The Seismic Analysis for a Multi-Story Building Due To UBC 1997&IBC 2006 Codes

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Abstract

This Study is aimed to investigate the seismic design for typical ten-story building by using codes formulas for evaluating the base shear forces, and distribution of these forces, and lateral displacements along the height of this building, also a comparison is made between two seismic codes. These different design codes are: UBC 1997 and IBC 2006 codes. It is concluded from this analysis that the maximum computed lateral displacements for this building by using UBC 1997 is equal to (58.6%) relative to lateral displacements computed by using the IBC 2006, also it is concluded from the results that the value of base shear obtained by using IBC 2006 code is higher than the value obtained by using UBC 1997 code by (66.6%).

The results of the bending moments obtained from the computer analysis of the applied static seismic codes, shows that the bending moments of columns is higher when using IBC 2006 code.

التحليل للقوى الزلزالية على بناية متعددة الطوابق وفق المدونات (UBC 1997 & IBC 2006)

الخلاصة

تهدف هذه الدراسة إلى تحري التصميم الزلزالي على بناية نموذجية مؤلفة من عشرة طوابق باستخدام مدونات زلزالية لإيجاد قيمة قوى القص القاعدي وكيفية توزيعها، كذلك لإيجاد قيم الازاحات الجانبية على ارتفاع هذه البناية ، وقد أجريت مقارنة بين مدونتين مختلفتين لهذا الغرض وهما: (UBC 1997 & IBC 2006 codes). ومن خلال التحليل وحساب أعظم إزاحة جانبية لهذه البناية وفق المدون (UBC 1997) وكانت تساوي (58.6%) نسبة إلى الإزاحة الجانبية المحسوبة وفق المدون (IBC 2006)، ومن خلال التحليل أيضا وجد إن قيمة قوة القص القاعدي المستخرج من التحليل وفق (IBC 2006) هو أعلى من ذلك المستخرج من التحليل وفق (UBC 1997) بحدود (66.6%).

من خلال النتائج المستحصلة لعزوم الانحناء من التحليل بالحاسوب للقوى المسلطة وفق المدونات الزلزالية، أظهرت إن عزوم الانحناء للأعمدة تكون اكبر عند استخدام المدون (IBC2006).

Introduction

In the design of high rise buildings in seismically active areas, the effects of earthquakes become a predominant consideration. To estimate the design lateral loads due to earthquake, three alternatives are available, the first one by using equivalent static load as suggested by the building codes. The second alternative to estimate the lateral loads by using dynamic analysis based on the response spectrum technique. Last one is by using the time history

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response of the proposed structure.

Codes are particularly well suited to preliminary design stages and "Standard" design. It requires minimal information about structural proportions.

The codes provide procedure to estimate the equivalent static forces that are applied to a structure to approximate the effects of the dynamic response of buildings to earthquake motion.

The lateral shear force at the base of the building, (base shear), is distributed in proportion to an inverted triangle, where the largest lateral story forces are applied at the top of the building and the smallest story forces are applied at the bottom.

This procedure is generally acceptable for buildings that are essentially uniform and regular in size, shape, and structural layout. Buildings with unusual features require consideration of the dynamic characteristics of the structure.

In the following sections, the required analysis are made for evaluating the seismic forces exerted on a typical building in Baghdad city. Two different seismic codes with STAAD PRO structural analysis program are used for analysis this typical building.

Description of the Typical Building

A 10-story reinforced concrete building is chosen for the analysis by using STAAD PRO structural program. The height of the first story is designed to be (4.5 m) while the height of the other stories is (3.5 m). The plan of the building contains four bays in each direction, each one is (5 m) as shown in Fig. (1). All beams have a cross-section of (350*600 mm) and all columns have a cross-section of (500*500 mm). The weight of the building is calculated to be (34046 kN).

Uniform Building Code (UBC 1997)[1]:

The procedure of UBC seismic load is based on chapter 16, section 1630.2 of the UBC-1997.

Base Shear (v):

Base shear is the total lateral force at the base of the building distributed on the height of the structure, where the largest lateral forces are applied at the top building and the smallest story forces applied at the bottom.

The design base shear (v) is calculated using Eq. (1) (1997 UBC Eq.30-4). This base shear value is then checked against the limits specified in Eq. (2) & (3) and modified as necessary to obtain the final base shear.

$$V = \frac{C_v I W}{R T} \qquad ....(1)$$

where:

C_V =1997 UBC seismic coefficient, determined from UBC Table 16-R.

