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ANALYSING THE EFFECTS OF SETBACK ON R/F FRAMED MULTISTORY BUILDING

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***Abstract:** Response of setback buildings under seismic loading, effect of vertical irregularity on fundamental period of building and the quantification of setback and the recommendations proposed by seismic design codes on setback buildings. The first part of this chapter is devoted to a review of published literature related to response of irregular buildings under seismic loading. The response quantities include ductility demand, inter-story drift, lateral displacement, building frequencies and mode shapes. The second half of this chapter is devoted to a review of design code perspective on the estimation of fundamental period of setback building. This part describes different empirical formulas used in different design codes for the estimation of fundamental period, and the description and quantification of irregular buildings.. In some cases, these weaknesses may be created by discontinuities in stiffness, strength or mass between adjacent storeys. Such discontinuities between storeys are often associated with sudden variations in the frame geometry along the height. There are many examples of failure of buildings in past earthquakes due to such vertical discontinuities. A common type of vertical geometrical irregularity in building structures arises from abrupt reduction of the lateral dimension of the building at specific levels of the elevation. This study shows that it is difficult to quantify the irregularity in a setback building with any single parameter. Also, 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 irregularity by the previous researchers or design codes. The way design codes define setback irregularity by only geometry is found to be not adequate. Period of setback buildings are found to be always less than that of similar regular building. Fundamental period of a framed building without infill stiffness depends not only on the height of the building but also on the bay width, irregularity and other structural and geometric parameters. It is not proper to relate the fundamental period of a framed building to height only as given in design code.*

***Keywords:** Geometric irregularity, setback building, fundamental period, regularity index.*

RESEARCH ON SETBACK BUILDING

The seismic response of vertically irregular building frames, which has been the subject of numerous research papers, started getting attention in the late 1970s. Vertical irregularities are characterized by vertical discontinuities in the geometry, distribution of mass, stiffness and strength. Setback buildings are a subset of vertically irregular buildings where there are discontinuities with respect to geometry. However, geometric irregularity also introduces discontinuity in the distribution of mass, stiffness and strength along the vertical direction.

INTRODUCTION

The study in this thesis is based on analysis of a family of structural models representing vertically irregular multi-storeyed setback buildings. The first part of this chapter presents a summary of various parameters defining the computational models, the basic assumptions and the building geometries considered for this study. All the selected buildings were designed as per Indian Standards.
Later half of this chapter presents brief description of the design procedure followed in the present study. Free vibration analysis procedures of building system considered in the study also explained briefly at the end of the chapter.

COMPUTATIONAL MODEL

Modelling a building involves the modelling and assemblage of its various load-carrying elements. The model must ideally represent the mass distribution, strength, stiffness and deformability. Modelling of the material properties and structural elements used in the present study is discussed below.

Material Properties

M-20 grade of concrete and Fe-415 grade of reinforcing steel are used for all the frame models used in this study. Elastic material properties of these materials are taken as perIndian Standard IS 456 (2000). The short-term modulus of elasticity (Ec) of concrete is taken as:

$$E_c \quad 5000 \; f_{ck} \; \text{MPa} \quad \sqrt{}$$

Where fck characteristic compressive strength of concrete cube in MPa at 28-day

(20 MPa in this case). For the steel rebar, yield stress (fy) and modulus of elasticity (Es) is taken as per IS 456 (2000).

Structural Elements

Beams and columns are modelled by 2D frame elements. The beam-column joints are modelled by giving end-offsets to the frame elements, to obtain the bending moments and forces at the beam and column faces. The beam-column joints are assumed to be rigid (Fig. 3.1). The column end at foundation was considered as fixed for all the models in this study.

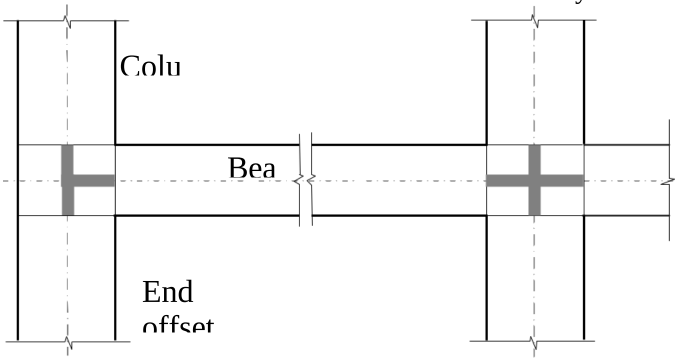
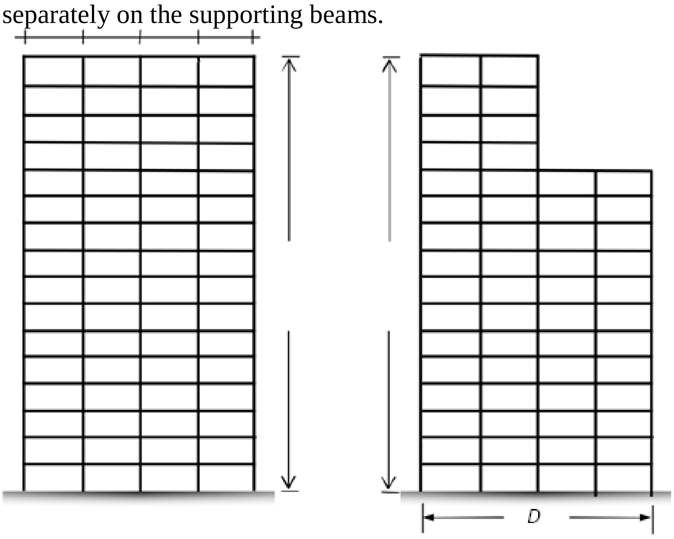


Fig: Use of end offsets at beam-column joint

The structural effect of slabs due to their in-plane stiffness is taken into account by assigning 'diaphragm' action at each floor level. The mass/weight contribution of slab is modelled separately on the supporting beams.



