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COMPARISON OF BASE SHEAR AND LATERAL FORCE FOR FORCE BASED DESIGN METHOD AND DISPLACEMENT BASED DESIGN METHOD OF RC FRAME STRUCTURES

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Abstract - *The paper shows that an alternative design other than Forced-Based Design method for seismic design of structures has been proposed, that is, Displacement-Based Design method. A three, six and nine storey building has been taken for three different zones, that is, Zone III, Zone IV and Zone V and is designed with both the methods and their respective base shear and design lateral force has been calculated. The design procedure has been elaborated and comparison of base shear and design lateral force for both the procedure has been plotted. Finally concluding remarks has been highlighted.*

Keywords – *Forced-Based Design Method: Seismic Coefficient Method, Displacement-Based Design Method, RC frame building, Storey, Lateral force, Base shear.*

I. INTRODUCTION

When earthquakes occur, a building undergoes dynamic motion. This is because the building is subjected to inertia forces that act in opposite direction to the acceleration of earthquake excitations. These inertia forces, called seismic loads, are usually dealt with by assuming forces external to the building. Most seismic structural analyses are based on the relative-displacements formulation where the base accelerations are used as the basic loading. Hence, experience with the direct use of absolute earthquake displacement loading acting at the base of the structure has been limited. Several new types of numerical errors associated with the use of absolute seismic displacement loading are identified. Those errors are inherent in all methods of dynamic analysis and are directly associated with the application of displacement loading. It is possible for the majority of seismic analyses of structures to use the ground accelerations as the basic input, and the structural displacements produced are relative to the absolute ground displacements. For earthquake resistant design, evaluation of the seismic performance of buildings, it is essential to determine if an acceptable solution in terms of capacity and performance is achieved.

Earthquake induced forces are direct functions of the energy absorption, damping and ultimate damage capacity of structural members, which all depend on deformation. Modern constructions must satisfy seismic design criteria which are often associated to the most adverse combination of actions with regard to building resistance under lateral loads.

The aim of this Paper is to compare two different design approaches: the Force-Based Design (FBD) and the Direct Displacement-Based Design (DDBD).

II. FORCE BASED DESIGN

The force-based design, FBD, procedure is based on calculating the base shear force resulting from the earthquake dynamic motion using the acceleration response spectrum and the expected elastic period of the building. In this procedure the static loads are applied on a structure with magnitudes and directions that closely approximate the effects of dynamic loading caused by earthquakes. Concentrated lateral forces due to dynamic loading tend occur at each floor in buildings, where concentration of mass exists. Concentrated lateral forces tend to follow the fundamental mode shape of the building, in other words it is larger at higher elevations in a structure. The greatest lateral displacements and the largest lateral forces often occur at the top level of a structure. These effects are modeled in equivalent static lateral force procedures of most design codes by placing a force at each story level in the structure, which is directly proportional with the height. A Force based design where characteristic material strength is used. It uses variable load combination:

1) 1.5(DL+LL),
2) 1.2(DL+LL±SL),
3) 1.5(DL±SL),
4) 0.9DL±1.5SL, Where DL stands for dead load, LL for imposed load and SL for seismic load along the frame.

2.1 Limitations of Force-Based Design are

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The fundamental period required to start the design is determined using empirical expressions. The values specified for the modification factor, *R*, by seismic codes, appear to be somewhat arbitrary. Displacements are checked at the end of the design process only. There appears to be a lack of concern about the implied inelastic displacements which may be excessive and contribute to the instability of the structure.

2.2 Design Spectrum

The design horizontal seismic coefficient A_h for a structure shall be determined by the following expression:

$$A_h = ZIS_a/2Rg$$

Where

Z = Zone factor , The factor 2 in the denominator of Z is used so as to reduce the Maximum Considered Earthquake (MCE) zone factor to the factor for Design Basis Earthquake (DBE).

I = Importance factor, depending upon the functional use of the structures, characterized by. Hazardous consequences of its failure, post-earthquake functional needs, historical value, or economic importance.

R = Response reduction factor, depending on the perceived seismic damage performance of the structure, characterized by ductile or brittle deformations. However, the ratio (I/R) shall not be greater than 1.0.

