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Full Length Research Paper

Drift analysis due to earthquake load on tall structures

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Earthquake is one of the destructive events in the world. Prediction of earthquake is not feasible at all. In the horizon, earthquakes of different intensities and magnitudes occurred. So it is a threat to all especially the tall structures of the mega cities. Due to shaking of ground surface, the substructure as well as the superstructure is vibrated. During earthquake, there will be a drift on the high rise structures. Then it can be included that the more the height, the more the drift. The drift of the structure decreases with increase in the width of the structure. So our concern is to calculate the drift of tall structures due to the vibration of ground. Hand calculation and programming with C (version C++ 4.5) is used to calculate the drift.

Key words: Earthquake, drift, tall building, lateral deflection, laterals forces.

INTRODUCTION

As building heights increase, the forces of nature begin to dominate the structural system and take on importance in the overall building system. The analysis and design of tall building are affected by lateral loads, particularly drift or sway caused by such loads. Drift or sway is the magnitude of the lateral displacement at the top of the building relative to its base. Recent studies (Freeman and Searer, 2000) have found that the drift provisions in the UBC, 1997 are extremely complicated, are fairly difficult to use (Searer and Freeman 2004), and may be over conservative. It can be very difficult to ensure that exterior elements conform to the drift requirements in current codes (SEAOC, 1999). However, Lateral deflection is the predicted movement of a structure under lateral loads; and story drift is defined as the difference in lateral deflection between two adjacent stories. During an earthquake, large lateral forces can be imposed on structures, require that the designer assess the effects of this deformation on both structural and nonstructural elements. The lateral displacement of a frame places beam-column joints under shear stresses because of the change from positive to negative bending in the flexural members from one side of the joint to the other (Nilson et al., 2010). Lateral deflection and drift have three primary effects on a structure; the movement can affect the structural elements (such as beams and columns); the movements can affect nonstructural elements (such as the windows and cladding); and the movements can affect adjacent structures (Schueller, 1997). Without proper consideration during the design process, large deflections and drifts can have adverse effects on structural elements, nonstructural elements and adjacent structures. When the initial sizes of the frame members have been selected, an approximate check on the horizontal drift of the structures can be made. The drift in the non-slender rigid frame is mainly caused by racking. This racking may be considered as comprising two components: the first is due to rotation of the joints, as allowed by the double bending of the girders, while the second is caused by double bending of the columns. If the rigid frame is slender, a contribution to drift caused by the overall bending of the frame, resulting from axial deformations of the columns may be significant. If the frame has a height width ratio less than 4:1, the contribution of overall bending to the total drift at the top of the structure is usually less than 10% of that due to racking (Bryan and Alex, 1991). The following method of

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calculation for drift allows the separate determination of the components attributable to beam bending and overall cantilever action.

OBJECTIVES OF THE STUDY

The objectives of the study are as follows:

1) To observe the drift analysis on high-rise structure due to earthquake loads.

2) To observe the longitudinal impact on high rise structure.

3) The analysis of drift of different types of tall structures and also calculation of drift by hand and programming with C (version C++ 4.5)

4) To compare the value of drift from programming with C (version C++ 4.5) for different types of tall buildings.

METHODOLOGY

For rigid frame structures, to isolate the effect of girder bending, assume the columns are flexural rigid and again to isolate the effect of column bending, assume the girder are flexural rigid. The total frame shear deflection is given by Δ_s

$$\Delta_s = \Delta_c + \Delta_g = \frac{V_i h_i^2}{12}\{(h_i)/((\Sigma EI)_{col}) + \frac{I}{(\Sigma EI/L)_{beam}}\}$$

For coupled-shear wall structure, consider the plane coupled- wall structure subjected to distributed lateral loading if intensity *w* per unit height. A general form of loading is used to illustrate the derivation of the governing differential equation, before solutions are derived for common standard design load cases (Bryan and Alex, 1991). The lateral deflection for coupled-shear wall structure is:

$$y = \frac{wH^4}{EI}\left[\frac{1}{24}\left\{\left(1-\frac{z}{H}\right)^4 + \frac{4z}{H} - 1\right\} + \frac{1}{k^2}\{1/2(k\alpha H)^2\left[\frac{2z}{H} - (z/H)^2\right] - \frac{1}{24}\left[\left(1 - z/H\right)^4 + \frac{4z}{H} - 1\right]\right.$$
$$\left. - \frac{1}{(k\alpha H)^4}\cosh k\alpha H\,[1 + k\alpha H \sinh k\alpha H - \cosh k\alpha H - k\alpha H \sinh k\alpha\,(H - z)]\right\}$$

