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RELIABILITY ASSESSMENT OF THE EXISTING DWELLING PANEL BUILDING UNDER SEISMIC LOAD IN GEORGIA

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ABSTRACT:

In paper is given the assessment of influence of structural joint nonlinear deformation on seismic response of 9-storied large panel diaphragm under effect of real accelerograms of earthquakes those had place in Georgia (Racha-Oni, May 5, 1991 and Tbilisi, April 25, 2002).

At acting of two-component accelerogram "Tbilisi" the common picture of normal and tangent strength distribution in diaphragm is not distinguished from one, obtained on the basis of calculation considering two-component accelerogram "Oni", though in this case the maximum values of indicated strength's were decreased by 10-15 % in the mean.

The mode of deformation of diaphragm, corresponding to two-component accelerogram of "Oni" that more danger for diaphragm, can be characterized by seismic loading that 2.2 times less, than the loading on the same diaphragm, deforming absolutely linear, but it 1,8 times greater than design seismic loading. In this case the coefficient of plasticity ? =2.28 and the normative coefficient K_1 that takes into consideration the capacity of structure to develop nonlinear deformations, is equal to 0.43. It must be noted that increasing of real loadings 1.8 times comparatively to normative ones causes the crack development as in horizontal, as in vertical joints and in supporting cross-sections of spandrel beams along the height of diaphragm. There has been shown that the building reliability greater than the limit acceptable value 0.9 that ensures the integrity of structure and the full safety of population at earthquakes.

KEYWORDS: Panel, Non-elastic, Seismic, Influence, Reliability.

INTRODUCTION

For the purpose of large-panel building stress-strain state investigation, considering structural seams nonlinear deformation, the internal longitudinal diaphragm of the 9-storeyed large-panel residential building half-section of a series 1-464 EXPERT, developed in "TbilZNIIEP" has been considered.

The considered diaphragm consists of the panels made of both heavy concrete of class B 12.5 and light-weight concrete- class B5, thickness 30 cm. Edges of the structural elements and bearing sections have deepened surface and key joints. In key parts of the structural seams connection is implemented by reinforce outlets welding (in horizontal joints - 2Φ12A1, in vertical - 4Φ10A1) and the subsequent build in by concrete of class B15 on fine-grained aggregate. The height of the storey makes up 3 meters.

MODELLING OF THE DIAPHRAGM

Depending on specific task, the diaphragm is divided into various quantity of plane stressed quadrangular finite elements and contact elements, modeling structural seams between elements (Mdivani K.I.,2005).

Calculation of the large-panel diaphragm was carried out by the computing program "WALL" for 8-intensity design seismicity under current seismic codes. Dynamic parameters were designed on the basis of the one-dimensional (console) dynamic design scheme with corresponding distribution of mass at the levels of floors and roof. At the same time, mass of the typical floor makes up m=806.5 kN, and at the level of roof m=656.7 kN.

At the first stage the elastic problem is considered. In this case contact element shear and tension-compression strength correspondingly make up: for horizontal joints - K_n =2369990 kN/m, K_s=205580 kN/m, and for vertical units - K_n =3318000 kN/m, K_s =200390 kN/m, and in the process of the influence are constant.

Two different types of the design schemes are considered:

1 – without contact elements;
2 – structural seams between panels in horizontal and vertical directions (on axis x and y)

SEISMIC ANALYSIS

Numerical results analysis shows that according to the first design scheme period of vibrations makes up 0.41 c, and transverse force value in the diaphragm base from seismic load equals: 664 kN.

When taking into account seam ductility in both directions, period of vibrations has increased by 53% and decrease of the transverse force value in the base in comparison with obtained by first scheme, made up 59 %.

The analysis of deformation of a diaphragm shows that vertical displacement under design seismic load for both versions is slight. Regarding maximal horizontal relative displacement of the diaphragm at the level of covering when its height H=31 m., for the first scheme their value varies within the limits of 0.0000405-0.000277; for the second scheme accordingly within the limits of 92-56 % increases, but does not exceed limiting value of relative displacement of a building which is equal to 1/1500 (Polljakov S.V. ,1983).

