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# THE CALCULATION OF FLAT PLATE SYSTEMS TAKING INTO ACCOUNT SEISMIC ACTION

**The four storey in situ reinforced concrete frame-wall building by flat plate system is presented in the article, which under static and seismic loads was calculated. Only the middle column of the building in the paper was reviewed and all computations by LIRA were done. The calculations according to Armenian and Russian building codes were implemented and satisfied these conditions. The supremum and infimum bending moments and axial forces of column for flat plate analyses were determined and compared. At the same time there were carried out computations taking into account the punching shear action of slabs. The results are shown that the differences of axial forces between static and dynamic loads are negligible, however of the volume of punching shear is huge enough.**

**Keywords: flat plate, reinforced concrete, seismic load, bending moment, axial force**

## INTRODUCTION

A flat plate is a reinforced concrete slab supported directly by concrete columns without the use of beams. When needed additional stabilizing can be obtained by the use of shear walls. Flat plate system has several advantages in comparison with simple beam system for instance, the room layout becomes flexible, the height of the building reduces, consequently is reduced the foundation load, the construction time decreases, formworks are easier to install, even the sanitation conditions are improved. Flat plate design will facilitate the use of big table formwork to increase productivity. In addition to the design of flexural capacity of a flat plate the shear capacity above the columns need to be addressed. The intersection between the column and the slab is critical as the concentrated forces can induce a cone shape perforation through the slab thickness. For enhancing the shear capacity usually in slabs are installed stirrup cages.

The purpose of the paper is to determine the supremum and infimum bending moments, the axial forces of the building and to calculate the punching shear condition for not seismic zone and three seismic zones according to Armenian building codes, then, to compare obtaining results and give the conclusion.

The flat plate system has some calculation difficulties, which structural engineer must take into account, especially when the construction was erected in a seismic zone.

## 1. INPUT DATUM OF FLAT PLATE

The flat plate (Fig. 1a) building has simple scheme: three spans in one direction and three in the other (Fig. 1b). All spans are equal to each other and the distance is 6 m. The storey's height of the structure is equal to 3 m. The four storey structure has symmetric diaphragms and the thickness is equal to 16 cm up to the end. The cross section of columns is 50×50 cm. The class of concrete was chosen B30, the class of steel bar - A400 and class of stirrup - A240.

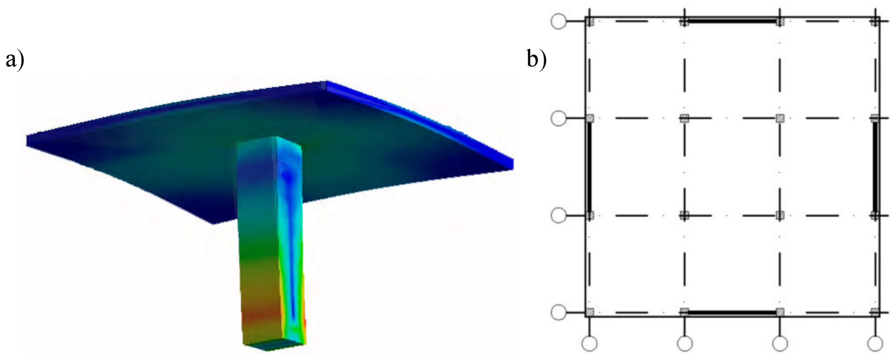


Fig. 1. Flat plate system: a) 3D view of flat plate system, b) plan of the flat plate building with shear walls

## 2. FLAT PLATE COMPUTATION IN ACCORDANCE WITH BUILDING CODES

The calculation under punching shear is performed for flat reinforced concrete members (slabs), when the concentrated forces and the bending moments are existed (Fig. 2). Design outline of transverse cross section is accepted locked and placed around the area of the load transmission, when the platform of load transmission is located inside of the flat element. In accordance with SP 63.13330.2012 building codes [2] the shear stress computation of elements with transverse reinforcement under punching force taking into account the concentrated force and bending moments mutually of two perpendicular planes are determined from the following condition:

$$\frac{F}{F_{b,ult}+F_{sw,ult}}+\frac{M_x}{M_{bx,ult}+M_{sw,x,ult}}+\frac{M_y}{M_{by,ult}+M_{sw,y,ult}}\le 1 \qquad (1)$$

where:

$F$, $M_x$, $M_y$ - concentrated force and bending moments in X and Y direction from external load,

$F_{b,ult}$, $M_{bx,ult}$, $M_{by,ult}$ - ultimate force and accordingly the bending moments in X and Y direction were carried out by concrete,

$F_{sw,ult}$, $M_{sw,x,ult}$, $M_{sw,y,ult}$ - ultimate force and accordingly the bending moments in X and Y direction were carried out by stirrup.