For wall-frame structure, the planer wall frame may be taken to represent either a structure with walls and frames interacting in the same plane or one with walls and frames in parallel planes. Since, in a no-twisting structure, parallel walls and frames translate identically, they may be simulated by a planar linked model. The analytical solution requires the structure to be presented by a uniform continuous model. The derivative general equation for laterally deflection is:

$$y(z) = \frac{wH^4}{EI}\left(\frac{1}{(\alpha H)^4}\left[\frac{\alpha H \sinh \alpha H + 1}{\cosh \alpha H}(\cosh \alpha z - 1) - \alpha H \sinh \alpha z + (\alpha H)^2\left[\frac{z}{H} - \frac{1}{2}\left(\frac{z}{H}\right)^2\right]\right]\right.$$

Effects of drift on structural elements

In terms of seismic design, lateral deflection and drift can affect both the structural elements that are part of the lateral force resisting system and structural elements that are not part of the lateral force resisting system. In terms of the lateral force resisting system, when the lateral forces are placed on the structure, the structure responds and moves due to those forces. Consequently, there is a relationship between the lateral force resisting system and its movement under lateral loads; this relationship can be analyzed by hand or by computer. Using the results of this analysis, estimates of other design criteria, such as rotations of joints in eccentric braced frames and rotations of joints in special moment resisting frames can be obtained. Similarly, the lateral analysis can also be used and should be used to estimate the effect of lateral movements on structural elements that are not part of the lateral force resisting system, such as beams and columns that are not explicitly considered as being part of the lateral force resisting system.

Design provisions for moment frame and eccentric braced frame structures have requirements to ensure the ability of the structure to sustain inelastic rotations resulting from deformation and drift. Without proper consideration of the expected movement of the structure, the lateral force resisting system might experience premature failure and a corresponding loss of strength. In addition, if the lateral deflections of any structure become too large, P-Δ effects can cause instability of the structure and potentially result in collapse.

Structural elements and connections not part of the lateral force resisting system need to be detailed to withstand the expected maximum deflections and drifts. Though these elements are generally ignored during the design lateral analysis, they must effectively “go along for the ride” during an earthquake, meaning that they experience deflections and rotations similar to those of the lateral force resisting system.

Effects of drift on nonstructural elements

Since lateral deflection and drift affect the entire building or structure, design of nonstructural elements is also governed by these parameters. The nonstructural elements should be designed to allow the expected movement of the structural system.

If the nonstructural elements are not adequately isolated from the movements of the lateral force resisting system, adverse effects are likely to occur. For example, in a large earthquake, the cladding may become damaged or fall off the structure, posing a life-safety hazard to passers-by. Even in smaller earthquakes, if the cladding does not permit lateral movement of the structure, the cladding may experience premature damage, resulting in water intrusion and/or economic loss. Similarly, if windows do not permit movement of the structure, the windows may break, posing a potentially significant falling hazard.

The effects of deflections and drift on stair assemblies are sometimes neglected. Without proper detailing that permits adequate inter story movement to occur, stair assemblies have the potential to act as a diagonal brace between floors; the stair assemblies resist the movement of the structural frame until damage to the stair assemblies or their connections occurs. If the vertical support for the stair assembly breaks or is damaged, the stairs can collapse during the earthquake or even after the earthquake as the occupants attempt to exit.

Finally, if the nonstructural elements are not adequately isolated from the structural elements, the nonstructural elements may interfere with the structural elements and cause adverse effects to the structural elements themselves, creating short columns, torsion or stiffness irregularities.

