	24	533	
		500 x 300x 85000	1	24	306	
	Beam (M Jin)	500 x 250x 5540	1	24	17	
	Beam (Y-dir)	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	
Storey 5		875 x 600 x 4800	1	24	60	
		16810 x 7100 x 125		24	358	
	Slab	27020 x 5000 x 150	1	24	486	
		14180 x 6350 x 165		24 24	357	
		7500 x 7030x 175 3000 x 42630 x 250	1	24	221 767	
	Concrete Wall (X-direction)	1800 x 44880 x 250	1	24	485	
		3000 x 27030 x 250	1	24	487	
	Concrete Wall (Y-direction)	1800 x 34680 x 250	1	24	375	
	Finishes	18330 x 22100	1	1.5	608	

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

a .			Dimensions	No of	Density of	Weight	Total
Storey	7	Element	(in mm)	Elements	(kN/m ³)	(kN)	(kN)
			500 x 300 x 101660	1	24	366	<u>()</u>
		Beam (X-dir)	500 x 250x 1610	1	24	5	
	ŀ		500 x 300x 89740	1	24	323	
_	Beam (Y-dir)	500 x 250x 9120	î	24	27		
	F		600 x 600 x 1800	16	24	249	
			500 x 500 x 1800	16	24	173	
		Columns	875 x 600 x 1800	1	24	23	
0			875 x 500 x 1800	1	24	19	
Storey	6		9330 x 6900 x 125	1	24	193	
		01-h	41380 x 5000 x 150	ī	24	745	
		Slab	13640 x 6350 x 165	1	24	343	
			7500 x 7200x 175	1	24	227	
	Ī	Concrete Wall (X-direction)	3600 x 44880 x 250	ī	24	969	
	Ī	Concrete Wall (Y-direction)	3600 x 34680 x 250	1	24	749	
		Finishes	18330 x 22100	1	1.5	608	
	Ī	Masonry Walls	18330 x 22100	1	2.5	1013	6032
		•	500 x 300 x 101660	1	24	366	
		Beam (X-dir)	500 x 250x 1610	1	24	5	
	Ī		500 x 300x 89740	1	24	323	
		Beam (Y-dir)	500 x 250x 9120	1	24	27	
		Q-1	500 x 500 x 3600	16	24	346	
		Columns	875 x 500 x 3600	1	24	38	
Storey	(7-		9330 x 6900 x 125	1	24	193	
16)		Sl_L	41380 x 5000 x 150	1	24	745	
,	,	Slab	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 BA680 x 250	ri Lan	SA 24	749	
		Finishes	18330 x 22100	1.	1.5	608	
	[Masonr WallsOn1C	he18330 \$22100 SSC	rtation	S 2.5	1013	5952
		Allowed and a second and a se		1	24	366	
		Beam (X-dir) lib.m	1. 500 x 250x 1610	1	24	5	
	[Doorr (V dir)	500 x 300x 89740	1	24	323	
		Beam (Y-dir)	500 x 250x 9120	1	24	27	
		Columns	500 x 500 x 4400	16	24	422	
		Columb	875 x 500 x 4400	1	24	46	
			9330 x 6900 x 125	1	24	193	
Storey	17	Slab	41380 x 5000 x 150	1	24	745	
		5140	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
			500 x 300 x 94520	1	24	340	
		Beam (X-dir)	500 x 250x 1610	1	24	5	
			1300 x 300x 6920	1	24	65	
			500 x 300 x 66810	1	24	241	
		Beam (Y-dir)	500 x 250x 2220	1	24	7	
			1300 x 300x 26340	1	24	247	
Roof		Columns	500 x 500 x 2600	16	24	250	
1001	ļ	Condities	875 x 500 x 2600	1	24	27	
			43190 x 5000 x 150	1	24	777	
		Slab	23490 x 6350 x 165	1	24	591	
	ļ		7500 x 7200x 175	1	24	227	
		Concrete Wall (X-direction)	2600 x 44880 x 250	1	24	700	
					24	4.00	
		Concrete Wall (Y-direction) Finishes	2600 x 29620 x 250 18330 x 22100	1	<u>24</u> 2.4	462 972	4911

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

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 A4 : Approximate calculation of imposed load on the test buildings

Table A5 : Fundamental period of vibration obtained from modal analysis

	University of Morati Electronic Theses &	IWA, Sri Lanka. Fundamental period (T1) Dissertations
AN OWNER	Translation in y-dir WWW. 110. mrt. ac. lk	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 $\lambda = 1.52$ (29.49m/19.38m) which can be considered as satisfied.