I = Importance factor.

W =Weight of the building (based on specified mass).

R = Over strength factor specified on UBC Table 16-N.

T = Building period.

The total design base shear, V, need not exceed that specified in Eq. (2) (1997 UBC Eq. 30-5). If the base shear calculated per Eq. (1) exceeds that calculated per Eq. (2) then the base shear equals to that calculated per Eq. (2) is considered.

$$V = \frac{2.5 C_a I W}{R} \qquad ....(2)$$

where:

C_a = 1997 UBC seismic coefficient determined from UBC Table 16-Q.

The total design base shear, V, can not be less than that specified in Eq. (3) (1997 UBC Eq. 30-6). If the base shear calculated per Eq. (3) exceeds that calculated per Eq. (1) then the base shear equals to that calculated per Eq. (3).

$$V = 0.11 C_a I W \qquad ....(3)$$

Building Period (T):

The building period is the fundamental period of vibration in seconds in the direction under consideration. The fundamental period of the building may be estimated by one of the following two methods[2].

Method A**:** For all buildings, the value of T may be approximated from the following formula (1997 UBC Eq. 30-8).

$$T = C_t (h_n)^{3/4} \qquad ....(4)$$

where:

C_t = 0.0853 for steel moment-resisting frames.
= 0.0731 for reinforced concrete moment-resisting frames and eccentrically braced frames.
= 0.0488 for all other buildings.

h_n = Height of the building.

Method B**:** The fundamental period T may be calculated by using the following formula (1997 UBC Eq. 30-10).

$$T = 2\pi \sqrt{\left(\sum_{i=1}^{n} w_i \delta_i^2\right) \div \left(g \sum_{i=1}^{n} f_i \delta_i\right)} \quad ...(5)$$

where:

δ_i = Horizontal displacement at level i relative to the base due to applied lateral force f_i .

w_i = Weight of floor i .

g = Acceleration due to gravity.

Lateral forces distribution

The total force is distribution over the height of the building in accordance with the following formula (1997 UBC Eq. 30-15).

$$F_{story} = (V - F_t) \frac{w_{story} h_{story}}{\sum_{story=1}^{n} w_{story} h_{story}} \quad ....(6)$$

where:

F_{story} = Portion of base shear applied to a story level.

V = Building base shear.

F_t = Concentrated force at the top of the building.

w_{story} = Weight of story level (based on specified mass).

h_{story} = Story height, distance from base of building to story level.

n = No. of story in the building.

The concentrated force at the top of the building, F_t, is calculated as shown in the Eq. (7) (1997 UBC Eq. 30-14).

$$F_t = \begin{Bmatrix} 0 & for & T \le 0.7\sec \\ 0.07TV & for & o.7 < T < 3.6 \\ 0.25V & for & T \ge 3.6 \end{Bmatrix} \quad ...(7)$$

Factors and Coefficients:

The factors and coefficients can be determined according to UBC 1997 for the building described:

The soil profile type is specified in UBC Table 16-J, for stiff soil profile use S_D profile.

The seismic zone factor Z specified in UBC Table 16-I, for zone 1, Z = 0.075.

The seismic coefficients C_a and C_v can either be determined based on the soil profile or a seismic zone. These values are C_a = 0.12 and C_v = 0.18.

The over strength factor (R) is specified in UBC Table 16-N, R = 5.6.

The Importance factor (I) is specified on UBC Table 16-K, I = 1.

International Building Code (IBC 2006)[(3)]

Seismic Base Shear. The seismic base shear, V, in a given direction shall be determined in accordance with the following equation:

$$V = C_s W \quad \text{.........(8)}$$

where

C_s = The seismic response coefficient.

W = The effective seismic weight of a structure shall include the total dead load and other loads listed below:

- In areas used for storage, a minimum of 25 percent of the floor live load (floor live load in public garages and open parking structures need not be included).
- Where provision for partitions is required in the floor load design, the actual partition weight or a minimum weight of 10 psf (0.48 kN/m^2) of floor area, whichever is greater.
- Total operating weight of permanent equipment.
- Where the flat roof snow load, P_f , exceeds 30 psf (1.44 kN/m^2), 20 percent of the uniform design snow load, regardless of actual roof slope.