The analysis of normal stresses distribution situation in the direction of horizontal and vertical axes, has shown, that the maximal normal compressing stresses from static loading arise in the panels of the ground floor, and under different design schemes their value varies within the limits of -2.8 MПa. It should be mentioned, that their value together with growth of floors decreases and on the ninth floor makes up 0.2-0.3 MПa.

Root mean square value of normal stresses σx and σy from seismic loading, considering first three forms, when designing according to the first design scheme, in compliance with the floors in a diaphragm, varies within the limits of 0.015-0.07 and 0.005-0.022 MПa.

When taking into account pliability of horizontal and vertical seams, significant decrease of the value σx of normal stress is observed, while value σy almost has not changed in comparison with the value, obtained under the first design scheme.

Calculation, taking into account structural seams nonlinear deformations, has been carried out on earthquakes accelerograms, that took place in Georgia (in Racha-Oni on May, 5 1991 and in Tbilisi on April, 25, 2002). Accelerograms, recorded at bed rocks, are normalized in such a manner that the maximal amplitude of horizontal components acceleration according to 8-intensity influence makes up 2/0 m/cm^2, and vertical component maximal amplitude is obtained equal to 0.7 of horizontal.

The design dynamic scheme of the diaphragm, in this case, represents 66-mass system, with the concentration of masses in joints of panels connection and thus each mass has two forward degrees of freedom.

The analysis of the calculation results carried out without considering seams when using "Oni" single-component accelerogram, has shown, that at the level of covering the maximal horizontal displacement has made up 0.0245 m. and vertical – 0.0019 m, that is approximately 1.7 times more than the value of displacement calculated by a normative method

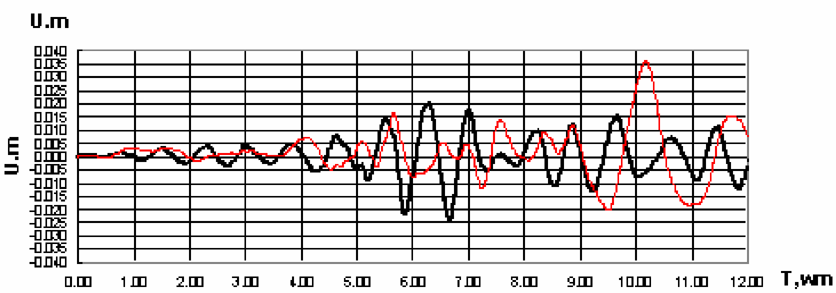
.
When considering nonlinearity of seams in both directions, the value of the maximal displacement at the level of covering in the horizontal direction has reached 0.036 m, that is 33 % more, than the value of displacement obtained by the first scheme at the same level, and in the vertical direction has increased by 78 %, in comparison with the first scheme (fig. 1, a).

Under the influence of the single-component accelerogram of Tbilisi earthquake, according to the first design scheme, the maximal displacement at the level of covering in the horizontal direction has made up 0.0093 m, that is 2.6 times less than the value, obtained by "Oni" single-component accelerogram, but in the vertical direction is 5 times less and is equal to 0.000351м.

The analysis has shown, that difference between the mentioned displacements values and displacements, defined under normative method, in horizontal and vertical direction accordingly makes up 34 % and 90 %.