2.3 Design Seismic Base Shear

- The total design lateral force or design seismic base shear (V_B)along any principal direction shall be determined by the following expression:

$$V = A_hW$$

2.4 Fundamental Natural Period

- The approximate fundamental natural period of vibration (***T,),*** in seconds, of all other buildings, including moment resisting frame buildings with brick infill panels, may be estimated by the empirical expression:

$$T_a = 0.09/d^{1/2}$$

Where,

h = Height of building, in m

d = Base dimension of the building at the plinth level, in m, along the considered direction of the lateral force.

2.5 Distribution of Design Force

$$Q_i = V_B \frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2}$$

where

Q_i = Design lateral force at floor *i*,

W_i = Seismic weight of floor *i*,

h_i = Height of floor *i* measured from base, and

n = Number of storeys in the building is the number of levels at which the masses are located.

III. DIRECT DISPLACEMENT – BASED DESIGN

This approach uses the displacement response spectrum as a basis for calculating the base shear force. It also depends on studying the building considering its inelastic phase. This is presents the fundamentals of the new seismic design method known as Direct Displacement-Based Design (DDBD). It is considered as one of the simplest design approaches for analysis of the multi-degree of freedom structures. In this method, the structure is characterized by the secant stiffness and equivalent damping of an equivalent single degree of freedom structure. This design is based on achieving a specified displacement limit state, defined either by material strain limits, or non-structural drift limits obtained from design codes under the design level seismic intensity. The characterization of the structure using the substitute structure avoids many problems inherent in force-based design, (FBD), where initial stiffness is used to determine an elastic period which is a drawback that is present in most of the building codes. The design approach attempts to design a structure which would achieve, rather than be bounded by, a given performance limit state under a given seismic intensity, essentially resulting in uniform-risk structures, which is philosophically compatible with the uniform-risk seismic spectra incorporated in most design codes. A Displacement based design which uses expected material strength in the design stage. It also uses constant beam section for a particular frame.

It uses load combination as

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1) DL+LL,
2) DL+LL±SLx
3) DL+LL±SLy

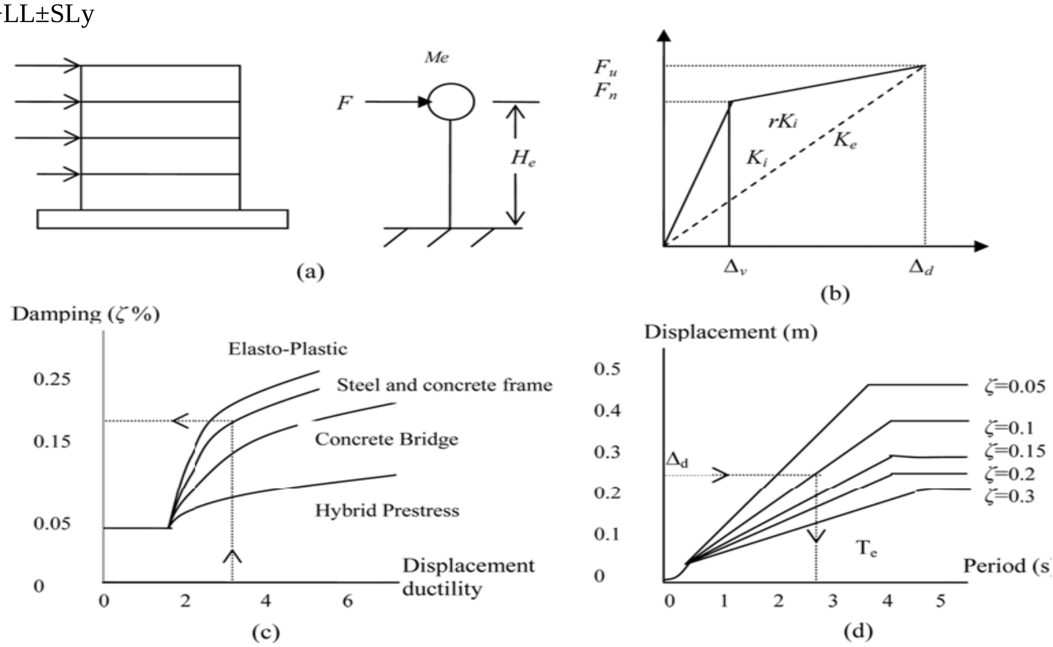

Fig. 1 Fundamentals of Displacement-Based Design (M. J. N. Priestley- Page 64)