Regular Setback

Fig. : Typical structural models used in the present study

BUILDING GEOMETRY

The study is based on three dimensional RC building with varying heights and widths. Different building geometries were taken for the study. These building geometries represent varying degree of irregularity or amount of setback. Three different bay widths,

i.e. 5m, 6m and 7m (in both the horizontal direction) with a uniform three number of bays at base were considered for this study. It should be noted that bay width of 4m – 7m is the usual case, especially in Indian and European practice. Similarly, five different height categories were considered for the study, ranging from 6 to 30 storeys,
with a uniform storey height of 3m. Altogether 90 building frames with different amount of setback irregularities due to the reduction in width and height were selected. The building geometries considered in the present study are taken from literature (Karavasisis et. al., 2008). The regular frame, without any setback, is also studied shown in Fig. 3.2.

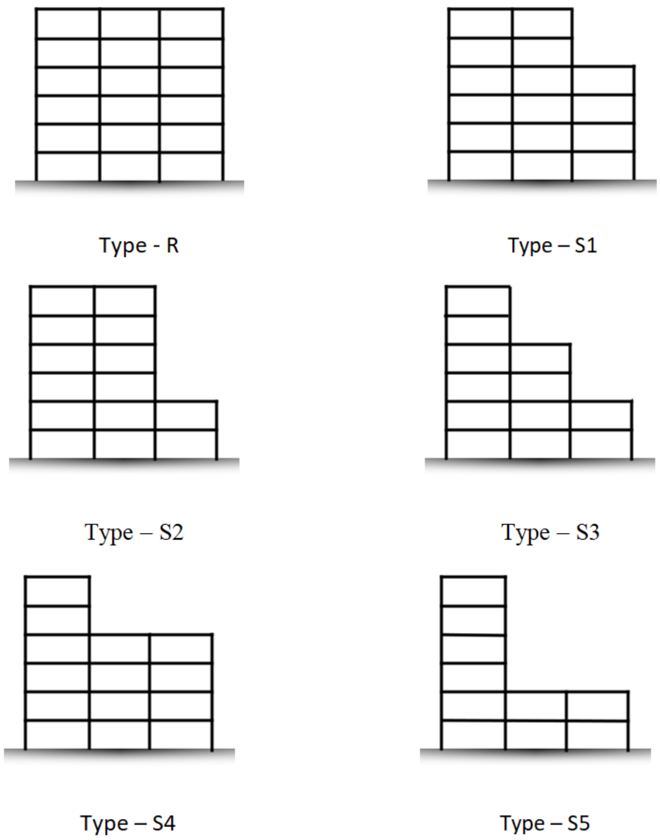


Fig : Typical building elevations for six-storey building variants (R, S1 to S5) .

CONCLUSIONS

Period of setback buildings are found to be always less than that of similar regular building. Fundamental period of setback buildings are found to be varying with irregularity even if the height remain constant. The change in period due to the setback irregularity is not consistent with any of these parameters used in literature or design codes to define irregularity. 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 irregularity by the previous researchers or design codes. However, it requires further investigation to arrive at single or multiple parameters to accurately define the irregularity in a three dimensional setback buildings. Based on the work presented in this thesis following point-wise conclusions can be drawn:

i) The code (IS 1893:2002) empirical formula gives the lower-bound of the fundamental periods obtained from Modal Analysis and Raleigh Method. Therefore, it can be concluded that the code (IS 1893:2002) always gives conservative estimates of the fundamental periods of setback buildings with 6 to 30 storeys. It can also be seen that Raleigh Method underestimates the fundamental periods of setback buildings slightly which is also conservative for the selected buildings. However the degree of conservativeness in setback building is not proportionate to that of regular buildings.

ii) Unlike other available equations, Eq. 2.9 from ASCE 7: 2010 does not consider the height of the building but it considers only the number of storeys of the buildings. Although this is not supported theoretically this approach is found to be most conservative among other code equations.

iii) It is found that the fundamental period in a framed building is not a function of building height only. This study shows that buildings with same overall height may have different fundamental periods with a considerable variation which is not addressed in the code empirical equations.

iv) In the empirical equation of fundamental period, the height of the building is not defined in the design code adequately. For a regular building there is no ambiguity as the height of the building is same throughout both the horizontal directions. However, this is not the case for setback buildings where building height may change from one end to other.

v) The buildings with same maximum height and same maximum width may have different period depending on the amount of irregularity present in the setback buildings. This variation of the fundamental periods due to variation in irregularity is found to be more for taller buildings and comparatively less for shorter buildings. This observation is valid for the periods calculated from both modal and Rayleigh analysis. It is found that variation of fundamental periods calculated from modal analysis and Rayleigh method are quite similar.

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