When considering nonlinear deformation of seams in both directions, the maximal displacement at the level of covering in the horizontal direction has made up 0.02518 m, and in vertical – 0.00544 m, that accordingly in 2.7 times and by 89 % exceeds displacement value, obtained as a result of calculation under the first scheme (fig.1.б).

a)



b)

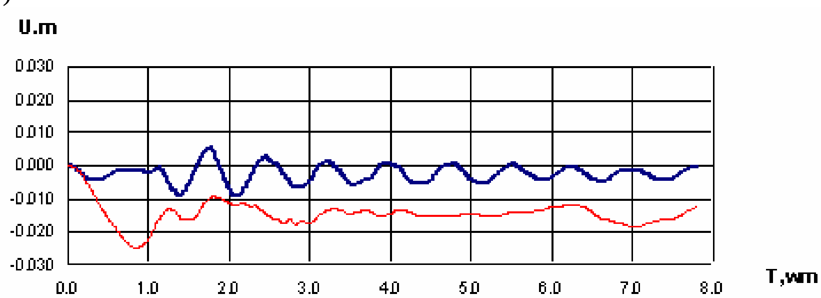


Fig. 1. Displacements at the level of covering in the direction of X under the influence a) " Oni " and b) " Tbilisi " single-component accelerogram

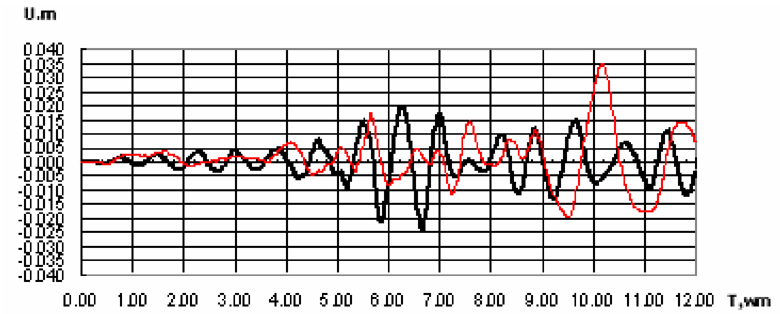
The analysis of the numerical results shows that horizontal relative displacements under the first design scheme vary within the limits of 1/1200 up to 1/1500 [2], and according to the 2-nd scheme by "Oni" accelerogram its value has exceeded permissible value n 43 %.

It is established, that at simultaneous calculation on horizontal and vertical components of accelerograms, the maximal displacement at the level of covering in horizontal direction decreases, and in vertical increases, in comparison with the results of calculation by single component accelerogram. For example, in case of "Oni" earthquake, under the first design scheme its value has decreased 1.3 times, and in the vertical direction has increased by 90 %. Under the same influence when considering nonlinearity of seams in both directions, at the same level the maximal displacement in horizontal direction has decreased by 5 %, and in vertical has increased

2.9 times (fig. 2, a).

When calculating, under the first design scheme, to “Tbilisi” two-component accelerogram the maximal displacement at the level of covering in horizontal direction almost has not changed, but in vertical has increased by 92 %. When considering the nonlinearity of seams in both directions, at the mentioned level, the maximal displacement in horizontal direction has decreased by 78 %, and in vertical has increased by 28 % (fig. 2, b).

a)



b)

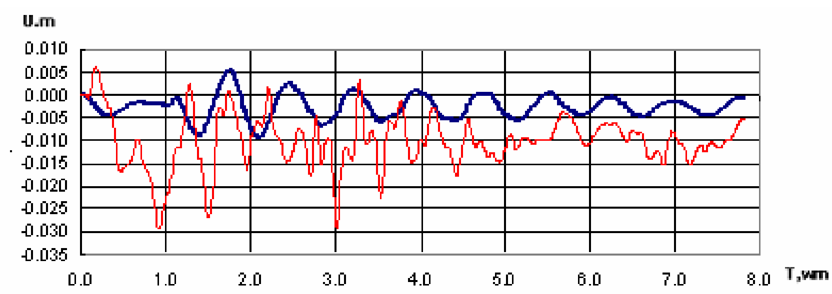


Fig. 2. Displacements at the level of covering in the direction of X under the influence a) " Oni " and b) " Tbilisi " two-component accelerogram

The analysis of the general situation of stress distribution in the diaphragm has shown, that under the influence of "Oni" two-component accelerogram when calculating without taking into account structural seams, normal compressive stresses reach the maximal value 2.1-2.4 MПa in panels, being at the diaphragm edge and weakened by large aperture, though their value is less than design compression resistance for class B5 concrete