3.1 Design Displacement Profile:-

Design profiles are defined in the Model Code for regular structures by Priestley et.al. 2007, based on the results of Non-linear Time History Analysis. For regular frame structures, the design displacement profile is given by,

$$\Delta_i = \omega\theta . \theta c . H_i . 4Hn - H_i / 4Hn - H_1 \quad (1)$$

Where,

$\omega_\theta = 1.15 - 0.0034Hn \leq 1$ is a reduction factor for higher mode amplification of drift

θc = Drift limit (0.02 for life safety perspective) [FEMA 356 (2002)]

The properties for single degree of freedom system is determined by,

- Design displacement of the equivalent SDOF structure is related to the storey displacements. It is given by,

$$\Delta d = \Sigma\, (m_i \Delta_i 2) / \Sigma\, (m_i \Delta_i) \quad (2)$$

$$me = \Sigma\, (m_i \Delta_i) / \Delta d \quad (3)$$

$$He = \Sigma\, (m_i \Delta_i H_i) / \Sigma\, (m_i \Delta_i) \quad (4)$$

Where, m*i*, h*i* and Δ*i* are respectively the mass, height from base and displacement for *ith* storey. *Δd* is target (spectral) displacement, *m*e is equivalent mass, *H*e is the effective height of the ESDOF system.

The design displacement ductility factor is a relation between design displacement and yield displacement.

For reinforced concrete frames, yield drift can be developed from the yield curvature as,

$$\theta y = 0.5 \varepsilon y . LdHb \quad (5)$$

Yield displacement will be,

$$\Delta y = \theta y . He \quad (6)$$

$$\mu = \Delta d \Delta y \quad (7)$$

Equivalent damping for Concrete Frame building is dependent on design displacement ductility. It is given by:

$$\xi eq = 0.05 + 0.565 . \mu - 1 / \mu\pi \quad (8)$$

The effective period T*e* corresponding to Δ*d* and *ξeq* is to be obtained from the design displacement spectra.

The effective stiffness Ke, of the substitute SDOF structure, derived from its effective mass me and effective period Te and hence the base shear is obtained

$$Ke = 4\pi^2 me / Te^2 \quad (9)$$

$$F = Vbase = Ke . \Delta d \quad (10\ a)$$

Then the base shear force is distributed to the floor levels in proportion to the product of mass and displacement as,

$$Fi = Ft + Vb . mi\Delta i / \Sigma\, (mi\Delta i) \quad (10\ b)$$

Where,

Ft = 0.1Vb (at roof) and 0 (at all floors)

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IV. LITERATURE REVIEW

Damir Dzakic, Ivan Kraus, Dragan Moric[1] are investigated that the theory and application of Displacement method using a reinforced concrete frame structures as an example. The frame structure is designed with implementing Euro code 8 regulations. Results obtained using direct displacement based design method are compared to the ones obtained using multimodal response spectrum method. Among other things, significant differences are highlighted in regard to current design regulations.

H. G. Urrego, R. L. Bonett[2] are presented the procedure for displacement-based design is presented. The method assumes a geometrical section of known flexural reinforcement at the critical section. Using concrete and reinforcing steel properties and axial forces, the moment capacity is obtained by equilibrium of the section.It is possible to define whether is necessary to change the initial reinforcement proposed until structural capacity is equal or bigger than the seismic demand. When this iterative procedure concludes, the section is satisfactorily designed because the analyses, as well as the design, are made simultaneously. Finally, the maximum displacement and curvature ductility are calculated.

Adel ElAttar, Abdel HamdZaghw and Ahmed Elansary[3] are apply DBD on different reinforced concrete frame buildings. The base shear forces calculated by (DBD) are compared with those calculated by (FBD) that is defined in the Euro-Code (EC8). Three computer programs have been used in analysis of the studied buildings to perform a pushover analysis and to get the displaced shape corresponding to the drift limit at the first floor. Analyses for six moment-resisting frame buildings with different heights have been applied–without any shear walls. The (DBD) is more suitable for moment resisting frame type buildings with number of storey more than 8 subjected ground accelerations exceeding 0.5 g.

