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(Research Article)

Behavior of Flood Resistant Building and Ductile Detailing of G +7 RC Building Using IS 13920-2016

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Abstract

Floods are one of the most widespread and destructive natural disasters occurring in the world and with the increase in constructions along river courses and concentration of population around floodplain areas, flood-induced damages have been continuously increasing. The annual disaster record reveals that flood occurrence increased about ten folds over the past five decades. Thus, floods are posing a great threat and challenge to planers, design engineers, insurance industries, policymakers, and to the governments. Structural and non-structural measures can be used to deal with floods. Structural measures include a set of works aiming to reduce one or more hydraulic parameters like runoff volume, peak discharge, rise in water level, duration of flood, flow velocity, etc. Non-structural measures involve a wide range of measures to reduce flood risk through flood forecasting and early warning systems, emergency plans, and posing land use regulations and policies. The futuristic reinforced concrete buildings can be considered as a symbol of modern civilization. These buildings are usually constructed based on the guide lines given by the standard code books(like IS: 456:2000 and IS 13920:2016).Unfortunately, the code provisions consider the seismic loads and wind effects alone, while accounting the dead and live design loads, and exclude the flood loads. This implies the necessity to bring out corrective measures that can be adopted to reduce vulnerability before harm occurrences. In this project focuses on both the incorporation of flood loads during the analysis and design in CSI-ETABS software and the assessment of flood vulnerability of reinforced concrete residential buildings. Vulnerability is expressed as a fraction of ground floor height and maximum flood level at most immerse the building up to ground floor and first floor level. The importance of the outcome arises from the need of a strengthening solution to avoid failure of new or existing structures during floods.

Keyword: Flood Resistant; ETABS; IS 456:2000; IS 13920:2016; Earthquake Resistant

1. Introduction

In the present-day scenario, the necessity of more flexible civil engineering structures such as tall buildings and long span bridges is increased and they are subjected to undesirable vibration, deformation and accelerations due to strong earthquakes, blasts, wind, moving loads, machines and large ocean waves. Excessive vibration in structures is an unwanted phenomenon which causes human discomfort, waste of energy, partial collapse of structural parts, transmits unnecessary forces and also poses a threat to structural safety and, sometimes leads to collapse. In order to eliminate the undesirable effects of vibrations in structures, it is necessary to understand the behavior and response of structural systems subjected to dynamic loads such as earthquake and wind loads. One of the main challenges the structural engineers of the present decade are facing, is towards the development of innovative design concepts to protect the civil engineering structures from damages, including the material content sand human occupants from the hazards of strong winds, floods and earthquakes. Traditionally, the structural systems relied on their inherent strength and ability to

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dissipate energy to survive under severe dynamic loading and blast loads. The energy dissipation in such systems may occur by the inelastic cyclic deformations at the specially detailed plastic hinge regions of structural members. This causes localized damages in the structure as the structure itself must absorb much of the input energy from dynamic forces and this involves high cost of repair. But essential structures such as hospitals, police and fire stations must remain functional even after an earthquake. Tall buildings are a special class of structures with their own peculiar characteristics and requirements. Tall buildings are often occupied by a large number of people. Therefore, their damage, loss of functionality, or collapse will have very severe and adverse consequences on the life and limb and on the economy of the affected regions. Each tall building represents a significant investment and as such tall building analysis and design is generally performed using more sophisticated techniques and methodologies. Furthermore, typical building code provisions are usually developed without particular attention to tall buildings, which represent a very small portion of the construction activity in most regions. Therefore, understanding modern approaches to seismic analysis and design of tall buildings is very much essential for the structural engineers and researchers who would like to have a better grasp on design and performance of these icons of a modern megacity. In recent years, innovative means of enhancing structural functionality and safety against dynamic loadings have gained momentum. This includes the use of supplemental energy absorption and dissipation devices in structures to mitigate the effects of these dynamic loadings. These systems work by absorbing and reflecting a portion of input energy that would be otherwise transmitted to the structure itself. These systems can be classified as passive, active, semi active and hybrid vibration control systems based on the manner in which they act to control the vibrations.

2. Forces due to flood

The physical forces which act on the buildings include hydrostatic loads (Fig.1.1), hydrodynamic loads (Fig.1.2), and impact loads, and these loads can be exacerbated by the effects of water scouring soil from around and below the foundation. The hydrostatic loads are both lateral (pressures) and vertical (buoyant) in nature. The lateral forces result from differences in interior and exterior water surface elevations. As the floodwaters rise, the higher water on the exterior of the building acts inward against the walls of the building. Sufficient lateral pressures may cause permanent deflections and damage to structural elements within the building. The buoyant forces are the vertical uplift of the structure due to the displacement of water, just as about displaces water causing it to float. These uplift forces may be the result of the actual building materials (the floating nature of wood products), or due to air on the interior of a tightly built structure. When the buoyant forces associated with the flood exceed the weight of the building components and the connections to the foundation system, the structure may float from its foundation. The water flowing around the building during a flood creates hydrodynamic loads on the structure. These loads are the frontal impact loads from the upstream flow, the drag on the sides of the building, and the suction on the rear face of the building as the floodwaters flow around the structure. The magnitude of the hydrodynamic loads depends on both the velocity of water and the shape of the structure. Like the hydrostatic pressures, these lateral pressures may cause the collapsing of either structural walls or floors. Impact loads during floods may be the direct forces associated with waves, as typically encountered during coastal flooding, or the impact of debris floating in the waters, including logs, building components, and even vehicles. Impact loads can be destructive because the forces associated with them may be an order of magnitude higher than the hydrostatic and hydrodynamic. Floating debris can have devastating effects, as they apply large and/or concentrated loads to the structural elements of the building.