The structural eccentricity
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 Refer Table A6

- The torsional radius shall be larger than the radius of the gyration of the floor mass in plan
- $r_x \ge l_x$ $r_y \ge l_y$

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

Level		Direc	tion X			Direc	tion Y	
Lever	e _{o,x}	0.3r _x	r _x	ls	eo,y	0.3ry	ry	ls
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

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

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 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.

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	Univers	11v2.2589M	oralaawa.	Sr6.0502nk	0.3734	0.0544
Storey 10	10^{6}	2.2837	0.3213	6.0785	0.3757	0.0529
Storey 11	Flectro	$11C_{2.3063}CSC$	S 0.3138 1S	CT 6.1049115	0.3778	0.0514
Storey 12	www.li	h 12-3248ac	0.3062	6.1267	0.3795	0.05
Storey 13	106	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

Table A7 :Structural eccentricity in each horizontal direction

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;

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

(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.

level	$\mathbf{F}_{ix} = \mathbf{F}_{iy} = \mathbf{M}_i$	$\mathbf{U}_{x,i}$	$\mathbf{U}_{y,i}$	$\mathbf{R}_{z,i}(\mathbf{M}_i)$	r _x	ry
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

Table A8 : Torsional radii in each horizontal direction

University of Moratuwa, Sri Lanka. Electronic Theses & Dissertations A2.1.1.3 Parties of gyration of the floor mass in plan $(l_x \text{ and } l_y)$

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,

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

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

Table A9 :Radius of gyration

Level	<i>l</i> (m)	<i>b</i> (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

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In the case of investigated building demonstrates of shifts at fifth floor level. In 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 Softwarers Completers wat Structures Incol Berkeley) on a three dimensional contract Finathematical houses & Dissertations www.lib.mrt.ac.lk