C. Hofmayer , C. Miller , Y. Wang, J. Costello[4] are researched to determine the need for any changes to seismic regulatory practice to reflect the move, in the earthquake engineering community, toward using expected displacement rather than force (or stress) as the basis for assessing design adequacy. The research explored the extent to which displacement based seismic design methods, such as given in FEMA 273, could be useful for reviewing nuclear power stations. Simplification is likely to reduce the potential for erroneous results and to increase the number of engineers that have the background required to perform the analysis. To evaluate the details of the structure to determine whether sufficient ductility is available to accommodate the displacement pattern with adequate margin.

G. M. Calvi, M. J. N. Priestley, M. J. Kowalsky[5] are summarizes the general design approach, the background research, and some of the more controversial issues identified in a book, currently in press, summarizing the design procedure. In this paper presents an alternative approach to current force-based design. Different structural systems including frames, cantilever and coupled walls, dual systems, bridges, wharves, timber structures and seismically isolated structures have been considered in a series of coordinated research programs are analyzed.

Anil K. Chopra, M. EERI, Rakesh K. Goel , M. EERI[6] are presented an equally simple procedure is developed that is based on the well-known concepts of inelastic design spectra. The procedure provides: (1) accurate values of displacement and ductility demands, and (2) a structural design that satisfies the design criteria for allowable plastic rotation. In contrast, the existing procedure using elastic design spectra for equivalent linear systems is shown to underestimate significantly the displacement and ductility demands. The plastic rotation demand on structures designed by this procedure may exceed the acceptable value of the plastic rotation, leaving an erroneous impression that the allowable plastic rotation constraint has been satisfied.

B. Massena, R. Bento, H. Degee[7] are investigated to apply the Direct Displacement Based Design to a simple case of study, a reinforced concrete frame building and to assess the applicability of the method and the needed of develop an automatic design tool. Different seismic intensities were considered: peak ground accelerations of 0.35g and 0.27g were adopted. For the peak ground acceleration of 0.35g, the design displacement capacity of the frame structure obtained through the DDBD procedure is less than the maximum possible spectral displacement demand for the considered damping level. For the low seismicity case (0.27g) the displacement capacity exceeds the maximum possible spectral displacement demand. The DDBD procedure is based on hand calculations and throughout the design process some design choices must be done based on engineering judgment. Moreover, the DDBD procedure can be more difficult to apply, becoming an iterative procedure in some cases it is suggested to develop an automatic program.

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Avadhoot Bhosale[8] is worked on modeling shear hinges is necessary to correctly evaluate strength and ductility of the building. Study on shear strength and displacement capacity of rectangular RC sections and seismic evaluation based on nonlinear static pushover analysis. Beams and columns in the present study were modeled as frame elements with the centre lines joined at nodes using commercial software SAP2000.The results show that the presence of shear hinge can correctly reveal the non-ductile failure mode of the building.

Jack P. Moehle[9] is presented Displacement – based seismic design criteria possess the benefit of being relatively simple and direct in the design process. Limitations of these criteria should be recognized. Probabilistic (Ductility & Displacement) approaches should be developed and applied to deal with the uncertainties in estimating demands and capacities.

Abderrachid Boulaouad, Ahmed Amour[10] have worked on The Displacement-Based Design method for linear and nonlinear systems with some numerical applications on one storey and multistory buildings using the spectra and formulae provided by the Algerian seismic code. Fundamentals and design procedure of this method are given with implications and inherent problems. Comparison between the two methods is made and the limits and advantages of each one are discussed. The results of the analysis show that the Displacement-Based method is simple and efficient with enough accuracy and confirm the idea, developed by many authors, a good alternative to the Force-Based one providing that some problems can be resolved by the elaboration of appropriate design spectra.

Alefiya T. Dohadwala, Rutvik K. Sheth, Dr. Indrajit N. Patel[11] had taken Four storey building for three different zones, that is, Zone III, Zone IV and Zone V and is designed with both the methods. Comparison of base shear for both the procedure has three different zones, that is, Zone III, Zone IV and Zone V and is designed with both the methods. Comparison of base shear for both the procedure has been plotted. buildings designed with Forced-Based Design method are having more base shear than those designed with the Direct Displacement-Based Design method.

