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EFFECT OF SETBACK ON FUNDAMANTAL PERIOD OF RC FRAMED BUILDINGS

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Abstract: To characterize the ground motion and structural behaviour, design codes provide a Response spectrum. Response spectrum conveniently describes the peak responses of structure as a function of natural vibration period. Therefore it is necessary to study of natural vibration period of building to understand the seismic response of building. The behaviour of a multi-storey framed building during strong earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of the building. This study presents the design code perspective of this building category. Almost all the major international design codes recommend dynamic analysis for design of setback buildings with scaled up base shear corresponding to the fundamental period as per the code specified empirical formula. However, the empirical equations of fundamental period given in these codes are a function of building height, which is ambiguous for a setback building.

I. INTRODUCTION

The magnitude of lateral force due to an earthquake depends mainly on inertial mass, ground acceleration and the dynamic characteristics of the building. To characterize the ground motion and structural behaviour, design codes provide a Response spectrum. Response spectrum conveniently describes the peak responses of structure as a function of natural vibration period, damping ratio and type of founding soil. The determination of the fundamental period of structures is essential to earthquake design and assessment.

Seismic analysis of most structures is carried out using Linear Static (Equivalent Static) and Linear Dynamic (Response Spectrum) methods. Lateral forces calculated as per Equivalent Static Method depends on structural mass and fundamental period of structure. The empirical equations of the fundamental period of buildings given in the design codes are function of building height and base dimension of the buildings. Theoretically Response Spectrum Method uses modal analysis to calculate the natural periods of the building to compute the design base shear. However, some of the international codes (such as IS 1893:2002 and ASCE 7:2010) recommend to scale up the base shear (and other response quantities) corresponding to the fundamental period as per the code specified empirical
formula, so as to improve this base shear (or any other response quantity) for Response Spectrum Analysis to make it equal to that of Equivalent Static Analysis. Therefore, estimation of fundamental period using the code empirical formula is inevitable for seismic design of buildings.

II. RESEARCH ON SETBACK BUILDING

The present study is limited to reinforced concrete (RC) multi-storeyed building frames with setbacks. Infill stiffness is not considered in the present study. However, associated mass and weight is assumed in the analysis. Setback buildings from 6 storeys to 30 storeys with different degrees of irregularity are considered. The buildings are assumed to have setback only in one direction. Soil-structure interaction effects are not considered in the present study. Column ends are assumed to be fixed at the foundation.

The steps undertaken in the present study to achieve the above-mentioned objectives areas follows:

- Carry out extensive literature review, to establish the objectives of the research work.
- Select an exhaustive set of setback building frame models with different heights (6 to 30 storeys), Bay width in both horizontal direction (5m, 6m and 7m bay width) and different irregularities (limit to 90 setback building models).
- Perform free vibration analysis for each of the 90 building models.

Analysing the results of free vibration analysisHumaret. al. (1977) studied the dynamic behaviour of multi-storey steel rigid-frame buildings with setback towers. The effects of setbacks upon the building frequencies and mode shapes were examined. Then the effects of setbacks on seismic response are investigated by analysing the response of a series of setback building frame models to the El Centro ground motion. Finally, the computed responses to the El Centro earthquake are compared with some code provisions dealing with the seismic design of setback buildings. The conclusions derived from the study include the following: The higher modes of vibration of a setback building can make a very substantial contribution to its total seismic response; this contribution increases with the slenderness of the tower.

Modal Analysis

When free vibration is under consideration, the structure is not subjected to any external excitation (force or support motion) and its motion is governed only by the initial conditions. There are occasionally circumstances for which it is necessary to determine the motion of the structure under conditions of free vibration. However, the analysis of the structure in free motion provides the most important dynamic properties of the structure which are the natural frequencies and the corresponding modal shapes.

III. RESULTS

The behaviour of a multi-storey framed building during strong earthquake motions depends on the distribution of mass, stiffness, and strength in both the horizontal and vertical planes of a building. In multi-storeyed framed buildings, damage from earthquake ground motion generally initiates at locations of structural weaknesses present in the lateral load resisting frames. Further, these weaknesses tend to accentuate and concentrate the structural damage through plastification that eventually leads to complete collapse. In some cases, these weaknesses may be created by discontinuities in stiffness, strength or mass between adjacent storeys.

Normalised average height and width of the buildings with 6m bay width

Building Designation	h_{av}/h	d_{av}/d	Fundamental Period
R-6-6	1.00	1.00	1.37
S1-6-6	0.89	0.89	1.23
S2-6-6	0.78	0.78	1.28
S3-6-6	0.67	0.67	1.11
S4-6-6	0.78	0.78	1.13
S5-6-6	0.56	0.56	1.17
R-12-6	1.00	1.00	1.72
S1-12-6	0.89	0.89	1.57
S2-12-6	0.78	0.78	1.60
S3-12-6	0.67	0.67	1.41
S4-12-6	0.78	0.78	1.42
S5-12-6	0.56	0.56	1.56
R-18-6	1.00	1.00	2.45
S1-18-6	0.89	0.89	2.28
S2-18-6	0.78	0.78	2.35
S3-18-6	0.67	0.67	2.08
S4-18-6	0.78	0.78	2.06
S5-18-6	0.56	0.56	2.37
R-24-6	1.00	1.00	2.68
S1-24-6	0.89	0.89	2.52
S2-24-6	0.78	0.78	2.65
S3-24-6	0.67	0.67	2.35
S4-24-6	0.78	0.78	2.30
S5-24-6	0.56	0.56	2.84
R-30-6	1.00	1.00	3.45
S1-30-6	0.89	0.89	3.19
S2-30-6	0.78	0.78	3.32
S3-30-6	0.67	0.67	2.94
S4-30-6	0.78	0.78	2.84
S5-30-6	0.56	0.56	3.64

IV. CONCLUSIONS

Fundamental period of all the selected building models were estimated as per modal analysis, Rayleigh method and empirical equations given in the design codes. The results were critically analysed and presented in this chapter. The aim of the analyses and discussions were to identify a parameter that describes the irregularity of a setback building and arrive at an improved empirical equation to estimate the fundamental period of setback buildings with confidence. However, this study shows that it is difficult to quantify the irregularity in a setback building with any single parameter. This study indicates that there is very poor correlation between fundamental periods of three dimensional buildings with any of the parameters used to define the setback irregularityby the previous researchers or design codes.

Scope of future study: This study could not conclude on the appropriate parameter defining the irregularity in three-dimensional multi-storeyed setback buildings. There is a scope to investigate different parameters either geometrical or structural or combination of both to define the setback irregularity.
The present study is limited to reinforced concrete (RC) multi-storeyed building frames with setbacks only in one direction. There is a future scope of study on three dimensional building models having setbacks in both of the horizontal orthogonal directions.

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