Effects of drift on adjacent structures

Under lateral loads from a large earthquake, the expected movements of a structure can be significant. If adjacent buildings or structurally separate portions of the same structure do not have

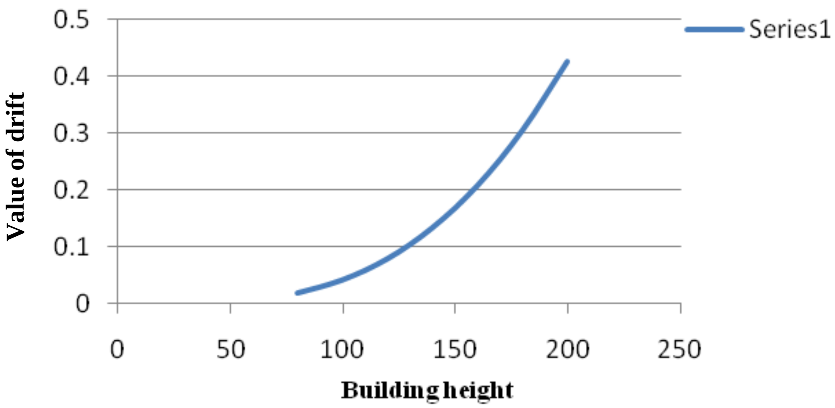

Figure 1. Variation of drift with building height.

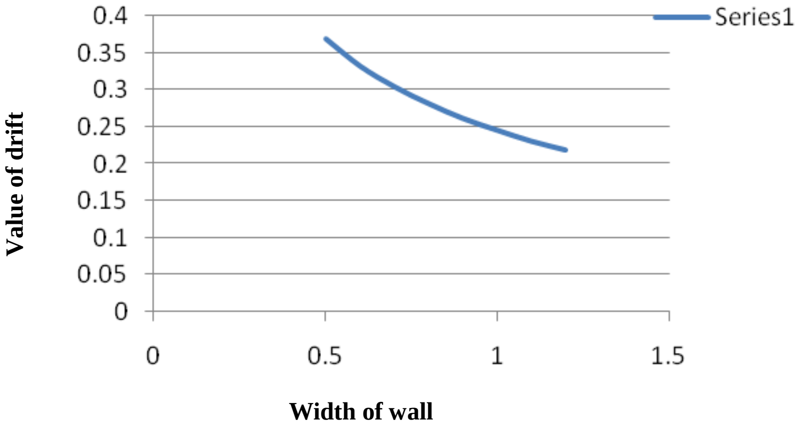

Figure 2. Variation of drift with width of wall.

adequate separation, they may "pound" against each other during an earthquake. Pounding can have significant adverse effects, especially when the floors are not coplanar. Pounding of structures with non-coplanar floors can result in the floors of one building impacting the columns of another building at mid-height. This impact induces large shears and bending moments into the impacted columns, potentially causing the columns to fail and the structure to collapse.

When adjacent structures have coplanar floors, pounding may be advantageous in some respects. If floors are coplanar, the two adjacent structures will have a more difficult time resonating with the earthquake. Since pounding is a highly nonlinear response, pounding will tend to damp out vibrations and reduce the responses of the two structures. However, the pounding is likely to increase floor accelerations (a consideration for the design of nonstructural elements) and is likely to result in significant localized damage between the structures (Taranath, 1988).

ANALYSIS AND DISCUSSION

There are three major types of structures identified in this study, such as rigid frame, coupled shear wall and wall frame structures. For rigid frame structures, the drift are depended on total building height, number of spans, cross sectional length and width of girder, cross sectional length and width of column, and shear value of girder and shear value of column. It is shown in Figure 1 that the value of drift increases with increase in building height. The value of drift decreases with increase in number of span as shown in Figure 2. Also Figure 3 shows the value of drift decreases with increase in dimension of beam and column. By using the programming with C (version C++ 4.5), we get the different values of drift as shown in Table 1.

For couple shear wall structures, the drift are depended on total building height, length of wall, width of wall and length of beam between two wall. By using the programming with C (version C++ 4.5), we get the different values of drift as shown in Table 2.

For wall-frame structures, the drift are depended on total building height, number of span, length of span, dimension of core and cross section of beam. By using the programming with C (version C++ 4.5), we get the different values of drift as shown in Table 3.