Calculation of Seismic Response Coefficient (C_s):

The seismic response coefficient, **C_s**, shall be determined in accordance with Eq. (9).

$$C_s = \frac{S_{DS}}{\frac{R}{I}} \quad \text{............ (9)}$$

Where:

S_{Ds}= the design spectral response acceleration parameter in the short period range.

R = The response modification factor in ASCE 7-05 Table 12.2-1.

I = The occupancy importance factor in ASCE 7-05 Table 11.5-1.

The value of Cs computed in accordance with Eq. (9) need not exceed the following:

$$C_S = \frac{S_{D1}}{T_a\left(\frac{R}{I}\right)} \quad for \quad T_a \le T_L \quad ...(10)$$

$$C_S = \frac{S_{D1}T_L}{T_a^{\,2}\left(\frac{R}{I}\right)} \quad for \quad T_a \succ T_L$$

…(11)

C_S shall not be less than the following:

$$C_S = 0.01 \qquad ..... (12)$$

In addition, for structures located where S1 is equal to or greater than 0.6g, C, shall not be less than:

$$C_S = \frac{0.5S_1}{\left(\frac{R}{I}\right)} \qquad ... (13)$$

where:

I and R are as previously described for Eq. (9). And:

S_{D1}=The design spectral response acceleration parameter at a period of 1 sec.

T_a = The fundamental period of the structure

T_L = Long-period transition period.

S_1=The mapped maximum considered earthquake spectral response acceleration parameter.

Approximate Fundamental Period.

The approximate fundamental period (T_a), in sec., shall be determined from Eq. (14).

$$T_a = C_t (h_n)^X \qquad ...... (14)$$

Where:

h = the height above the base to the highest level of the structure.

the coefficients C_t and x are determined from

ASCE 7-05 Table 12.8-2.

Alternatively, it is permitted to determine the approximate fundamental period (T_a), in sec., from the Eq. (15) for structures not exceeding 12 stories in height in which the seismic force-resisting system consists entirely of concrete or steel moment resisting frames and the story height is at least (3 m).

$$T_a = 0.1N \qquad ..... (15)$$

where:

N = Number of stories.

Design Spectral Acceleration Parameters.

Design earthquake spectral response acceleration parameter at short period, S_{Ds} , and at 1 sec. period, S_{Dl} , shall be determined from Eqs. (16) and (17), respectively.

$$S_{DS} = \frac{2}{3} F_a S_S \qquad ......(16)$$

$$S_{D1} = \frac{2}{3} F_v S_1 \qquad ......(17)$$

where:

S_S = The mapped maximum considered earthquake spectral response acceleration parameter at short period.

S_1 = The mapped maximum considered earthquake spectral response acceleration parameter at a period of 1 sec.

F_a and F_v = Site coefficients are defined in ASCE 7-05 Tables 11.4-1 and 11.4-2, respectively.

Distribution of Seismic Forces.

The lateral seismic force (F_{story}) induced at any level shall be determined from Eq. (18).

$$F_{story} = \frac{V * W_{story} * h_{story}^{K}}{\sum_{story=1}^{n} W_{story} * h_{story}^{K}} \quad .....(18)$$

where:

F_{story} = Portion of base shear applied to a story level.

V = Total design lateral force or shear at the base of the structure.

W_{story} = Weight of story level (based on effective seismic weight).

.

h_{story} = the height from the base to level of story.

n = Number of stories.

k = An exponent related to the structure period as follows:

- for structures having a period of 0.5 sec. or less, k = 1.
- for structures having a period of 2.5 sec. or more, k = 2.
- for structures having a period between 0.5 and 2.5 sec., k shall be 2 or shall be determined by linear interpolation between 1 and 2.

Factors and Coefficients:

The factors and coefficients can be determined according to IBC 2006 for the building described:

The soil profile type, for stiff soil profile, used D profile. The spectral response acceleration parameters S_S and S_1 are 0.25 and 0.1 respectively. The Site coefficients F_a and F_v are defined in ASCE 7-05 Tables 11.4-1 and 11.4-2, respectively and equal to 1.6 and 2.4 respectively.

The response modification factor (R) is equal to 3.

The occupancy importance factor (I) is equal to 1.25.

Static Results

The STAAD PRO 2007 computer program is used to calculate bending moments, shear, and axial forces for each of the structural elements and to determine the lateral displacements due to the codes forces.

Table-1 shows the comparison between Codes by distribution of lateral forces, and it can be shown that the base shear ratio of (IBC 2006/UBC 1997) to be equal to 1.666.