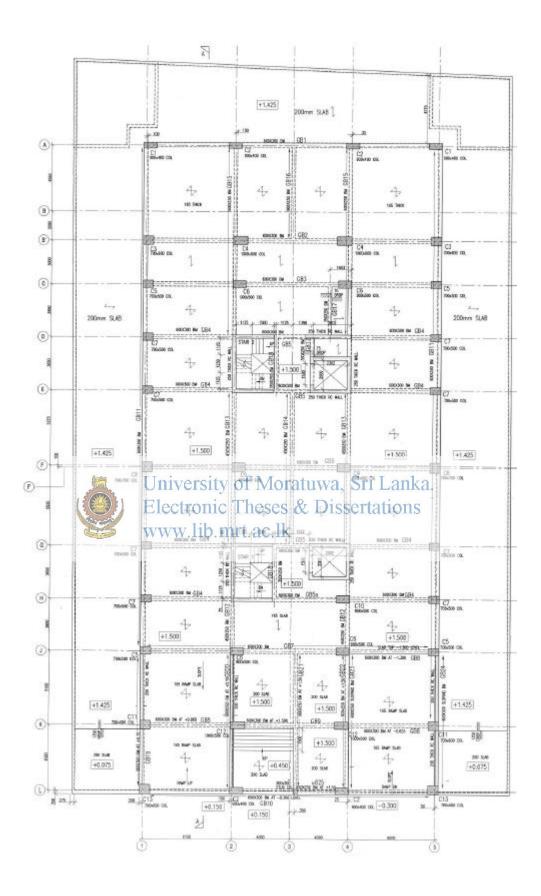


Figure B1: Plan View - Ground floor

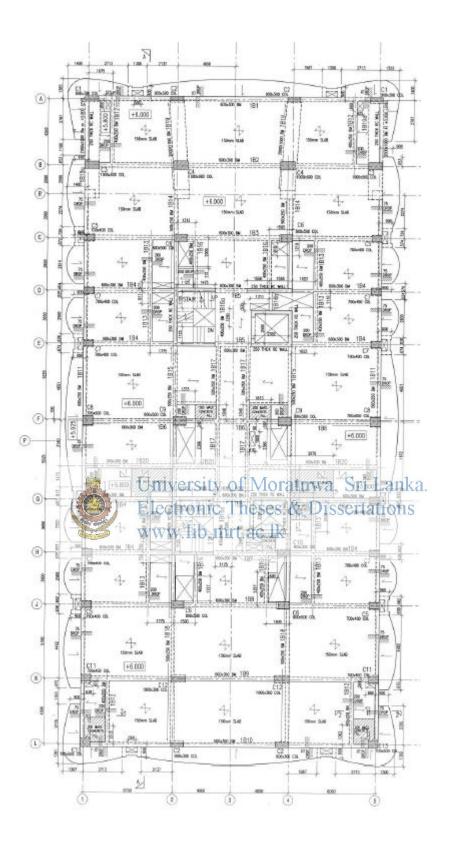


Figure B2 : Plan View - First floor

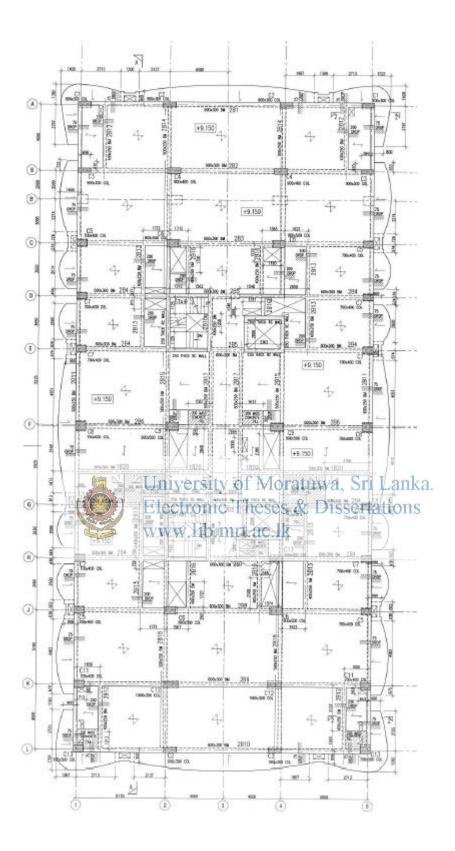


Figure B3 : Plan View – 2nd to 13th floor

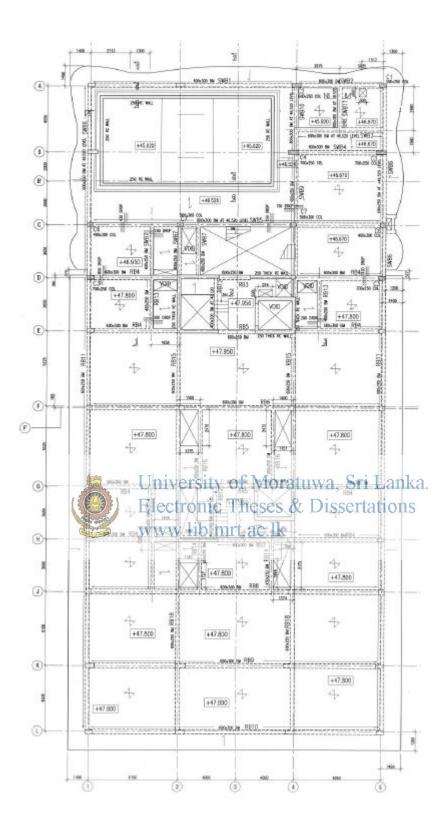


Figure B4 : Plan View – Roof floor

USE FLOOR LEVEL	lance a	1	Ú	1	Ú			1/		1	1
13th FLOOR LEVEL	Second on	MINISTE COL		AND IN THE AND	100-100 IN 100-100 IN 201 102 510	100-001 IN 100-001 IN 100-040	NO. 051400	- 100-101 (M	405.500 IN 405.500 IN	400.20 M	106-300 SM
1216 FLOOR LEVEL	Samaa uu	ADD-200 RM ADD-250 RM	1000000.00. 400-000.00	500,000 DM	MARKEN M SOLAR M	185.30 M	105,100 BK		1000-300, 59.	SOLIDI AN	ANNER IN ADDATO TR
1116 FLOOR LEVEL	506238 IN 506238 IN 506230 IN	ASSAULTS IN ASSAULTS IN ASSAULTS IN	406400 RK	100-000 JN. 200-000 GR	SIGNAL IN SIGNAL IN SIGNAL IN SIGNAL IN INCOMENT	100-00 JR 40-30 (0) - 10 LM	1000.000 JM.	305.30 IN. 305.00 IN.	100.300 IN 100.300 IN	1000-201 201 1000-201 201	500-00 JM. 200-00 JM.
10% FLOOR LEVEL	1000.000 SN 1000.000 SN 1000.000 CR	500.320 M	at 12200	NOLIDE IN	ADDRESS MALERAL	100100.00. 100100.00. 100100.00.	300-330 JM	ANNESS IN MARKED	AND CARLES OF CARLES	ADDRESS OF	1005.102 MR. 005.202 004
9th FLOOR LEVEL	enouse ca	ADDRESS OF	800-00 IN. 500-00 CM	800.001 MR - 100.001 CB	00010 81 10010 19 00010 10 10 10 10 10	100.100 IN. 100 S.40	New Jac Int.		100-000 EN 100-000 EN	AND LOO LOO LAN	
ELS FLOOR LEVEL	Interest in Sector in Interest cos	AND SECTION AND SECTION	MERCEN EM.	1985-198. 198. 1986-198. 005	105-55 JM 105-55 JM	900300 DM	NIBOR IN 796/39 00	386-338 (M. 	NORMOO DE INTRACTO DE	809/200 IN 809/200 IN	
716 FLOOR LEVEL	International Antical and Antical and Antical and Antical and	SOLUE N. SOLUE R.	SINGON IN Sinetia cos	506-00.00	MIDLINE SM. SPOLICE IM MIDLINE SM. SUDJUC IM Months Ch. [2] J.I. SAM	AND ON ON ON AN	500-500 IN 200-210 ID	98.00 IN. 	400400 in 100400 N	ADDASSE IN ADDASSE IN ADDASSE IN	Second In.
Sin FLOOR LEVEL +21,750	1404-250 IN 1404-300 IN 104-300 CR	1003-100 NJ 706-001 CA	Jan 200 All a	536-200 JM. 	SON-DIL IN SUN-DIL IN ZIN-JIN COL ZIN SUN ZIN SUN	NUMBER OF THE SAME	800-300 IN	AND THE OFFICE	000-00 (M 000-00 (M 000-00 (M	00120 M	MILION IN JOINTO IN
56h FLOOR LEVEL +18.500	1406-220. BH 300-300. BH 300-300. CR	000.000 Jan 190.000	0054300_BK	30530. Sk.	NO. COLORE	500.520 JM. 	0003300 Jar 2004300 DB	805-300 JHL 305-300 DX	100-101 02	NO.200 IN COLOUR	SHECKO DM
RM FLOOR LIVEL	ASSANCE IN ASSANCE IN ASSANCE IN ASSANCE IN	003300 Ja 206300 IS	BEDJIC IN	106-300 DL	100-102 Mar. 200-202 Mar. 100-102 Mar. 200-202 Mar. 100-102 Ch. 101 Ch.	400-320 Sec. 	1005000 SM	90.302.00 30.302.00	ADDALINE DAY MIDALINE DAY MIDALINE DAY	AND DE LA	AND