Sunil S. Mayengbam, Choudhury.S[12] was investigated that Buildings of two different plans, three different heights are designed with the method for the Performance levels achieved from those designed by the codal method and their respective costs of structural frame members are compared. The frame buildings designed with the method is more economical than those designed with the codal method for the performance levels achieved by the said codal under similar conditions of modeling and Performance levels.

Prof. Rekha Shinde, Prof. Mukesh Shinde[13] are worked on a detailed 3 dimensional seismic analysis and capacity based design of G+3, G+8 & G+15 storied three bay reinforced concrete frame. It highlights various aspects related to the capacity based designing and explains about Limit State design which an old method of building designing. The study reveals modeling and analysis. The capacity based design of G+3; G+8 & G+15 of old and new building design methods have been modeled and analyzed. It is conclude that more research work is needed especially for development of PBED method for various other different types of structures. control of drift and yielding is built into the design process from the very start, eliminating or minimizing the need for lengthy iterations to arrive at the final design. Other advantages include the fact that innovative structural schemes can be developed by selecting suitable yielding members and/or devices and placing them at strategic locations, while the designated non-yielding members can be detailed for no or minimum ductility capacity.

J. Goggins, S. Salawdeh[14] gives the comparison carried out by designing 4 and 12-storey CBF buildings using both DDBD and FBD methodologies. The performance for both methodologies is verified using nonlinear time history analysis (NLTHA) employing eight different accelerograms with displacement response spectra matching the design displacement spectrum. The seismic base shear from the FBD is larger than the base shear obtained from DDBD. The use of larger sections for the structure designed by the FBD approach to resist the lateral forces. Because of that, the lateral displacements the structure endures in the FBD approach are less than the design lateral displacements used to design the structure in DDBD approach.

V. PROBLEM STATEMENT

The example consists of designing a 3, 6 and 9-storeyed Moment Resisting RC frame using Force Based Design and Direct Displacement Based Design method. The frame has equal bay width of 5.0m and storey heights of 3.50m. It is located in Zone-III, Zone-IV and Zone-V. The building is assumed to be constructed in soft soil condition.

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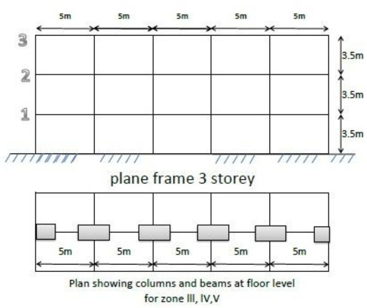
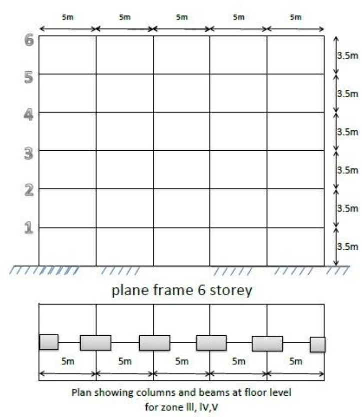
Table 1 - Building Specification

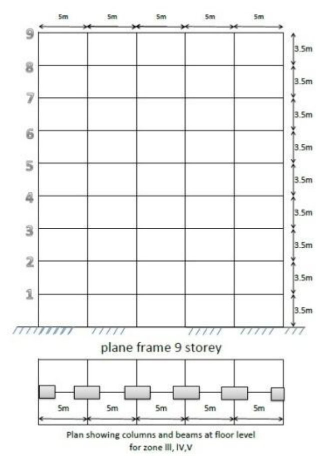
Beam size	230 x 450 mm all
Column size	300 x 800 mm all
Thickness of slab	200 mm all
Imposed load	3 KN/m^2
Floor finish	1 KN/m^2
Thickness of wall	230 mm (exterior) and 115 mm (interior)
Bay width	5 m
Storey height	3.5 m
Viscous damping	10%
Type of building	Hospital