Figs. (2) and (3) show the lateral forces and lateral displacements for the building for the static codes forces and the calculated fundamental periods of vibration.

No difference is to be noted between the deflected shapes of the model by UBC 1997 and the model by IBC 2006, while the difference is noted in the amount of lateral displacements.

From same figures, it shown that the smallest value of lateral forces and lateral displacements are obtained by (UBC 1997), and the larger value of lateral forces and lateral displacements are obtained by (IBC 2006), also it can be shown that the lateral forces at first and second levels are to close to each other but at higher levels the forces become different among them.

Table 2 show the comparison between lateral displacements computed by using UBC 1997 and IBC 2006 codes, and it can be shown that the average lateral displacements ratio of (IBC 2006/UBC 1997) to be equal to 1.698.

Figs. (4) to (7) show the results of the calculated bending moments obtained from the computer analysis of the applied static seismic codes, these figures shows the moment diagrams for the two selected columns (column No. 1 and column No. 2 as shown in plan of building Fig. 1). It can be shown the moments are higher when using IBC 2006 code.

Conclusions

Based on this study the following conclusions may be drawn:

1. The period of vibration for the 10-story building is different in different codes. The period of vibration for this building computed by using UBC 1997 and IBC 2006 codes are (1.074 sec.) and (1.337 sec.) respectively.

2. From the analysis results of this building, it was found that the value of base shear obtained by using IBC 2006 code is higher than the value obtained by using UBC 1997 code by (66.6%).

3. From the analysis results of this building, it was found that the average value of lateral displacements obtained by using IBC 2006 code is higher than the value obtained by using UBC 1997 code by (69.8%).

References

[1]UBC, (1997), Uniform Building Code, International Conference of Building Officials, Whittier, California, 1997.

[2]Clough, R.W., and Benzien, J., "Dynamics of Structures", McGrow-Hill, Newyork, 1975.

[3]IBC, (2006), International Building Code 2006, International Code Council, Birmingham, Alabama, January, 2006.

[4]ASCE 7-05 Standard, Structural Engineering Institute, Virginia, 2005.

Table-1Comparison between Codes by distribution of lateral forces (kN).

Story level	UBC 1997	IBC 2006	IBC2006/ UBC1997
1	21.68	19.38	0.894
2	37.723	42.923	1.138
3	54.234	71.821	1.324
4	70.72	104.691	1.480
5	87.215	140.97	1.616
6	103.734	180.255	1.738
7	120.241	222.239	1.848
8	136.727	266.733	1.951
9	153.238	313.531	2.046
10	233.44	334.926	1.435
Base Shear	1018.952	1697.469	1.666

Table-2 Comparison between Codes by lateral displacements (mm).

Story level	UBC 1997	IBC 2006	IBC2006/ UBC1997
1	3.89	6.484	1.667
2	6.708	11.236	1.675
3	9.414	15.848	1.683
4	12.0	20.312	1.693
5	14.42	24.532	1.701
6	16.624	28.401	1.714
7	18.56	31.806	1.708
8	20.183	34.63	1.715
9	21.446	36.751	1.714
10	22.302	38.082	1.707
Average			1.698