He FLOOP LEVEL	406,000 (M	INTERNE DE BROZEL DE DE BROZEL DE BROXEL DE BR	MOHECON	000.300 .04 300.400 (33	100-000 100 200-000 100 100-000 100 100-000 100	No stran	MERCARE DM. MERCARE MERCARE	303300.3M. 786400.0R	5001-001 SH (1050-011 SH 	ADDITION OF	2005-000 JM
and FLOCK LEVEL +9.150	HINZE DA	100400 ID. (20.256)	NIGULE IN TOGETH CO.	NO-400 (N	100-02 00 02-02 00 02-02	RIECTE IN. 	100-500 AM	NOT THE OWNER	1005-100 IN 2005-100 IN 2005-100 ID	STRATE DA	500-500 NK 900-500 ON
Tat FLOOR LEVE, +5.000	ATTACAL IN	10 1.4	ersit	y of	1 21.58	10000 m. 51.9.8	riLa	inka	100-200_300 200-000_300 200-000_300 100_500	455-59.84	
			rom Tib.	1000.00	eses & ac.1k	Disse	a	ons 		LINGLER IN DOLLED OF LINGLED LIN	- 100-100 IN. - 100-00 CO.
CRICIND PLOOR LDD	ME LONGET FU	NS Dar		St KH	1000 M	120.884 +1.500	100-100, Dr. 2	1.000x300,00e	Juncian Inc.		75.67 23.4 106.00.1M
ASEMENT FLOOR LEVEL-2.50	1704680 COL -2.700	141505 - 206405 (20. 	Model CO.	19.56	131 XAM		38688.03	79660103,			- 10649.03.

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 13 th 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						



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5 4	F14	Dimensions	No of	Density of	Weight	Total
Storey	Element	(in mm)	Element	(kN/m ³)	(kN)	(kN)
	Dearm (V. dir.)	600 x 300 x 208000	1	24	899	
	Beam (X-dir)	500 x 300 x 18300	1	24	66	
		600 x 250x 88000	1	24	317	
	Beam (Y-dir)	500 x 250 x 71800	1	24	216	
		400 x 250 x 70000	1	24	168	
		2000 x 1000 x 26200	1	24	1258	
		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	
	Columns	700 x 600 x 1575	2	24	32	
Storey 1	Columns	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	
	l Unive	900 x 500 x 1575	va Bri I	anka.	35	
1 St Car		rs800 x 500 x 1573 uv	va, gill	24	61	
1 E) Electr		lisserta		11	
-194	www.	1:1900 x 300 x 1575	4	24	41	
and the second sec		109000 x 0000 x 150	1	24	2355	
	Slab	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	10000
	Masonry	44300 x 20600	1	1.5	1369	12023
	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		24	317	
		500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	2	24	168	
		700 x 600 x 3150 700 x 500 x 3150	2	24 24	64 53	
			14	24		
		700 x 400 x 3150 900 x 300 x 3150	2	24	<u>297</u> 41	
		900 x 300 x 3150 900 x 300 x 3150	2	24	41	
Storey (2 - 3)	Columns	900 x 300 x 3150	2		55	
5.0.0, (2-5)	COMINIS	1000 x 300 x 3150	2	24 24	46	
		900 x 500 x 3150	2	24	40 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	
				1		