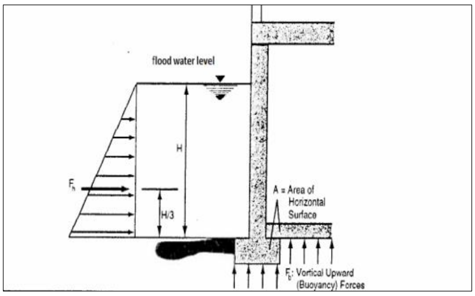


Figure 1 Schematic Sketch of Hydrostatic Force

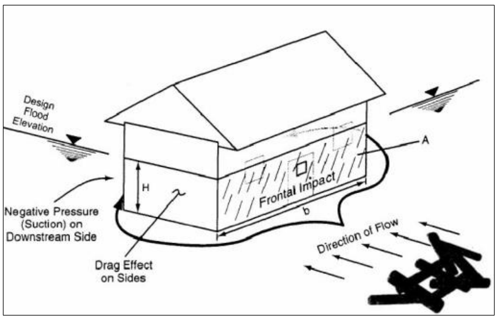


Figure 2 Schematic sketch of hydrodynamic force acting on building

Objectives

The major objectives of the present work are:

- To Study Ductile Detailing Of G+7 RC Building using IS 456:2000 & IS 13920 – 2016
- To study flood Load and evaluate flood load on the structure.
- Modelling and analysis of G+7 residential building.
- Comparison of analysis report of earthquake resistant Building, non-earthquake resistant building and flood resistant building.

2.1. Problem statement

The building configuration used for the study is residential and rectangular in shape, with plan dimensions 25m×15m the data associated with G + 7 storey reinforced concrete building. Considered for the analysis, while the plan of the building is shown in Fig.3.1.In Fig.3.1, the direction of interest refers the perpendicular direction of flood.

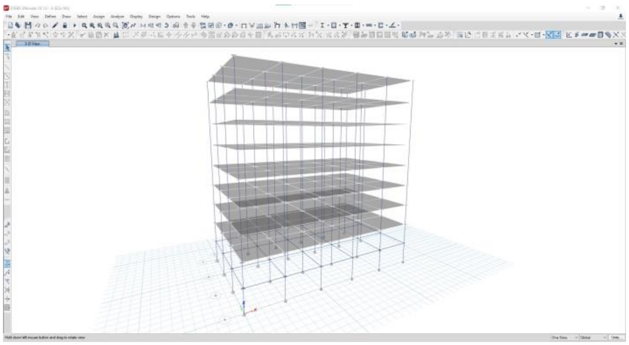


Figure 3 Typical floor plan of G+7 RC Building

Table 1 RC G+7 Building Details

Floor height of building	3 m
No.of bays in X direction	5
No.of bays in Y direction	3
Bay width	5m in both directions
Column size	500 mm X 500 mm
Beam size	230 mm X 600 mm
Slab thickness	150 mm
Total height of building	24 m above ground level
No of slab	8 Nos.

Walls (External and Internal)	150 mm thick brick masonry walls
Plinth level	0.6 m above road level
Ground beams	To be provided at 150 mm below G.L.

Table 2 General Design Parameters

Live Load	2.0 kN/m at typical floor, 1.5 kN/m^2 on terrace As per IS: 875 (Part 2) - 1987
Floor Finish Load	1 kN/m2 terrace As per IS: 875 (Part 2) - 1987
Water proofing (terrace)	1.5 kN/m2 terrace As per IS: 875 (Part 2) - 1987
Wind load	V_b = Basic Wind Speed = 44 m/s, As per IS: 875 (Part 3) – 2015 K1 = Probability Factor = 1 (Table no 1, page no 7) K2 = Terrain and Height Factor = 1 (Table no 2, page no 8) K3 =Topography Factor = 1 (Clause 6.3.3.1) K4 =Importance Factor = 1 (Clause 6.3.4)
Earthquake load	As per IS-1893 (Part 1)-2016
Type of Soil	Type II, Medium as per IS:1893 (Clause 6.4.2.1)
Allowable bearing pressure	200 kN/m2
Seismic zone	Zone – IV as per IS 1893 (Part 1) : 2016
Damping ratio	5 %

2.2. Need for the research

Purpose of this study is to evaluate resistance and strength of multi-storey residential high rise building structure against flood. The main aspect of this analysis is to compare analysis of earthquake resistant structure with analysis for loads exerted due to flood. The architect and engineer must recognize that building structure influences how that structurereacts to hazards those associated with floodwaters.