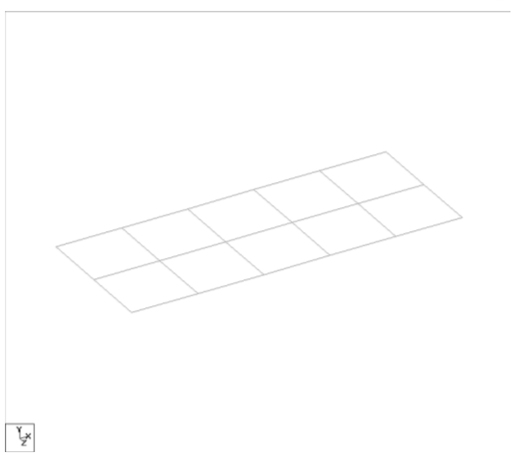
Table 2 - Zone Description

Zones	Place	Type of soil
III	Kerala	Soft soil
IV	Meghalaya	Soft soil
V	Bhuj	Soft soil

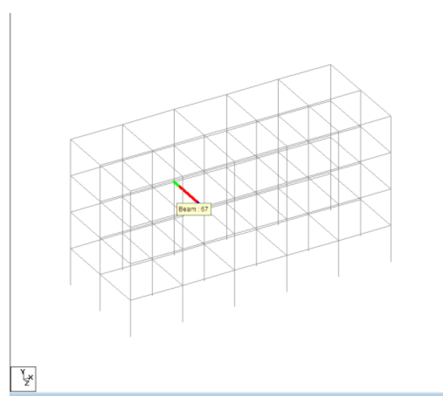








PLAN



G+ 3 STOREYS

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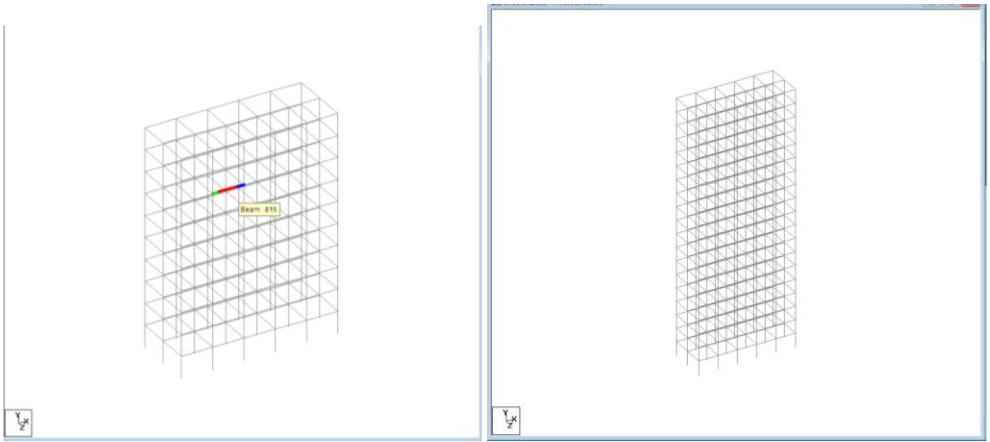

G+6 STOREYS **G+9 STOREYS**

Fig. 2 Problem Visualization

VI. RESULT AND DISCUSSION

Table 3 - G+ 3 Storey

SR. NO.	TYPE OF BUILDING	PARAMETERS (KN)	MANUAL ANALYSIS RESULTS					
			FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
			ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
1	G + 3	Seismic weight	4425	4425	4425	4425	4425	4425
2		Base shear	208.80	313.2	469.80	102.30	151.42	273.42
3		Lateral force	128.20	192.3	288.45	65.10	94.15	145.25

SR. NO.	TYPE OF BUILDING	PARAMETERS (KN)	ANALYTICAL ANALYSIS RESULTS					
			FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
			ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
1	G + 3	Seismic weight	4424.3	4424.3	4424.3	4423	4423	4423
2		Base shear	208.75	313.11	102.15	101.95	150.40	270.30
3		Lateral force	128.08	312.99	288.30	64.65	95.30	146.20

TYPE OF BUILDING	STOREY NO.	MANUAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 3	3	208.58	313.18	469.74	102.30	151.52	273.42
	2	192.51	288.9	433.47	88.03	114.52	241.58
	1	128.20	192.30	288.45	61.28	69.25	79.46
	GROUND	0	0	0	0	0	0

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TYPE OF BUILDING	STOREY NO.	ANALYTICAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 3	3	208.75	313.11	102.15	102.20	150.20	272.95
	2	192.40	288.58	433.80	89.05	114.09	242.00
	1	128.45	192.42	288.79	62.25	69.84	79.98
	GROUND	0	0	0	0	0	0`