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

C /		Dimensions		Density of	Weight	Total
Storey	Element	(in mm)	Element	(kN/m ³)	(kN)	(kN)
		600 x 300 x 208000	1	24	899	()
	Beam (X-dir)	500 x 300 x 18300	1	24	66	
		600 x 250x 88000	1	24	<u> </u>	
	Beam (Y-dir)	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	
Storey 4		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 300 x 1373 700 x 250 x 1575	2	24	14	
		900 x 300 x 1575	2	24	21	
л		900 x 300 x 1373	2	24	1	
	Unr	800 x 500 x 1575	uwa, S	ri l ²⁴ nk	$\frac{a. \frac{21}{31}}{31}$	
136	Flac	100 x 300 x 1373	D4sse	rtations	43	
250			1		4 <u>3</u> 9	
	www	900 x 250 x 1575 V. 900 x 250 x 1575	4	24 24	35	
	Slab	41250 x 22000 x 150	1	24	3267	
	Concrete Wall		1	 24		
		<u>3150 x 24000 x 225</u>	<u> </u>		409	
	Concrete Wall Finishes	3150 x 16300 x 225	1	24	278	
	Masonry	44300 x 20600 44300 x 20600	1	1.5 2.5	1369 2282	10145
		600 x 300 x 208000	1	2.3	899	10145
	Beam (X-dir)		1			
		500 x 300 x 18300		24	66	
	Beam (Y-dir)	600 x 250x 88000	1	24	317	
	Deam (I-ui)	500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	$\frac{1}{2}$	24 24	168 43	
		700 x 400 x 3150				
		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	
Storey (5-6)	Columns	700 x 300 x 3150	8	24	128	
Storey (3-0)	Columns	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	<u>3150 x 24000 x 225</u>	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.)

64		Dimensions	No of	Density of	Weight	Total
Storey	Element	(in mm)	Element	(kN/m^3)	(kN)	(kN)
	D (11.11)	600 x 300 x 208000	1	24	899	
	Beam (X-dir)	500 x 300 x 18300	î	24	66	
		600 x 250x 88000	1	24	317	
	Beam (Y-dir)	500 x 250 x 98000	1	24	294	
	, , ,	400 x 250 x 70000	1	24	168	
		700 x 400 x 1575	2	24	22	
		700 x 300 x 1575	2	24	16	
		700 x 300 x 1575	2	24	16	
	Columns	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	
a. 7		800 x 500 x 3150	2	24	61	
Storey 7		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	
line.	тт:	500 x 400 x 1575	4 1		31	
and the second se	Unive	rs400 x 250 x 9595 uv	va, şri i	$an_{24}^{24}a.$	53	
	Electr	01600 x 250 sets 75 [)isserta	10124	12	
Addre	Slab	41250 x 22000 x 150	1	24	3267	
and the second s	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
		600 x 300 x 208000	1	24	899	
	Beam (X-dir)	500 x 300 x 18300	1	24	66	
		600 x 250x 88000	1	24	317	
	Beam (Y-dir)	500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
		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	
Storey (8-10)	Columns	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.)