2.3. Modeling

To compute the critical effect, the flood was assumed to act along the 25m side and an intermediate 2D frame along 15m side was considered for the study. Five different models were considered for modeling, namely

- DL + LL + EQ + WL
- DL + LL + FL (at 1m)
- DL + LL + FL (at 2m)
- DL + LL + FL (at 3m)
- DL + LL + FL (at 4m)

2.4. Calculation of hydrodynamic forces

In cases where velocities do not exceed 3 m/sec, the hydrodynamic effects of moving water can be converted to an equivalent hydrostatic force by increasing the equivalent head due to low velocity flood flows (m). Flood water velocities in the area of the building average 2.9 m/sec and Floodwater flows parallel to front elevation and impact side elevation as per Equation 5.1 and Equation 5.2

$$dh = \frac{C_d}{2\,g} V^2 \qquad \text{(Equation - 5.1)}$$

Where,

dh = equivalent head due to low velocity flood flows (m)

C_d = drag coefficient

V = velocity of floodwater (m/sec)

g = acceleration of gravity (9.81 m/s^2) $C_d = \frac{b}{H} = \frac{15}{1.3}$ = 11.53 so C_d = 1.25 for H = 1.3 m

Similarly C_d = 1.25 for H = 2.3m, 3.3m and 4.4m

V = 2.9 m/sec, g = 9.81 m/s^2 $dh = \frac{1.25}{2 X 9.81} (2.9)^2$ = 0.536 As per Equation 3.8

$f_{dh} = \gamma_w (dh)H = P_{dh} H$ (Equation - 5.2)

Where,

f_{dh} = equivalent hydrostatic force due to low velocity flood flows under 3.05 m/sec and acting at H/2 height in (kN/m)

γ_w = specific weight of water (9.81 kN/m^3) dh = equivalent head due to low velocity flood flows (m) H = flood proofing design depth (m) P_{dh} = hydrostatic pressure due to low velocity flood flows (kN/ m^2) ($P_{dh} = \gamma_w (dh)$)

w = width of columns (w = 0.5 m) $f_{dh} = \gamma_w (dh)H$ = 9.81 X 0.536 X 1.3 = 6.84 kN f_{dh} Force acting at (H / 2) distance from ground that is (1.3 / 2) = 0.65 m

Similarly,

Table 3 Calculations of Force Due To Low Velocity Flood Flows

Sr. No.	H = flood proofing design depth (m)	dh	$f_{dh} = \gamma_w (dh)H$ x w (kN)	f_{dh} acting at $\frac{H}{2}$
1	1.3	0.536	6.84 x 0.5 = 3.42	0.65
2	2.3	0.536	12.09 x 0.5 = 6.05	1.15
3	3.3	0.536	17.35 x 0.5 = 8.68	1.65
4	4.3	0.536	22.61 x 0.5 = 11.31	2.15

Wave loads shall be determined by using Equation 5.3 and Equation 5.4

$H_b = 0.78\, d_s$ (Equation – 5.3)

Where,

H_b = breaking wave height in (m)

d_s= local still water depth in (m)

The net force resulting from breaking wave acting on a rigid vertical pile or column shall be assumed to act at the still water elevation and shall be calculated by the following:

$F_D = 0.5\, \gamma_w\, C_D\, D\, {H_b}^2$ (Equation – 5.4)

Where,

F_D = net wave force, in pounds (kN)

γ_w = specific weight of water (9.81 kN/m^3)

C_D = coefficient of drag for breaking waves, = l. 75 for round piles or columns, and = 2.25 for square piles or columns

D = pile or column diameter, in (m) for circular sections, or for a square pile or column, 1.4 times the width of the column in (m). ($\because$ Columns width = 0.5 m)(D = 1.4 x 0.5 = 0.7 m)

H_b = breaking wave height, in (m)

$H_b = 0.78\, d_s \;\; \because\; d_s$ = 1m

So, 0.78 x 1 = 0.78 m

$F_D = 0.5\, \gamma_w\, C_D\, D\;\, {H_b}^2$ = 0.5 x 9.81 x 2.25 x 0.7 x (0.78)^2 = 4.7 kN acting at still water depth which is 1m from ground.