BASE SHEAR DISTRIBUTION

TYPE OF BUILDING	STOREY NO.	MANUAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 3	3	128.20	192.30	288.45	14.27	37.00	31.84
	2	64.31	96.68	145.02	26.75	45.27	162.12
	1	16.07	24.17	36.17	61.28	69.25	79.46
	GROUND	0	0	0	0	0	0

TYPE OF BUILDING	STOREY NO.	ANALYTICAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 3	3	128.48	192.56	288.89	15.35	37.80	33.54
	2	64.41	96.78	145.58	27.80	45.87	163.22
	1	16.25	24.29	36.48	62.17	70.65	80.06
	GROUND	0	0	0	0	0	0

DESIGN LATERAL FORCE

Table 4 - G+ 6 Storey

SR. NO.	TYPE OF BUILDING	PARAMETERS (KN)	MANUAL ANALYSIS RESULTS					
			FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
			ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
1	G + 6	Seismic weight	8950	8950	8950	8950	8950	8950
2		Base shear	426.00	639.00	958.50	79.12	98.15	154.21
3		Lateral force	155.91	233.87	350.81	78.40	125.55	178.25

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SR. NO.	TYPE OF BUILDING	PARAMETERS (KN)	ANALYTICAL ANALYSIS RESULTS					
			FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
			ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
1	G + 6	Seismic weight	8951.5	8951.5	8951.5	8952.20	8952.20	8952.20
2		Base shear	425.58	638.40	958.25	80.25	99.57	155.65
3		Lateral force	155.85	233.14	350.57	78.92	125.98	172.85

TYPE OF BUILDING	STOREY NO.	MANUAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 6	6	155.91	233.87	350.81	79.12	98.15	154.21
	5	278.17	417.26	625.90	134.35	185.24	175.29
	4	356.56	534.83	802.26	154.21	152.54	181.20
	3	400.44	600.64	904.07	198.35	204.78	148.24
	2	420.03	630.03	948.17	199.21	198.27	220.57
	1	426.92	639.02	958.19	155.85	250.89	222.45
	GROUND	0	0	0	0	0	0

TYPE OF BUILDING	STOREY NO.	ANALYTICAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 6	6	156.02	234.10	350.94	79.25	98.68	155.15
	5	278.35	417.46	625.99	134.95	186.45	176.12
	4	356.80	534.89	802.78	155.24	152.78	181.99
	3	400.56	600.89	904.28	199.14	205.89	149.15
	2	420.54	630.50	948.38	200.55	199.54	221.65
	1	427.01	639.25	958.54	156.98	251.45	222.89
	GROUND	0	0	0	0	0	0

BASE SHEAR DISTRIBUTION

TYPE OF BUILDING	STOREY NO.	MANUAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 6	6	155.91	233.87	350.81	79.12	98.15	154.21
	5	122.26	183.39	275.08	55.23	87.09	21.08
	4	78.38	117.57	176.36	19.86	32.70	5.91
	3	43.87	65.81	101.81	44.12	52.24	32.96
	2	19.59	29.39	44.09	0.86	6.51	72.33
	1	4.89	7.35	11.02	43.36	52.62	1.88
	GROUND	0	0	0	0	0	0

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TYPE OF BUILDING	STOREY NO.	ANALYTICAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 6	6	156.02	234.10	350.94	80.45	99.78	155.02
	5	122.42	417.46	625.99	56.07	88.21	21.99
	4	78.50	117.69	176.52	20.22	33.05	6.82
	3	43.98	66.01	101.95	45.25	53.78	33.74
	2	19.64	29.64	44.48	1.20	7.09	72.95
	1	4.97	7.87	11.25	44.15	53.11	2.47
	GROUND	0	0	0			

DESIGN LATERAL FORCE

Table 5 - G+ 9 Storey

SR. NO.	TYPE OF BUILDING	PARAMETERS (KN)	MANUAL ANALYSIS RESULTS					
			FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
			ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
1	G + 9	Seismic weight	13400	13400	13400	13400	13400	13400
2		Base shear	673.20	964.80	1447.2	88.35	119.25	164.22
3		Lateral force	166.58	249.88	374.82	84.52	130.42	190.57