S 4	T ² 1 4	Dimensions	No of	Density of	Weight	Total (kN)
Storey	Element	(in mm)	Element	(kN/m ³)	(kN)	
		600 x 300 x 208000	1	24	899	. ,
	Beam (X-dir)	500 x 300 x 18300	1	24	66	
		600 x 250x 88000	1	24	317	
	Beam (Y-dir)	500 x 250 x 98000	1	24	294	
	, ,	400 x 250 x 70000	î	24	168	
		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	
	Columns	800 x 500 x 1575	2	24	31	
		700 x 400 x 1575	4	24	43	
		900 x 250 x 1575	1	24	9	
a. 11		900 x 250 x 1575	4	24	35	
Storey 11		400 x 300 x 1575	2	24	10	
		500 x 250 x 1575	2	24	10	
		600 x 250 x 1575	2	24	10	
		600 x 250 x 1575	2	24	12	
		400 x 300 x 1575	4	24	12	
		500 x 250 x 1575	8	24	38	
		500 x 250 x 1575	2	24	10	
		700 x 250 x 1575	2	. 24	10	
	Uni	ver8612250fx1373ra	tuwa, S	ri 54ant	a. 14	
15			D2		12	
22	Elec	400 x 300 x 1575	e Dasse	rta ²⁴ ons	<u>12</u> 19	
	WW		4	24		
		V. 700 x 250 x 1575	4	24	723	
	Slab	600 x 250 x 1575 41250 x 22000 x 150		24	<u> </u>	
	Concrete Wall		1	24	409	
		3150 x 24000 x 225	-			
	Concrete Wall	3150 x 16300 x 225	1	1.5	278	
	Finishes	44300 x 20600	1	1.5	1369	09/1
	Masonry	44300 x 20600		2.5	2282	9861
	Beam (X-dir)	600 x 300 x 208000	1	24	899	
		500 x 300 x 18300 600 x 250x 88000	1	24 24	66 317	
	Beam (Y-dir)		1			
		500 x 250 x 98000	1 1	24	294	
		400 x 250 x 70000		24	168	
		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	
Storey 12	Columns	500 x 250 x 3150	8	24	76	
5101Ey 12		500 x 250 x 3150		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.)

Stoney	Flomont	Dimensions	No of	Density of	Weight	Total
Storey	Element	(in mm)	Element	(kN/m ³)	(kN)	(kN)
	Boom (V. dir)	600 x 300 x 208000	1	24	899	
	Beam (X-dir)	500 x 300 x 18300	1	24	66	
		600 x 250x 88000	1	24	317	
	Beam (Y-dir)	500 x 250 x 98000	1	24	294	
		400 x 250 x 70000	1	24	168	
		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	
Storey 13	Columns	500 x 250 x 3575	2	24	22	
2		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
200	Beam (X-dir)	1 800 x 300 x 208000	v a, Sri I	Langa.	899	2004
	Flocts	01600 x 250x 88000	Disserta	10124	317	
200	Beam (Y-dir)	1:500 x 250 x 75000	ISSUITA	24	225	
	WWW	1100 x 250 x 7000	1	24	17	
			2	i		
		400 x 300 x 2000	2	24	12	
		500 x 250 x 2000	2	24	12	
		600 x 250 x 2000		24	15	
		600 x 250 x 2000	2	24	15	
		400 x 300 x 2000	4	24	24	
Roof	Columns	500 x 250 x 2000	8	24	48	
KOOI	Columns	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		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 B3 : Approximate calculation of dead load of the test building (Contd.)

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 I	Load (kN)		25,564

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

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 University of Moratuwa, Sri Lanka.
 B2.1Structural regularity Theses & Dissertations
 B2.1.1Criteria for regularity in color

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 150mm 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 $\lambda = 2.15$ (44.3/20.6m) which can be considered as satisfied.

• The structural eccentricity

 $e_{0x} \le 0.30r_x$ $e_{0y} \le 0.30r_y$ Refer Table B6

 \circ The torsional radius shall be larger than the radius of the gyration of the



According to Table B6, the selected building does not fulfill this requirement. The

building was considered as torsionally flexible.

Level		Direc	tion X		Direction Y			
Lever	e _{o,x}	0.3r _x	r _x	ls	eo,y	0.3ry	ry	ls
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

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

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.

Level	$\mathbf{F}_{ix} = \mathbf{F}_{iy} = \mathbf{M}_i$	$\mathbf{R}_{z,i}(\mathbf{F}_x)$	$\mathbf{R}_{z,i}(\mathbf{F}_y)$	$\mathbf{R}_{z,i}(\mathbf{M}_i)$	$\mathbf{e}_{o,y}$	$\mathbf{e}_{o,x}$		
Roof	106	0.1163	0.6021	0.4663	0.2494	1.2912		
Storey 13	106	0.1139	0.5987	0.4494	0.2534	1.3322		
Storey 12	106	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	106	0.0917	0.5004	0.3323	0.276	1.5059		
Storey 7	106	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	106	0.0395	0.2074	0.1241	0.3183	1.6712		
Storey 2	10 ⁶ Univ	ereo264 01	Mosatu	W20.079511	Janox33 21	1.7019		
Storey 1	10 ⁶ Elas	0.0135	0.0684	0.0393	0.3435	1.7405		
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 Table B7 : Structural eccentricity in each horizontal direction

Table B8 : Torsional radii in each horizontal direction

Level	$\mathbf{F}_{ix} = \mathbf{F}_{iy} = \mathbf{M}_i$	$\mathbf{U}_{x,i}$	$\mathbf{U}_{y,i}$	$\mathbf{R}_{z,i}(\mathbf{M}_i)$	r _x	ry
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	<i>l</i> (m)	<i>b</i> (m)	ls
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

University of Moratuwa, Sri Lanka.