Similarly,

Table 4 Calculations of Breaking Wave Load on Columns

Sr.No.	$H_b = 0.78\, d_s$ **(m)**	$F_D = 0.5\, \gamma_w\, C_D\, D\;\, {H_b}^2$ **(kN)**	**Still water depth (m) from GL**
1	0.78	4.7	1
2	1.56	18.80	2
3	2.34	42.30	3
4	3.12	75.20	4

2.5. Calculation of Impact Load

Impact loads are those that result from debris, ice, and any object transported by floodwaters striking against buildings and structures, or parts thereof. Impact loads shall be determined using a rational approach as concentrated loads acting horizontally at the most critical location at or below the design flood elevation using Equation – 5.5

$= W\, V\, C_D C_B C_{str}$ (Equation – 5.5)

Where,

- F_i = impact force acting at the BFE (kN)
- W = weight of the object (kN) = 5 kN
- V = velocity of water (m/sec) = 2.9 m/sec
- C_D = depth coefficient (see Table 3.4) for depth 1.3 m or greater height (C_D = 1)
- C_B = blockage coefficient (taken as 1.0 for no upstream screening)
- C_{str} = building structure coefficient (taken as 0.8 for reinforced concrete building)
- $F_i = W\, V\, C_D C_B C_{str}$ = 5 x 2.9 x 1 x 1 x 0.8 = 11.6 kN acting at 1m depth from GL. Similarly same force acting on 2m, 3m and 4m depth from ground level. Impact load and wave load are acting at still water level so resultant force to be,

$F_R = F_D + F_i$

Table 5 Calculations of Resultant Force at Still Water Depth

Sr.No.	Resultant Force (F_R) = F_D + F_i (kN)	Still water depth (m) from GL
1	4.7 + 11.6 = 16.3	1
2	18.80 + 11.6 = 30.4	2

3	42.30 + 11.6 = 53.9	3
4	75.20 + 11.6 = 86.8	4

2.6. Analysis of model

The procedure consists of linear static and linear dynamic analysis. When the linear static or dynamic procedures are used for seismic evaluation, the design seismic forces, the distribution of applied loads over the height of the buildings, and the corresponding displacements are determined using a linearly elastic analysis. The various steps involved in CSI-ETABS model analysis are the following:

- Modelling of frame sections.
- Defining and assigning material properties and section properties.
- Assigning support conditions.
- Defining and assigning load patterns and load cases.
- Assigning load combinations.
- Setting up of analysis option.
- Running analysis.
- Inferring the results.

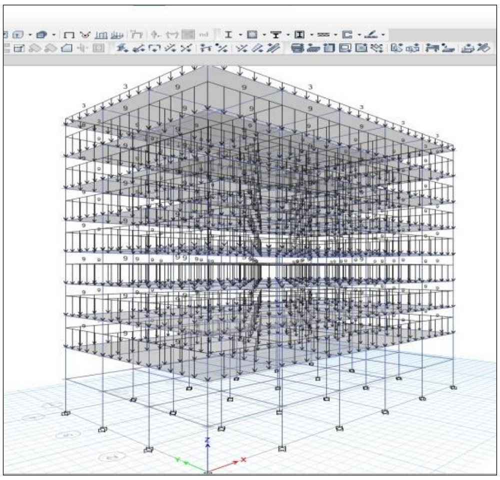


Figure 4 Assigning Wall Load on Floor Beam and Floor Load on Slabs

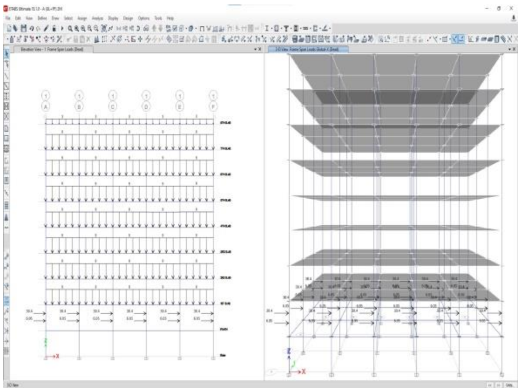
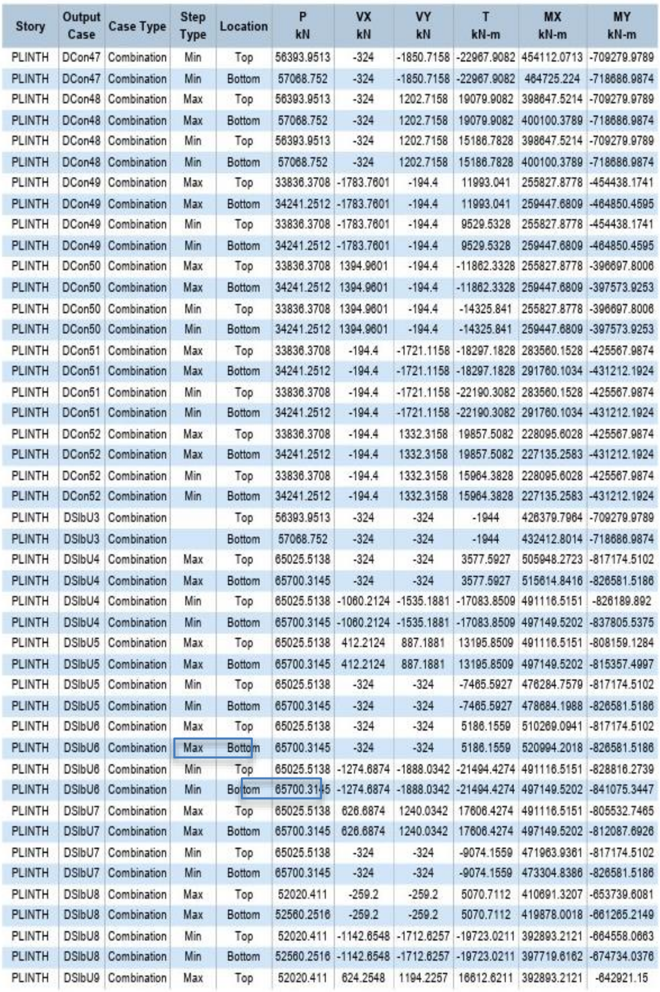