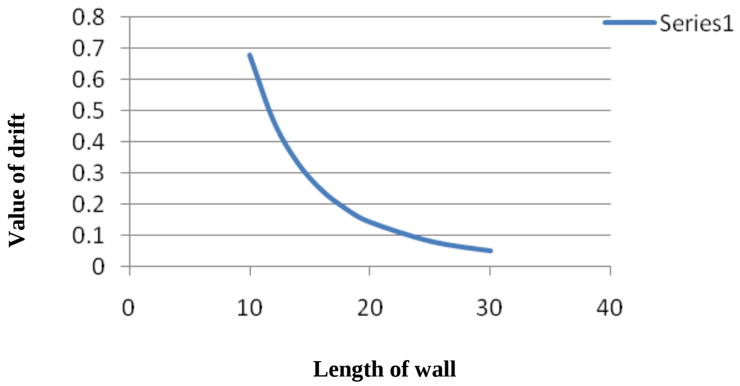

Figure 3. Variation of drift with length of wall.

Table 1. Summary of drift on various dimensions of rigid frame structures.

Total building height (ft)	Number of spans	Cross section of girder (ft × ft)	Cross section of column (ft × ft)	Shear value of girder (kips)	Shear value of column (kips)	Drift (ft)
80	3	1.5 × 1.5	1.5 × 1.5	4.50	4.50	0.0316
100	4	1.5 × 1.5	1.5 × 1.5	4.50	4.50	0.0471
120	4	2.0 × 2.0	2.0 × 2.0	5.50	5.50	0.0309
140	5	2.0 × 2.0	2.0 × 2.0	5.50	5.50	0.0404
160	5	2.0 × 2.0	2.0 × 2.0	5.50	5.50	0.0597
180	5	2.0 × 2.0	2.0 × 2.0	6.30	6.30	0.0967
200	6	2.0 × 2.0	2.0 × 2.0	6.30	6.30	0.1129

Table 2. Summary of drift on various dimensions of couple shear wall structures.

Total building height (ft)	Length of wall W_1 (ft)	Length of wall W_2 (ft)	Width of wall (ft)	Beam length between two wall (ft)	Width of beam (kips)	Depth of beam (ft)	Uniformly distributed earthquake loading intensity (kips/ft)	Lateral deflection of coupled shear wall (ft)
80	15	10	0.6	7.0	0.6	0.5	4.13	0.0215
100	15	10	0.6	7.0	0.6	0.7	4.13	0.0411
120	15	10	0.6	7.0	0.6	0.7	4.13	0.0769
140	15	12	0.6	7.0	0.6	0.7	4.13	0.1124
160	15	12	0.6	7.0	0.6	0.7	4.13	0.1739
180	15	12	0.6	7.0	0.6	0.8	4.13	0.2047
200	15	12	0.6	7.0	0.6	0.8	4.13	0.2850

Table 3. Summary of drift on various dimensions of wall frame structures.

Total building height (ft)	Number of span	Total length of span (ft)	Dimension of core (ft × ft)	Cross section of column (ft ×ft)	Cross section of beam (ft ×ft)	Uniformly distributed earthquake loading intensity (kips/ft)	Lateral deflection of coupled shear wall (ft)
80	3	27	5 × 5	1.5 × 1.5	1.5 × 1.5	4.13	0.00802
100	4	37	5 × 5	1.5 × 1.5	1.5 × 1.5	4.13	0.00840
120	4	37	5 × 5	1.75 × 1.75	1.75 × 1.75	4.13	0.00696
140	4	37	6 × 6	1.75 × 1.75	1.75 × 1.75	4.13	0.00935
160	5	47	6 × 6	1.8 × 1.8	1.8 × 1.8	4.13	0.00559
180	5	47	7 × 7	1.8 × 1.8	1.8 × 1.8	4.13	0.00923
200	5	47	7 × 7	2.0 × 2.0	2.0 × 2.0	4.13	0.02950

CONCLUSION AND RECOMMENDATION

Geographically, Bangladesh is the most earthquake vulnerable zone (Ansary, 2008). The numbers of high rise building is increasing here day by day. It experienced some catastrophic earthquakes in the last century. According to the specialist, there is possibility to occurrence of earthquake. So the tall structures are on the threat, due to earthquake drift occurrence. So every high rise structure should consider the effect of drift. Then the loss of life and property will be attenuated. In this study, regular shaped structures have only been considered. Estimation of drift was carried out for rigid frame structure, coupled shear wall structure and wall frame structure. This study indicates that the drift on high rise structures has to be considered as it has a notable magnitude. So every tall structure should include the drift due to earthquake load as well as wind load.

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