In the case of investigated buildings as mentioned tunden 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.

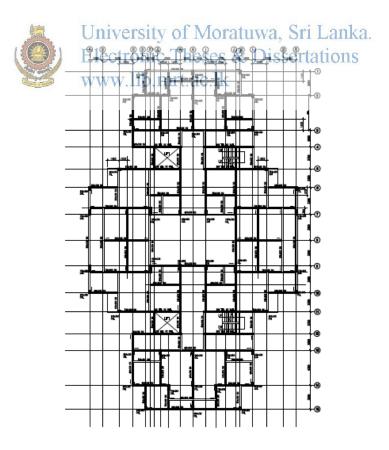


Figure C1: Plan View - First Floor

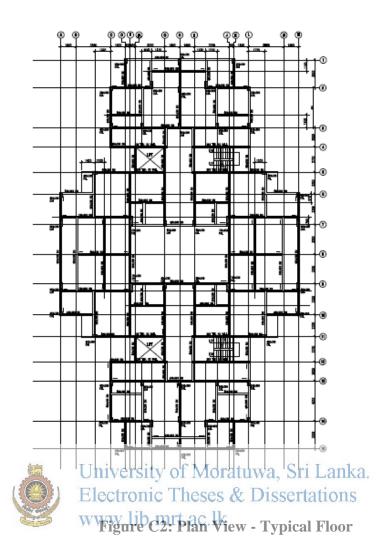


Table C1 :Material properties used in the analysis

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 9 th floor	1.5 kN/m ²					
Finishes –Roof floor	2.4 kN/m ²					
Masonry walls-From first floor up to 9 th floor	2.5 kN/m ²					

Storey	Element	Dimensions (mm)	No of	Density of Mat.	Weight (kN)	Total
_		400 700 100000			207	(kN)
	Element Dimensions (mm) Elements (ckNm3) or Weight (cN) Beam (X-dir) 400 x 200 x 13600 1.00 24.00 207 Beam (Y-dir) 600 x 200 x 131600 1.00 24.00 215 Beam (Y-dir) 600 x 200 x 13000 1.00 24.00 120 700 x 200 x 30000 1.00 24.00 128 Cohurms 750 x 350 x 3795 8.00 24.00 191 500 x 300 x 3795 16.00 24.00 197 Slab 2790 x 25600 x 125 1.00 24.00 2288 Concrete Wall 3795 x 43600 x 250 1.00 24.00 2939 Finishes 29790 x 25600 1.00 1.50 1144 Masonry Walls 29790 x 25600 1.00 24.00 207 Bearn (Y-dir) 600 x 200 x 131600 1.00 24.00 207 Bearn (Y-dir) 600 x 200 x 2985 18.00 24.00 130 Cohurms 600 x 200 x 2985 18.00 24.00 130					
	Beam (Y-dir)					
<u> </u>						
Storey 1	Columns					
	<u> </u>					
						01.05
	Masonry Walls					8195
	Beam (X-dir)					
	Beam (Y-dir)					
a. a						
Storey 2	Columns					
	and the second s					
	Masoury Walls					7809
	Beam (X-dir)		KTOORT R	APPENDING APPENDING		
	No. Star					
	W					
	Beam (Y-dir)					
		700 x 200x 30000		24.00		
	Columns	750 x 350 x 1495	8.00	24.00		
		600 x 300 x 1495	18.00	24.00	116	
Storey 3		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	
		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
	Beam (Y-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 131600	1.00	24.00	379	
		400 x 200x 127400	1.00	24.00	245	
	Beam (Y-dir)	600 x 200x 41800	1.00	24.00	120	
1		700 x 200x 30000	1.00	24.00	101	
l			4 00	24.00	75	
		750 x 350 x 2985	1.00		. –	
Storey 4-6	C-h			24.00		
Storey 4-6	Columns	600 x 300 x 2985	12.00		155	
Storey 4-6	Columns	600 x 300 x 2985 450 x 300 x 2985	12.00 22.00	24.00	155 213	
Storey 4-6		600 x 300 x 2985 450 x 300 x 2985 300 x 300 x 2985	12.00 22.00 8.00	24.00 24.00	155 213 52	
Storey 4-6	Slab	600 x 300 x 2985 450 x 300 x 2985 300 x 300 x 2985 29790 x 25600 x 125	12.00 22.00 8.00 1.00	24.00 24.00 24.00	155 213 52 2288	
Storey 4-6	Slab Concrete Wall	600 x 300 x 2985 450 x 300 x 2985 300 x 300 x 2985 29790 x 25600 x 125 2985 x 43600 x 250	12.00 22.00 8.00 1.00 1.00	24.00 24.00 24.00 24.00	155 213 52 2288 781	