Figure 5 Apply Flood Load on Structure along X Direction of Flood Flow

3. Result and discussion



Story	Output Case	Case Type	Step Type	Location	P kN	VX kN	VY kN	T kN-m	MX kN-m	MY kN-m
PLINTH	DCon47	Combination	Min	Top	56393.9513	-324	-1850.7158	-22967.9082	454112.0713	-709279.9789
PLINTH	DCon47	Combination	Min	Bottom	57068.752	-324	-1850.7158	-22967.9082	464725.224	-718686.9874
PLINTH	DCon48	Combination	Max	Top	56393.9513	-324	1202.7158	19079.9082	398647.5214	-709279.9789
PLINTH	DCon48	Combination	Max	Bottom	57068.752	-324	1202.7158	19079.9082	400100.3789	-718686.9874
PLINTH	DCon48	Combination	Min	Top	56393.9513	-324	1202.7158	15186.7828	398647.5214	-709279.9789
PLINTH	DCon48	Combination	Min	Bottom	57068.752	-324	1202.7158	15186.7828	400100.3789	-718686.9874
PLINTH	DCon49	Combination	Max	Top	33836.3708	-1783.7601	-194.4	11993.041	255827.8778	-454438.1741
PLINTH	DCon49	Combination	Max	Bottom	34241.2512	-1783.7601	-194.4	11993.041	259447.6809	-464850.4595
PLINTH	DCon49	Combination	Min	Top	33836.3708	-1783.7601	-194.4	9529.5328	255827.8778	-454438.1741
PLINTH	DCon49	Combination	Min	Bottom	34241.2512	-1783.7601	-194.4	9529.5328	259447.6809	-464850.4595
PLINTH	DCon50	Combination	Max	Top	33836.3708	1394.9601	-194.4	-11862.3328	255827.8778	-396697.8006
PLINTH	DCon50	Combination	Max	Bottom	34241.2512	1394.9601	-194.4	-11862.3328	259447.6809	-397573.9253
PLINTH	DCon50	Combination	Min	Top	33836.3708	1394.9601	-194.4	-14325.841	255827.8778	-396697.8006
PLINTH	DCon50	Combination	Min	Bottom	34241.2512	1394.9601	-194.4	-14325.841	259447.6809	-397573.9253
PLINTH	DCon51	Combination	Max	Top	33836.3708	-194.4	-1721.1158	-18297.1828	283560.1528	-425567.9874
PLINTH	DCon51	Combination	Max	Bottom	34241.2512	-194.4	-1721.1158	-18297.1828	291760.1034	-431212.1924
PLINTH	DCon51	Combination	Min	Top	33836.3708	-194.4	-1721.1158	-22190.3082	283560.1528	-425567.9874
PLINTH	DCon51	Combination	Min	Bottom	34241.2512	-194.4	-1721.1158	-22190.3082	291760.1034	-431212.1924
PLINTH	DCon52	Combination	Max	Top	33836.3708	-194.4	1332.3158	19857.5082	228095.6028	-425567.9874
PLINTH	DCon52	Combination	Max	Bottom	34241.2512	-194.4	1332.3158	19857.5082	227135.2583	-431212.1924
PLINTH	DCon52	Combination	Min	Top	33836.3708	-194.4	1332.3158	15964.3828	228095.6028	-425567.9874
PLINTH	DCon52	Combination	Min	Bottom	34241.2512	-194.4	1332.3158	15964.3828	227135.2583	-431212.1924
PLINTH	DSlbU3	Combination		Top	56393.9513	-324	-324	-1944	426379.7964	-709279.9789
PLINTH	DSlbU3	Combination		Bottom	57068.752	-324	-324	-1944	432412.8014	-718686.9874
PLINTH	DSlbU4	Combination	Max	Top	65025.5138	-324	-324	3577.5927	505948.2723	-817174.5102
PLINTH	DSlbU4	Combination	Max	Bottom	65700.3145	-324	-324	3577.5927	515614.8416	-826581.5186
PLINTH	DSlbU4	Combination	Min	Top	65025.5138	-1060.2124	-1535.1881	-17083.8509	491116.5151	-826189.892
PLINTH	DSlbU4	Combination	Min	Bottom	65700.3145	-1060.2124	-1535.1881	-17083.8509	497149.5202	-837805.5375
PLINTH	DSlbU5	Combination	Max	Top	65025.5138	412.2124	887.1881	13195.8509	491116.5151	-808159.1284
PLINTH	DSlbU5	Combination	Max	Bottom	65700.3145	412.2124	887.1881	13195.8509	497149.5202	-815357.4997
PLINTH	DSlbU5	Combination	Min	Top	65025.5138	-324	-324	-7465.5927	476284.7579	-817174.5102
PLINTH	DSlbU5	Combination	Min	Bottom	65700.3145	-324	-324	-7465.5927	478684.1988	-826581.5186
PLINTH	DSlbU6	Combination	Max	Top	65025.5138	-324	-324	5186.1559	510269.0941	-817174.5102
PLINTH	DSlbU6	Combination	Max	Bottom	65700.3145	-324	-324	5186.1559	520994.2018	-826581.5186
PLINTH	DSlbU6	Combination	Min	Top	65025.5138	-1274.6874	-1888.0342	-21494.4274	491116.5151	-828816.2739
PLINTH	DSlbU6	Combination	Min	Bottom	65700.3145	-1274.6874	-1888.0342	-21494.4274	497149.5202	-841075.3447
PLINTH	DSlbU7	Combination	Max	Top	65025.5138	626.6874	1240.0342	17606.4274	491116.5151	-805532.7465
PLINTH	DSlbU7	Combination	Max	Bottom	65700.3145	626.6874	1240.0342	17606.4274	497149.5202	-812087.6926
PLINTH	DSlbU7	Combination	Min	Top	65025.5138	-324	-324	-9074.1559	471963.9361	-817174.5102
PLINTH	DSlbU7	Combination	Min	Bottom	65700.3145	-324	-324	-9074.1559	473304.8386	-826581.5186
PLINTH	DSlbU8	Combination	Max	Top	52020.411	-259.2	-259.2	5070.7112	410691.3207	-653739.6081
PLINTH	DSlbU8	Combination	Max	Bottom	52560.2516	-259.2	-259.2	5070.7112	419878.0018	-661265.2149
PLINTH	DSlbU8	Combination	Min	Top	52020.411	-1142.6548	-1712.6257	-19723.0211	392893.2121	-664558.0663
PLINTH	DSlbU8	Combination	Min	Bottom	52560.2516	-1142.6548	-1712.6257	-19723.0211	397719.6162	-674734.0376
PLINTH	DSlbU9	Combination	Max	Top	52020.411	624.2548	1194.2257	16612.6211	392893.2121	-642921.15