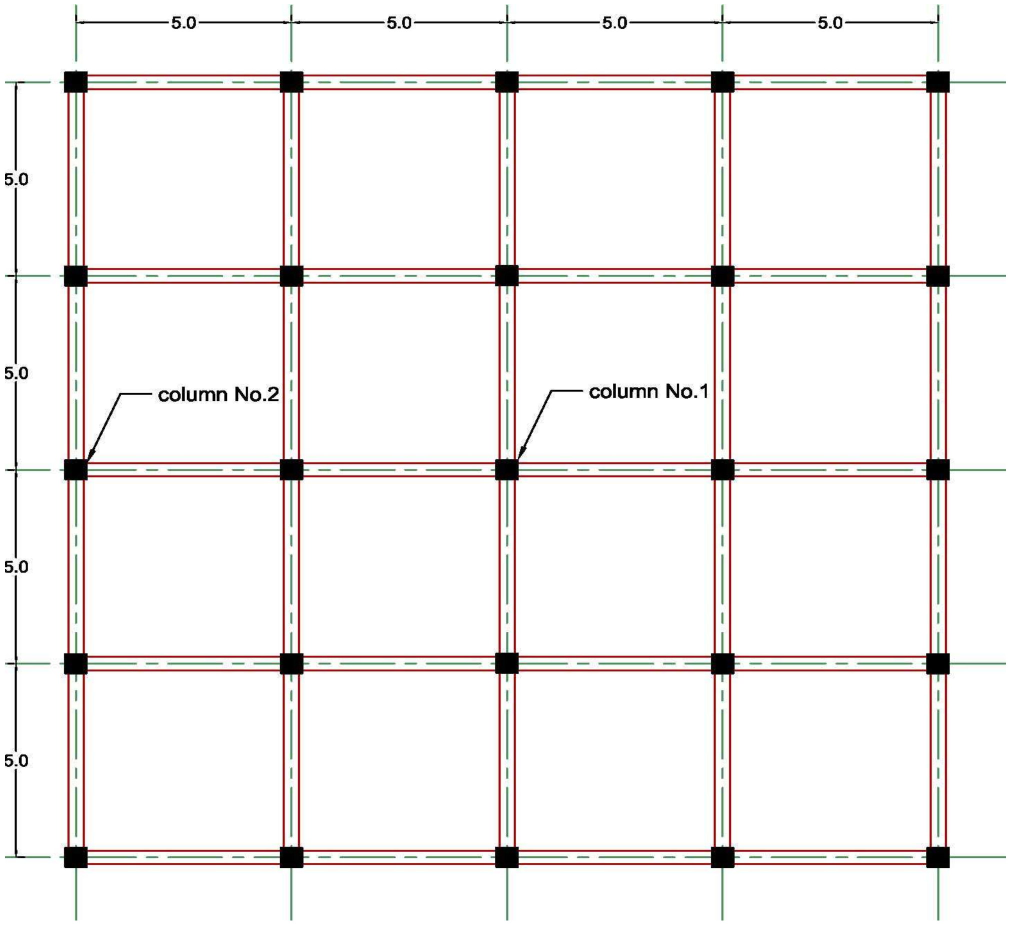
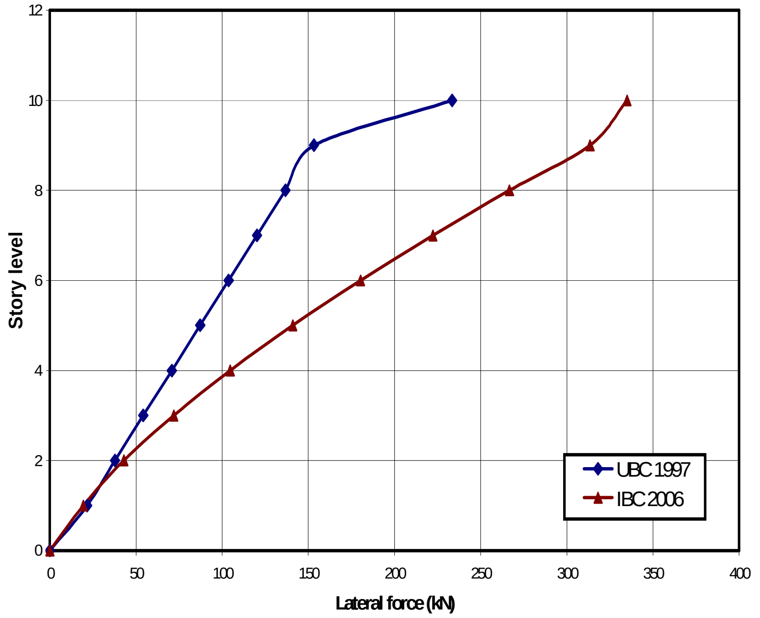
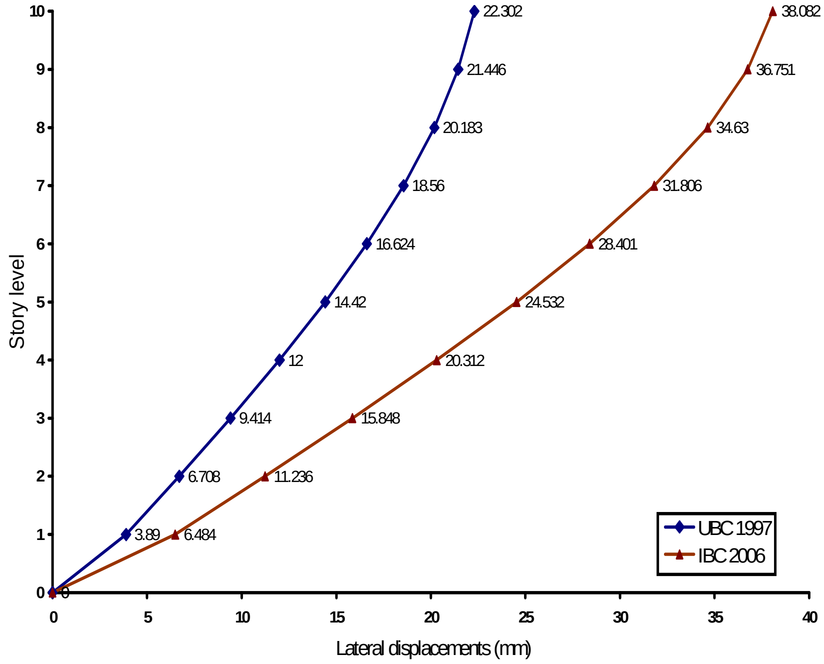