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)
	Barren (V. dire)	400 x 200 x 108000	1.00	24.00	207	
	Beam (X-dir)	600 x 200 x 131600	1.00	24.00	379	
		400 x 200x 127400	1.00	24.00	245	
	Beam (Y-dir)	600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
		750 x 350 x 1495	4.00	24.00	38	
		600 x 300 x 1495	12.00	24.00	78	
a. -	Columns	450 x 300 x 1495	22.00	24.00	36	
Storey 7		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	
	Masorry Walls	29790 x 25600	1.00	2.50	1907	7509
		400 x 200 x 108000	1.00	24.00	207	1505
	Beam (X-dir)	600 x 200 x 117700	1.00	24.00	339	
		400 x 200x 127400	1.00	24.00	245	
	Beam (Y-dir)	600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
		600 x 350 x 2985	4.00	24.00	60	
Storey 8	Columns	450 x 300 x 2985	4.00	24.00	39	
		430 x 300 x 2985		24.00	219	
	Cl-h		34.00			
	Slab Concrete Wall	29790 x 25600 x 125 niver 2985 x 43600 x 256 ratur	va _{1.00} ri	La24.00	2288	
1						
	Finishes F	ectron29790x25609es & [1550rt	ations	1144	7450
	Masonry Walls	29790 x 25600	1.00	2.50	1907	7450
	Beam (X-dir)	WW.1400 x 200 x 108000K	1.00	24.00	207	
		600 x 200 x 117700	1.00	24.00	339	
		400 x 200x 127400	1.00	24.00	245	
	Beam (Y-dir)	600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
Storey 9		600 x 350 x 2985	4.00	24.00	60	
	Columns	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
	Beam (X-dir)	400 x 200 x 108000	1.00	24.00	207	
		600 x 200 x 117700	1.00	24.00	339	
		400 x 200x 127400	1.00	24.00	245	
	Beam (Y-dir)	600 x 200x 41800	1.00	24.00	120	
		700 x 200x 30000	1.00	24.00	101	
Roof		600 x 350 x 1495	4.00	24.00	30	
	Columns	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	

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

Storey	Area (m ²)	Load	Weight (kN)	Total (kN)
		(kN/m^2)		
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 C4 : Approximate calculation of imposed load on the test buildings

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)

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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 $\lambda = 1.61$ (41.3/25.6m) which can be considered as satisfied.

• The structural eccentricity

 $e_{\mathbf{0}x} \leq 0.3\mathbf{0}r_x$

 $e_{\mathbf{0}y} \leq 0.3\mathbf{0}r_y$

Refer Table C6

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• Che torsional radius shall be larger than the radius of the gyration of the
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$$r_x \ge l_x$$

 $r_y \ge l_y$

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

Level	Directio	on X			Direction	Y			
	e _{o,x}	0.3r _x	r _x	ls	e _{o,y}	0.3ry	r _y	ls	
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	

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

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.

Level	$\mathbf{F}_{ix} = \mathbf{F}_{iy} = \mathbf{M}_i$	$\mathbf{R}_{z,i}(\mathbf{F}_x)$	$\mathbf{R}_{z,i}(\mathbf{F}_y)$	$\mathbf{R}_{z,i}(\mathbf{M}_i)$	$\mathbf{e}_{o,y}$	e _{0,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	106	0.0392	0.0387	0.1276	0.3072	0.3033
Storey 4	106	0.029	0.0278	0.0952	0.3046	0.292
Storey 3	Le Un	iversity (of Mørati	w. 2647 Sri	La3045a.	0.2798
Storey 2	Ele	ectroffic 7	These's &	D937Sert	atio3061	0.2665
Storey 1	10 ⁶ WV	0.0048 m		0.0165	0.2909	0.2545

 Table C7 : Structural eccentricity in each horizontal direction

Table C8 :	Torsional	radii in	each	horizontal	direction
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Level	$\mathbf{F}_{ix} = \mathbf{F}_{iy} = \mathbf{M}_i$	$\mathbf{U}_{x,i}$	$\mathbf{U}_{y,i}$	$\mathbf{R}_{z,i}(\mathbf{M}_i)$	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	106	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	106	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

Level	<i>l</i> (m)	<i>b</i> (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	

Table C9 : Radius of gyration

C2.1.2 Criteria for regularity in elevation

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In this building, all the lateral load resisting system run without interruption from foundation to be topled so both the dateral 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.