Figure 6 Story Forces for Dead Load, Live Load Only, Earthquake Load and Wind Load Only

Max Mx observed for this combination for plinth is 502994.2018 k.NM and My is 841075.3447 k.NM. Flood load applied on 1m, 2m, 3m and 4m depth. The maximum moment in these four depth are 3m that Max Mx observed for this combination is 497149.5202 k.NM and Max My is 850551.9926 k.NM.

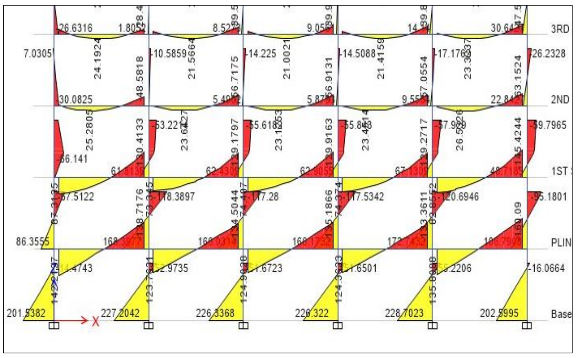
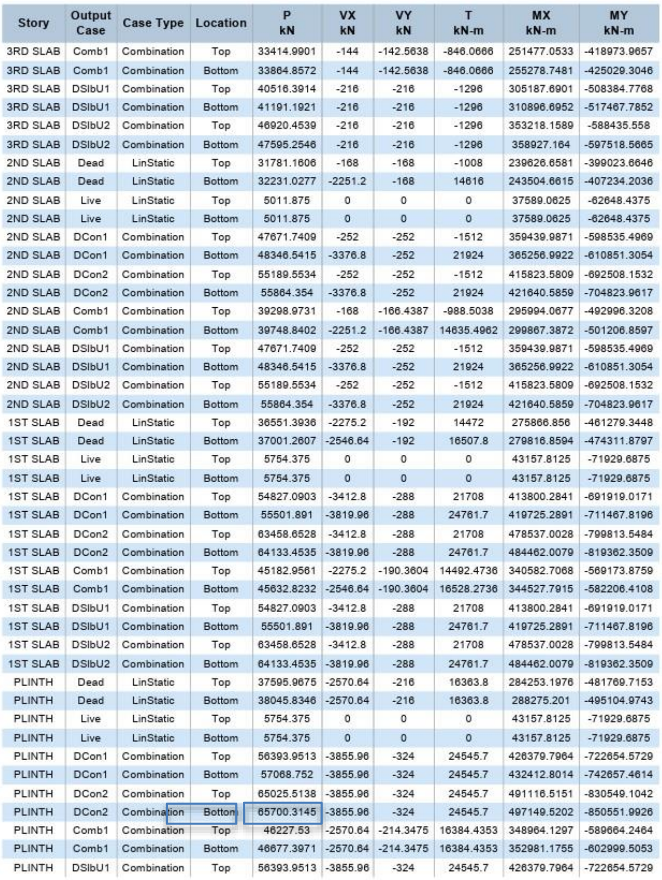