The $M_{sw,x,ult}$ and $M_{sw,y,ult}$ forces perceived by transverse reinforcement and arranged equally along to the outline of design cross section are determined at the action of bending moments accordingly in X and Y axes directions [2].

To clarify the equation, it will be:

$$\frac{F}{R_{bt}\,u\,h_0+0.8q_{sw}\,u}+\frac{M_x}{R_{bt}\,W_{bx}\,h_0+0.8q_{sw}\,W_{sw,x}}+\frac{M_y}{R_{bt}\,W_{by}\,h_0+0.8q_{sw}\,W_{sw,y}}\leq 1 \quad (2)$$

where:

$W_{bx}$, $W_{by}$ - section modulus of concrete in X and Y directions respectively,

$W_{sw,x}$, $W_{sw,y}$ - section modulus of steel bar in X and Y directions respectively,

$R_{bt}$ - design strength of concrete,

$q_{sw}$ - uniformly distributed force in stirrup,

u - control perimeter of design cross section outline,

$h_0$ - effective depth of cross section.

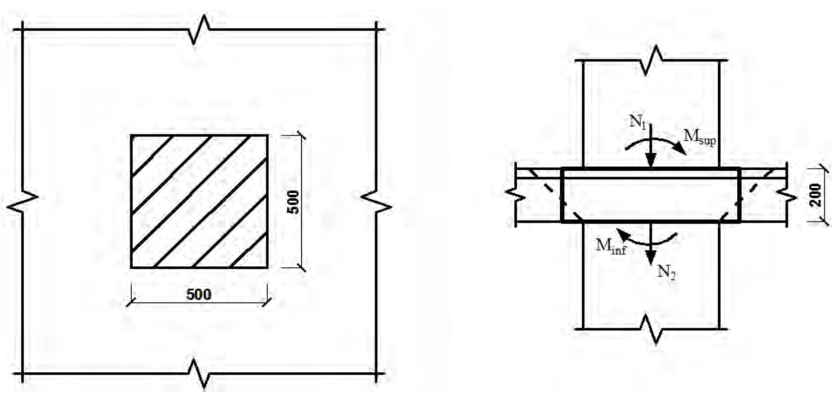


Fig. 2. Middle column of flat plate system under punching shear

According to SP 63.13330.2012 building codes the $F_{b,ult}+F_{sw,ult}$, $M_{bx,ult}+M_{sw,x,ult}$, $M_{by,ult}+M_{sw,y,ult}$ shall not be greater than $2F_{b,ult}$, $2M_{bx,ult}$, $2M_{by,ult}$ values respectively. Apart from these, the step of stirrups must not be more than $1/3h_0$ and 300 mm.

The area of Armenia is divided into three seismic zones, therefore acceleration of subsoil for the first zone is equal to 0.2g, for the second zone - 0.3g and for the third zone - 0.4g [1].

## 3. THE RESULTS OF FLAT PLATE CALCULATION

The axial forces in columns from static and dynamic loads were calculated, afterwards the divergence of these forces were determined. The results are shown in Table 1.

The supremum and infimum bending moments were determined and taken from software. The values of moments are shown in Table 2.

Table 1. **Values of axial forces**

| Seismic zone | Storey | Lower axial force [kN] | Upper axial force [kN] | Final value [kN] |
|---|---|---|---|---|
| | | Total static load /$N_g + N_{v1} + N_{v2}$/ | Total static load /$N_g + N_{v1} + N_{v2}$/ | Divergence axial force $N_{low}$ - $N_{upp}$ |
| – | I | 1461.6 | 1096.3 | 365.3 |
| | II | 1074.7 | 710.8 | 363.9 |
| | III | 689.2 | 327.8 | 361.4 |
| | IV | 306.2 | – | 306.2 |
| 0.2g | I | 1461.6 | 1096.3 | 365.3 |
| | II | 1074.7 | 710.8 | 363.9 |
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| | II | 1074.7 | 710.8 | 363.9 |
| | III | 689.2 | 327.8 | 361.4 |
| | IV | 306.2 | – | 306.2 |