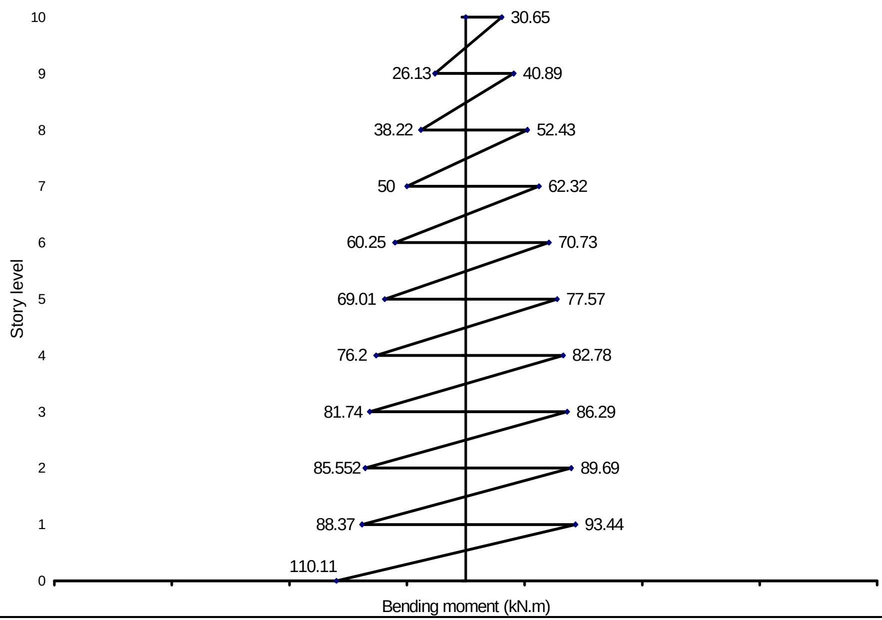
Figure (1) Plan of Building



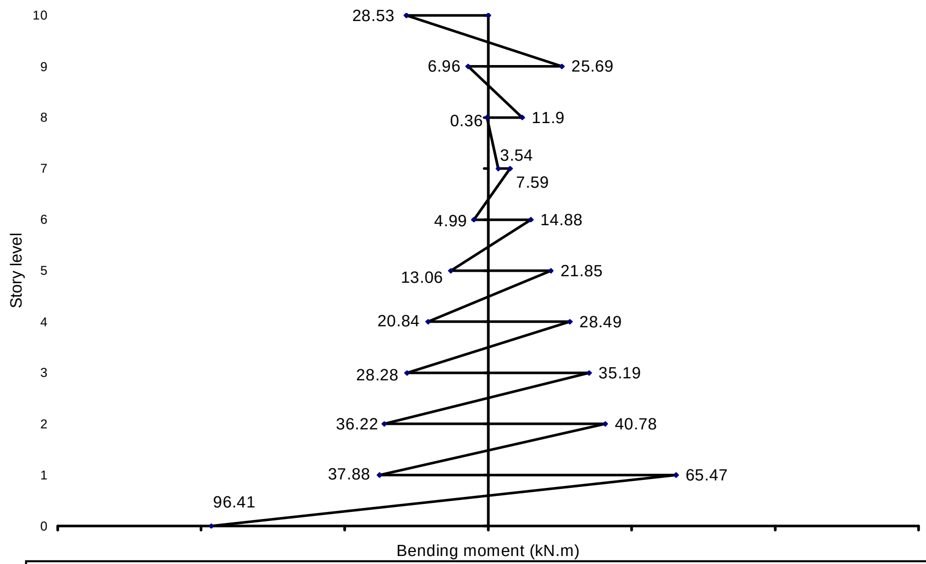
Figure(2) Comparison between UBC 1997 and IBC 2006 in lateral force