Figure 7 Bending Moment Diagram for 3m Depth



Story	Output Case	Case Type	Location	P kN	VX kN	VY kN	T kN-m	MX kN-m	MY kN-m
3RD SLAB	Comb1	Combination	Top	33414.9901	-144	-142.5638	-846.0666	251477.0533	-418973.9657
3RD SLAB	Comb1	Combination	Bottom	33864.8572	-144	-142.5638	-846.0666	255278.7481	-425029.3046
3RD SLAB	DSlbU1	Combination	Top	40516.3914	-216	-216	-1296	305187.6901	-508384.7768
3RD SLAB	DSlbU1	Combination	Bottom	41191.1921	-216	-216	-1296	310896.6952	-517467.7852
3RD SLAB	DSlbU2	Combination	Top	46920.4539	-216	-216	-1296	353218.1589	-588435.558
3RD SLAB	DSlbU2	Combination	Bottom	47595.2546	-216	-216	-1296	358927.164	-597518.5665
2ND SLAB	Dead	LinStatic	Top	31781.1606	-168	-168	-1008	239626.6581	-399023.6646
2ND SLAB	Dead	LinStatic	Bottom	32231.0277	-2251.2	-168	14616	243504.6615	-407234.2036
2ND SLAB	Live	LinStatic	Top	5011.875	0	0	0	37589.0625	-62648.4375
2ND SLAB	Live	LinStatic	Bottom	5011.875	0	0	0	37589.0625	-62648.4375
2ND SLAB	DCon1	Combination	Top	47671.7409	-252	-252	-1512	359439.9871	-598535.4969
2ND SLAB	DCon1	Combination	Bottom	48346.5415	-3376.8	-252	21924	365256.9922	-610851.3054
2ND SLAB	DCon2	Combination	Top	55189.5534	-252	-252	-1512	415823.5809	-692508.1532
2ND SLAB	DCon2	Combination	Bottom	55864.354	-3376.8	-252	21924	421640.5859	-704823.9617
2ND SLAB	Comb1	Combination	Top	39298.9731	-168	-166.4387	-988.5038	295994.0677	-492996.3208
2ND SLAB	Comb1	Combination	Bottom	39748.8402	-2251.2	-166.4387	14635.4962	299867.3872	-501206.8597
2ND SLAB	DSlbU1	Combination	Top	47671.7409	-252	-252	-1512	359439.9871	-598535.4969
2ND SLAB	DSlbU1	Combination	Bottom	48346.5415	-3376.8	-252	21924	365256.9922	-610851.3054
2ND SLAB	DSlbU2	Combination	Top	55189.5534	-252	-252	-1512	415823.5809	-692508.1532
2ND SLAB	DSlbU2	Combination	Bottom	55864.354	-3376.8	-252	21924	421640.5859	-704823.9617
1ST SLAB	Dead	LinStatic	Top	36551.3936	-2275.2	-192	14472	275866.856	-461279.3448
1ST SLAB	Dead	LinStatic	Bottom	37001.2607	-2546.64	-192	16507.8	279816.8594	-474311.8797
1ST SLAB	Live	LinStatic	Top	5754.375	0	0	0	43157.8125	-71929.6875
1ST SLAB	Live	LinStatic	Bottom	5754.375	0	0	0	43157.8125	-71929.6875
1ST SLAB	DCon1	Combination	Top	54827.0903	-3412.8	-288	21708	413800.2841	-691919.0171
1ST SLAB	DCon1	Combination	Bottom	55501.891	-3819.96	-288	24761.7	419725.2891	-711467.8196
1ST SLAB	DCon2	Combination	Top	63458.6528	-3412.8	-288	21708	478537.0028	-799813.5484
1ST SLAB	DCon2	Combination	Bottom	64133.4535	-3819.96	-288	24761.7	484462.0079	-819362.3509
1ST SLAB	Comb1	Combination	Top	45182.9561	-2275.2	-190.3604	14492.4736	340582.7068	-569173.8759
1ST SLAB	Comb1	Combination	Bottom	45632.8232	-2546.64	-190.3604	16528.2736	344527.7915	-582206.4108
1ST SLAB	DSlbU1	Combination	Top	54827.0903	-3412.8	-288	21708	413800.2841	-691919.0171
1ST SLAB	DSlbU1	Combination	Bottom	55501.891	-3819.96	-288	24761.7	419725.2891	-711467.8196
1ST SLAB	DSlbU2	Combination	Top	63458.6528	-3412.8	-288	21708	478537.0028	-799813.5484
1ST SLAB	DSlbU2	Combination	Bottom	64133.4535	-3819.96	-288	24761.7	484462.0079	-819362.3509
PLINTH	Dead	LinStatic	Top	37595.9675	-2570.64	-216	16363.8	284253.1976	-481769.7153
PLINTH	Dead	LinStatic	Bottom	38045.8346	-2570.64	-216	16363.8	288275.201	-495104.9743
PLINTH	Live	LinStatic	Top	5754.375	0	0	0	43157.8125	-71929.6875
PLINTH	Live	LinStatic	Bottom	5754.375	0	0	0	43157.8125	-71929.6875
PLINTH	DCon1	Combination	Top	56393.9513	-3855.96	-324	24545.7	426379.7964	-722654.5729
PLINTH	DCon1	Combination	Bottom	57068.752	-3855.96	-324	24545.7	432412.8014	-742657.4614
PLINTH	DCon2	Combination	Top	65025.5138	-3855.96	-324	24545.7	491116.5151	-830549.1042
PLINTH	DCon2	Combination	Bottom	65700.3145	-3855.96	-324	24545.7	497149.5202	-850551.9926
PLINTH	Comb1	Combination	Top	46227.53	-2570.64	-214.3475	16384.4353	348964.1297	-589664.2464
PLINTH	Comb1	Combination	Bottom	46677.3971	-2570.64	-214.3475	16384.4353	352981.1755	-602999.5053
PLINTH	DSlbU1	Combination	Top	56393.9513	-3855.96	-324	24545.7	426379.7964	-722654.5729