Table 2. **Values of infimum and supremum bending moments**

| Seismic zone | Storey | Infimum bending moment [kN·m] | | Supremum bending moment [kN·m] | |
|---|---|---|---|---|---|
| | | $M_{x,inf}$ | $M_{y,inf}$ | $M_{x,sup}$ | $M_{y,sup}$ |
| – | I | 9.10 | –9.00 | –12.60 | 12.70 |
| | II | 11.10 | –11.20 | –8.60 | 8.50 |
| | III | 7.70 | –7.70 | –10.00 | 10.00 |
| | IV | 13.20 | –13.20 | – | – |
| 0.2g | I | 11.70 | –11.00 | –24.70 | 13.70 |
| | II | 19.80 | –13.10 | –19.00 | 12.10 |
| | III | 17.80 | –10.50 | 18.30 | 10.80 |
| | IV | 24.60 | –14.20 | – | – |
| 0.3g | I | 13.70 | –12.80 | –31.60 | 15.20 |
| | II | 25.00 | –14.90 | –24.90 | 14.60 |
| | III | 23.50 | –12.50 | –23.10 | 11.90 |
| | IV | 31.30 | –15.60 | – | – |
| 0.4g | I | 14.80 | –13.70 | –35.50 | 16.00 |
| | II | 27.80 | –15.90 | –28.10 | 15.90 |
| | III | 26.60 | –13.60 | –25.70 | 12.50 |
| | IV | 34.90 | –16.40 | – | – |

According to RABC II-6.02-2006 building codes [3], the maximal value of storey drift for reinforced concrete frame-wall system shall not exceed 1/300h.

## CONCLUSION

To sum up, the research is shown that for middle columns the differences of axial forces between static and dynamic loads are slight. However, the maximal infimum bending moment for the third seismic zone (0.4g) is 2.64 times greater than for not seismic zone and the maximal supremum bending moment - 2.8 times. Lastly, the shear stress for the third zone and the last floor is 23.6% greater than for not seismic zone (Fig. 3).

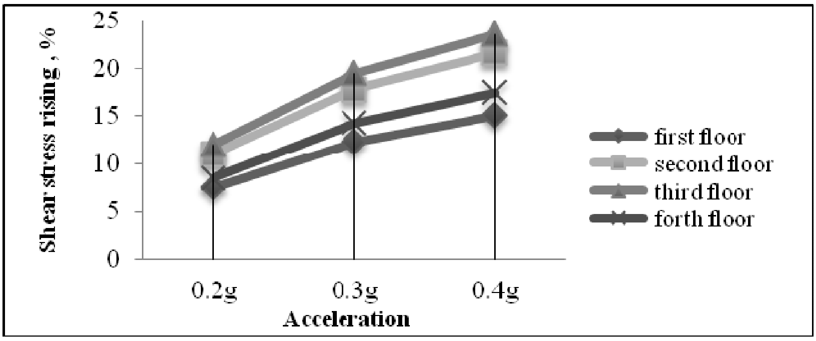


Fig. 3. Diagrams of seismic forces and reinforcement percents

## REFERENCES

[1] СП 63.133330.2012 Бетонные и железобетонные конструкции. Основные положения, Минрегион России, М.: 2012, 154 с.

[2] Дорфман А.Э., Левонтин Л.Н., Проектирование безбалочных бескапителных перекрытий, , Стройиздат, М.: 1975, 128 с.

[3] ՀՀՇՆ II-6.02 - 2006, Սեյսմակայուն շինարարություն, Նախագծման նորմեր, Երևան, 2006.

## OBLICZENIA PŁYT STROPOWYCH PŁASKICH PRZY UWZGLĘDNIENIU OBCIĄŻEŃ SEJSMICZNYCH

**W artykule przedstawiono istniejący budynek czterokondygnacyjny o żelbetowej konstrukcji szkieletowej słupowo-płytowej, do którego obliczeń przyjęto wpływ obciążeń statycznych oraz sejsmicznych. W opracowaniu omówiono słup środkowy, a analizy obliczeniowej dokonano za pomocą programu obliczeniowego LIRA. Analizę wykonano na podstawie norm armeńskich oraz rosyjskich, a otrzymane wyniki spełniają założenia obu norm. W celu przeprowadzenia analiz płyty płaskiej określono i porównywano obwiednie momentów zginających oraz sił osiowych słupa.**

**Przeprowadzono również obliczenia mające na celu sprawdzenie nośności płyty na przebicie. W wyniku analizy stwierdzono, że różnice sił osiowych wyznaczonych przy uwzględnieniu obciążeń statycznych oraz dynamicznych są niewielkie, jednakże różnice wielkości nośności na przebicie są dość duże.**

**Słowa kluczowe:** **płyty płaskie, konstrukcje żelbetowe, obciążenia sejsmiczne, momenty zginające, siły osiowe**