ASEISMIC DESIGN OF BUILDINGS WITH THE GROUND FRAME STOREY

by

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SYNOPSIS

The paper deals with the reasons of damage of buildings with ground frame storey free of wall filling subjected to severe earthquakes. Generally accepted analysis patterns of such buildings are considered and specific features of column strain-stress condition are discussed. The emphasis is put on the importance of vertical seismic component and on the necessity of its calculation jointly with the horizontal one.

INTRODUCTION

Recently the growing number of buildings with ground frame storey free of walls and comparatively rigid top storeys is constructed in seismic regions as well as in non - seismic areas. The choice of construction is mainly caused either by the wish to have considerable free space at the basement or by the tendency to decrease design seismic loads for buildings based on spectral curves of seismic (response) coefficient treated formally. Unfortunately the trend was supported by many researchers in various countries.

Hence, every new earthquake enlarges the number of such buildings distructions. In Scopje, Caracas and especially in San-Fernando buildings with soft storey were severely damaged or practically destroyed as the result of loss of basement columns strength (Fig. I). The mentioned circumstances lead to critical analysis of many publications where such constructions are considered capable to decrease the seismic force effect. Therefore it seems reasonable to discuss the behaviour of buildings with ground frame storey under seismic excitation, propose the design criteria and, in the first hand, to draw attention to some problems that need special research.

Nowadays in many countries the design seismic force is determined in function of structure dynamic parameters. Experimental data show that measured value of free vibration period is one and the half or two times smaller than that obtained by usually recommended formulae for one-degree - freedom system with rigidity as for constrained beam. In

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reality considerable vertical loads act on the first storey columns. As the result when their ends are mutually displaced in the horizontal direction the reactive moments appear at the supports and the construction stiffness reduces. This fact is worth to be investigated in details. Yet we think it is possible for practical design to take the soft storey stiffness of frames equal to the double sum of all columns rigidity as for constrained beams.

As for the damping capacity of discussed construction the acute data are miserable but it is by no means less than for usual structures. Therefore in the Soviet Union design seismic loads for buildings with soft storey are calculated regarding response coefficient to be multiplied by I.5.

As a rule, for buildings with decreased rigidity at the bottom stage, the dynamic pattern presents the single-degree-freedom model (Fig. 2a). It is possible for structures with a soft storey if its height is no more than 5-6 storeys. For higher buildings the flexibility of top structure should be regarded as well as the rotation of foundation. So the buildings are to be idealized as systems with several degrees of freedom and in some cases it is more convinient to present them as the systems with distributed masses (Fig. 2b). The first 2-3 modes of vibration should be encounted and it is quite necessary in all casses to include into design the vertical loads in the first storey columns due to overturning action of horizontal seismic forces.

According to that fact special attention should be paid to the distribution of shear seismic force $Q = \sum S_i$ between separate columns which posess dissimilar horizontal stiffness because of different degree of compression $N_\alpha = N_\alpha^P + N_\alpha^S$ (the exterior columns can be even tensile). Therefore each column should be checked under two combinations of loads, identical for symmetric columns (Fig. 2 c).

Another circumstance connected with the specificity of seismic action is worth to be discussed. The seismic response analysis of frame constructions under real excitation shows that combined action of bending moments and normal loads leads to earlier development of plastic deformations and to 30-50% increase of lateral displacements. The earthquake resistance of structures depends on their capacity to deform plastically and to absorb the energy of external effect. As a rule, the requirement is fulfilled for steel frame constructions. It is very important to take into consideration the peculiarities of seismic forces when the reinforced concrete frame soft storey is designed. The combined action of axial loads, bending moments and shearing forces, their alternating character define the extremely complex strain-stress state of columns and lead to great saturation with reinforcement. In many real projects of buildings the total reinforcement ratio exceeds 6% that may under dynamic loadings cause brittle failure of concrete in columns, decrease of their energy reserves and doesn't allow to realize completely the bearing capacity of the whole construction. The failure of reinforced concrete columns in buildings with ground frame storey occurs along inclined sections due to large shearing forces. The inclined sections are more sensitive than normal ones to concrete crash in compressed zone especially under dynamic loads.

Meanwhile the usual methods of the bearing capacity estimation for reinforced concrete elements under alternating shearing forces doesn't assume such factors as inclined cracks, dynamic character of loading, the influence of axial forces and the type of transverse reinforcement.

For preventing the brittle failure along normal and inclined cross-sections and for development of plastic deformations the following can be recommended: to enlarge design and constructive lateral reinforcement with simultaneous decrease of bars space; to use constructive confinement in the form of spiral welded rings or welded wire-nets, to reduce by I5-20% the limit reinforcement ratio and to design cross-sections in such a way that lateral force wouldn't exceed 30% of the ultimate bearing capacity of concrete in compression.

Thus, the acute analysis of buildings with ground frame storey can be provided only regarding combined action of horizontal and vertical components of seismic loading. The reliability of such structures under earthquakes is greatly determined by spectral characteristics of excitation. When the buildings are located on weak soils and the predominant period of oscillation is rather long the buildings with soft storey do not provide sufficient earthquake resistance due to possibility of resonance vibrations.

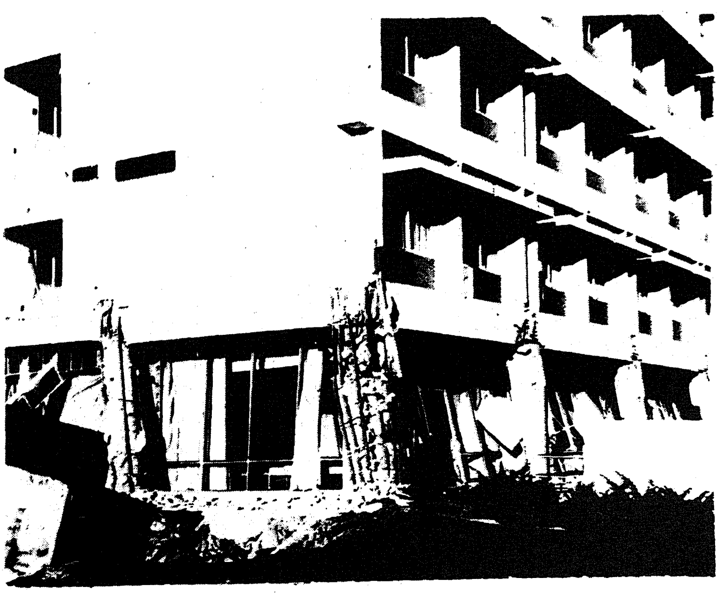

Fig. 1

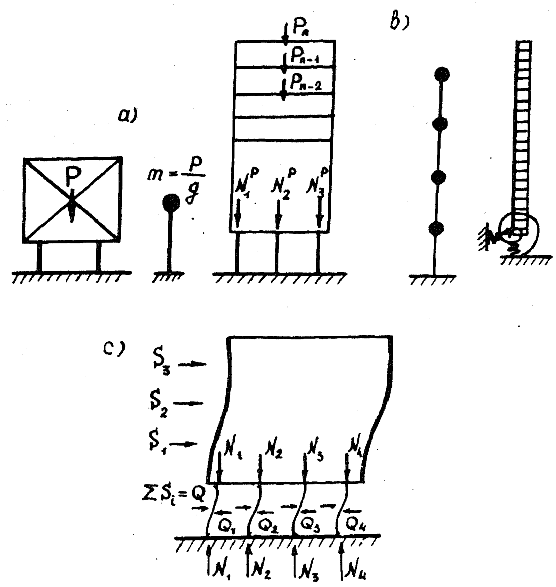

Fig. 2