Figure 8 Story Forces for Dead Load, Live Load and Flood Load at 3m Depth

4. Conclusion

Accurate structural analysis of every building is important aspect of structural design of any building an engineer analyzing any structural system takes into account, dead load, live load as well as earthquake load and wind loads etc. as may be applicable. With revision in IS 1893: 2016 it is mandatory to analyzes the structure for anticipatory earthquake loads as per zones prescribed. Although flood is also a natural calamity like earthquake, there is no standard procedure to calculate loads exerted due to floods on any structure. Considering climate change and increasing occurrences of floods, it is absolutely necessary to check capacity of any structure to resist loads caused due to floods.

The structural model chosen for the study has 5 bays in X direction and 3 bays in Y direction. Each bay is 5m X 5m. Structure is analyzed for varies combination of DL + LL + EQ + WL and DL + LL + Flood Loads (FL) (converted and applied as point loads). Summary of analysis is as follows:

Max values of story forces due to DL + LL + EQ + WL

Mx = 502994.2018 k.NM for plinth & Mx = 503614.58 k.NM for 1st slab

My = 841075.34 k.NM for plinth & My = 825234.54 k.NM

Max values of story forces due to DL + LL + FL

Mx = 497149.5202 k.NM & My = 850551.9926 k.NM (Difference is only 1.12 %, hence negligible)

Analysis of flood load was carried out considering different scenarios of four levels of flood, at 1m, 2m, 3m and 4m depth respectively. Impact load was also considered in analytical model. Above values are highest amongst all values for different depth as well as impact load. It can be clearly observed that loads exerted due to flood are exerting more forces on structure than any other load combinations. Considering the values of forces it is evident that forces exerted due to flood are less or almost equal to the forces exerted due to earthquake load. As it is mandatory to analysis and design structure for earthquake loads, we can say that such structure designed to withstand earthquake loads will also be able to resist loads exerted due to floods. Furthermore reinforcement detailing as per IS 13920:2016 for ductile detailing, will enhance rigidity and capacity of structure as whole and columns of stilt floor particularly.

- Through this Report, we have dealt with the brief history of Domes and have highlighted some of the recent innovations and focus on using it for modern housing.
- The advantage of using them over Flat roofs has also been done through the paper indicating the superiority of dome structures. Two popular types namely Geodesic and Monolithic domes have been discussed.
- Both Monolithic and Geodesic domes have advantages particularly for energy-efficient and disaster resistant housing. Thorough this paper we have attempted to bring out the relevance of carrying out further research and investigation in the use of suitable dome structures for popular constructions like housing.
- In Monolithic Dome method we can use the industrial waste fly ash to replace 15-20% of cement used in construction which also helps to save the environment and cost of construction.
- We can use composite hallow circular columns replaced by rectangular columns. Structural behaviour is studied of RC dome using STAAD.Pro v8i.

The assumed dimensions of beam is 350 mm x 400 mm, column of diameter 500mm & plate thickness is 250 mm are safe for carrying various load. For the applied load cases and combination structure comes under safe zone

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in publishing the paper.

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