SR. NO.	TYPE OF BUILDING	PARAMETERS (KN)	ANALYTICAL ANALYSIS RESULTS					
			FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
			ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
1	G + 9	Seismic weight	13402.5	13402.5	13402.5	13402.15	13402.15	13402.15
2		Base shear	672.98	964.75	1446.8	89.14	119.85	164.91
3		Lateral force	166.30	249.35	374.58	85.32	131.25	191.20

TYPE OF BUILDING	STOREY NO.	MANUAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 9	9	166.58	249.88	374.82	88.35	119.25	164.22
	8	315.80	473.71	710.57	148.92	199.65	210.54
	7	460.28	645.44	968.17	220.65	205.97	225.27
	6	544.53	771.84	1157.7	240.98	215.75	330.58
	5	603.06	859.64	1289.4	258.35	250.59	378.70
	4	640.36	915.59	1373.3	267.39	275.51	451.52
	3	661.58	947.43	1420.6	275.54	287.28	479.89
	2	670.90	961.43	1441.6	280.87	295.45	491.29
	1	673.21	964.80	1447.1	282.30	297.88	495.27
	GROUND	0	0	0	0	0	0

TYPE OF BUILDING	STOREY NO.	ANALYTICAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 9	9	166.90	250.04	374.95	88.98	120.01	164.69
	8	315.98	473.99	710.75	149.58	200.12	211.44
	7	460.56	645.74	968.28	221.11	206.87	226.16
	6	460.45	771.97	1157.9	241.56	216.84	331.14
	5	603.58	859.78	1289.6	259.01	251.91	379.19
	4	640.49	915.98	1373.6	268.20	276.87	452.21
	3	661.92	947.59	1420.8	276.29	288.97	480.41
	2	671.05	961.79	1441.8	281.45	296.50	491.92
	1	673.58	964.98	1447.6	283.25	298.54	496.09
	GROUND	0	0	0	0	0	0

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BASE SHEAR DISTRIBUTION

TYPE OF BUILDING	STOREY NO.	MANUAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 9	9	166.58	249.88	374.82	88.35	119.25	164.22
	8	149.22	223.83	335.75	60.57	80.40	46.32
	7	144.48	171.73	257.60	71.73	6.32	14.73
	6	84.25	126.40	189.58	20.33	9.78	105.31
	5	58.53	87.80	131.69	17.37	34.84	48.12
	4	37.30	55.95	83.93	9.04	24.92	72.82
	3	21.22	31.84	47.75	8.15	11.77	28.37
	2	9.32	14.00	20.98	5.33	8.17	11.40
	1	2.31	3.47	5.20	1.43	2.43	3.98
	GROUND	0	0	0	0	0	0

TYPE OF BUILDING	STOREY NO.	ANALYTICAL ANALYSIS RESULTS					
		FORCE BASED DESIGN			DISPLACEMENT BASED DESIGN		
		ZONE 3	ZONE 4	ZONE 5	ZONE 3	ZONE 4	ZONE 5
G + 9	9	166.90	250.04	374.95	89.18	119.65	165.25
	8	149.48	223.91	335.84	61.45	81.15	47.87
	7	144.58	171.81	257.72	72.82	7.09	15.58
	6	84.56	126.46	189.68	21.54	10.95	106.21
	5	58.61	87.95	131.79	18.45	35.65	49.24
	4	37.45	56.05	84.01	10.54	25.87	73.89
	3	21.54	31.98	47.93	9.27	12.89	29.67
	2	9.46	14.25	21.15	6.54	9.45	12.85
	1	2.50	3.58	5.58	2.54	3.87	5.01
	GROUND	0	0	0	0	0	0

DESIGN LATERAL FORCE

VII. REMARKS

The base shear of RC buildings designed with Displacement-Based Design has been compared with those designed with Forced-Based Design method. Frame buildings for three different zones have been designed with Forced-Based Design method. The same category of buildings has been designed with Displacement-Based Design for the criteria specified given by those designed with Forced-Based Design method. Results have been presented for various zones. The base shear and lateral forces for all the three zones have been evaluated. Results show that buildings designed with Forced-Based Design method are more base shear and lateral force than designed with Displacement-Based Design.

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