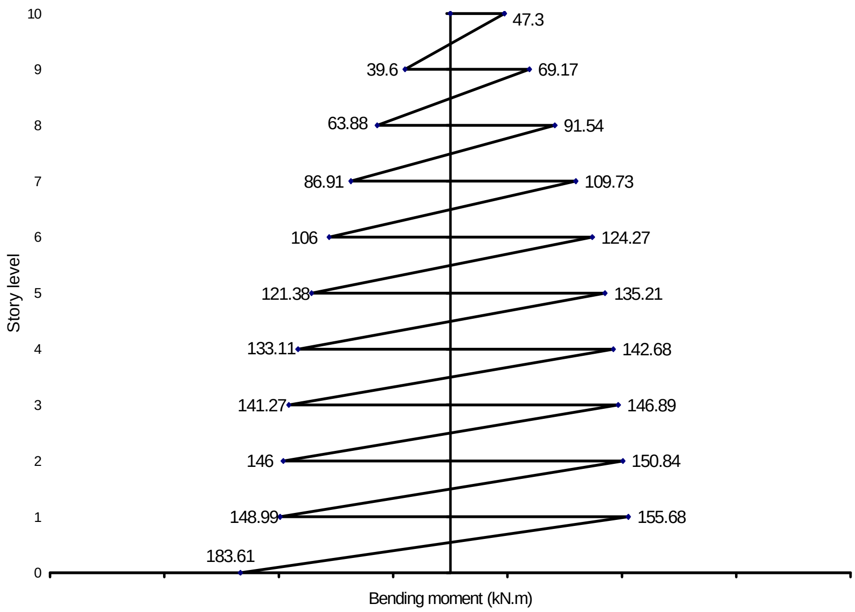
Figure(3) Lateral displacements (mm) due to static code forces



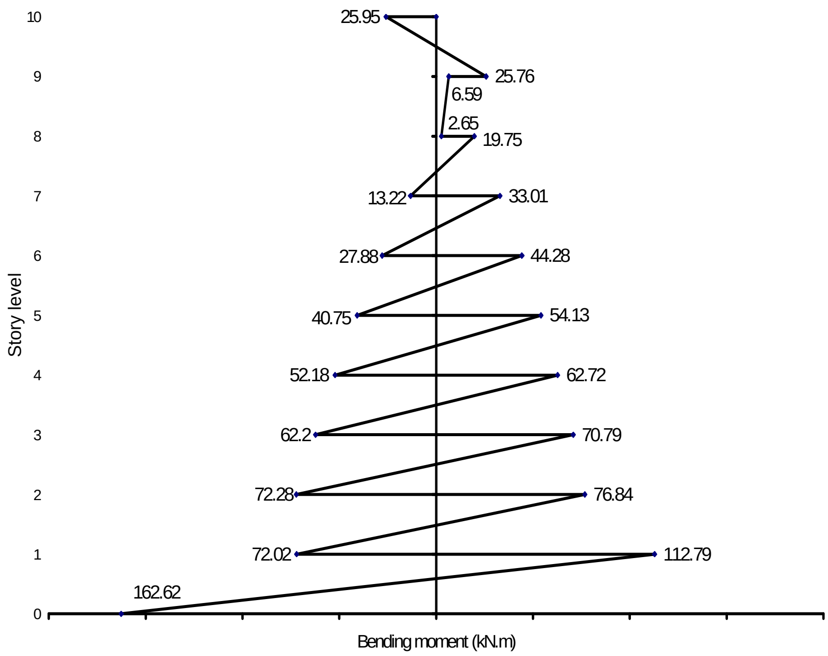
Figure(4) Column bending moment (kN.m) for column No.1 (UBC 1997)



Figure(5) Column bending moment (kN.m) for column No.2 (UBC 1997



Figure(6) Column bending moment (kN.m) for column No.1 (UBC 2006)



Figure(7) Column bending moment (kN.m) for column No.2 (UBC2006)