The analysis shows, that when considering nonlinear deformations simultaneously in horizontal and vertical seams, the maximal tensile and compressive stresses again are concentrated in panels of the diaphragm edge spans, though the areas of their concentration have been extended. Stress values have increased 1.1-1.3 times, in comparison with the first scheme, however have decreased 1.3-1.8 times in comparison with nonlinear deformation of vertical seams, and have made up 2.10 and 2.8 MПa when design tensile and compressive resistance for concrete of class B12.5 is accordingly equal to 0.67 and 7.5 MПa.

The analysis of numerical results comparison shows, that under the influence of "Tbilisi" two-component accelerogram the general situation of normal and tangent stresses distribution in diaphragm does not differ from obtained on the basis of two-component accelerogram "Oni" calculation though in this case the maximal values of the mentioned stresses on the average have decreased by10-15 %..

The fact, that the values of normal and tangent stresses, obtained when calculating for mentioned single-component accelerograms, are approximately by 10 % less than their values, determined on the basis of two-component accelerograms “Oni" and "Tbilisi", should be noted.

The analysis of the results shows, that the stress-strain state of the diaphragm which corresponds to two-component accelerogram "Oni", more dangerous for the diaphragm may be characterized by seismic load, that is 2.2 times less, than loading on the same diaphragm which deforms absolutely elastic, but is 1.8 times greater than design seismic loading. In this case the factor of plasticity μ=2.28 and normative factor $_{K1}$ which takes into account ability of the structure to develop inelastic deformations, makes up 0.43. It should be noted, that 1,8 times increase of real loadings, in comparison with normative, causes development of cracks, both in horizontal, and in vertical joints and in bearing sections of cross connections along the whole height of diaphragm. Thus, in seams at the certain degree the length of the compressed zone decreases. Formation of plastic hinges in the middle of diaphragm in joints of panels connection with large apertures takes place, from the 3-rd floor and higher. In spite of it, right in the panels, except for the sections which are in joints of connection, the damaged areas are not marked.

In the process of seismic influence deformation of joints has complex nature and the quantity of elastic - plastic cycles for different joints reaches18-22 cycles. This time development of residual displacements in horizontal and vertical seams of large-panel diaphragm value of which increases together with stresses increase, repeatability of loadings and growth of floors and for horizontal seams is within the limits of permissible value and makes up 0,002-0,003м, and for vertical seams equals to 0.014-0.017м, that is greater than permissible values of residual displacements. by 35 %.

RELIABILITY EVALUATION

On the basis of the displacements, obtained by calculation, the reliability of large-panel diaphragm has been assessed under seismic influence, considering nonlinear deformation of seams. The analysis shows, that under the influence of both “Oni” and “Tbilisi” accelerograms, reliability is greater than permissible values – 0.9 (fig. 3) which provides safety of the structure and full safety of tenants during earthquake.

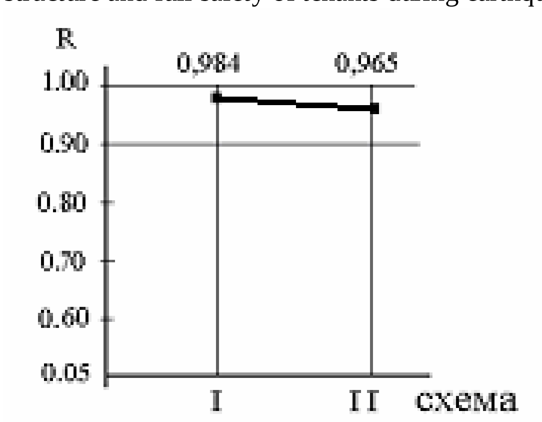


Fig. 3. Reliability of diaphragm depending on the design scheme under the influence of two-component accelerogram " Oni "

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