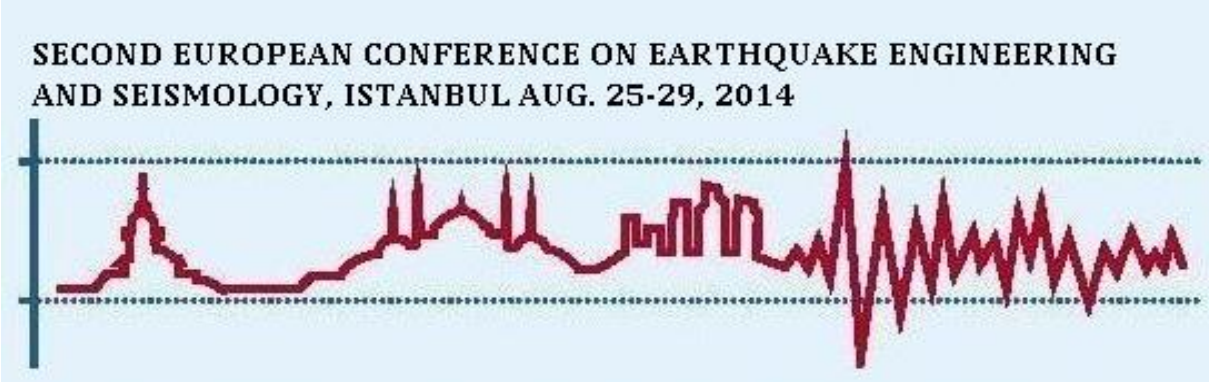

SEISMIC VULNERABILITY AND SEISMIC RESISTANCE OF YEREVAN ZVARTNOTS INTERNATIONAL AIRPORT'S DEPARTURE HALL

Zaven KHLGHATYAN[1], Nazeli GALSTYAN[2], Gurgen NAMALYAN[3],
Aram KHACHATURYAN[4], Vardan HAYRAPETYAN[5]

ABSTRACT

Whole territory of Armenia is situated in the active seismic zone therefore rehabilitation of the existing structures is an urgent need of country.

Main purpose of this paper is estimation of seismic vulnerability and resistance of Yerevan Zvartnots International Airport's old terminal's departure hall. It was constructed in 1980-s and had a cultural significance for the Republic of Armenia.

This research aims to discuss and give proposal about rehabilitation possibility of Departure Hall (structure in form of an open ring). Analytical design model and seismic calculation were done due to requirements of Armenian Earthquake Resistant Construction Design Codes (RABC II-6.02-2006), employing LIRA 9.6 software.

Results showed that the structure has high level of seismic vulnerability and rehabilitation of the building is strongly recommended. Proposals are carried out for rehabilitation design by implementation special systems of seismic resistance.

INTRODUCTION

The “Zvartnots” International Airport is located in the Ararat Valley, near the Yerevan city, capital of Armenia, which is one of the most seismic active areas of Armenia.
There were devastating earthquakes from ancient time. Beginning from 6 AD, when the destructive Ararat earthquake had occurred, strong earthquakes were noted in the region. The most hazardous seismic active source for this area is Parakar seismic source with seismic potential as high as M= 6.5. In XX century in that area were registered more than 10 earthquakes with magnitude M>4, the strongest of which have taken place in 1937 (M=4.7), and intensity 7 on MSK-64 scale in Parakar

[1] Director of EEC, Western Survey for Seismic Protection SNCO, Ministry of Emergency situations, Yerevan, zkhlghatyan@yahoo.com
[2] Lead Engineer, Western Survey for Seismic Protection SNCO, Ministry of Emergency Situations, Yerevan, nazeligalstyan@yahoo.com
[3] Chief of division at EEC, Western Survey for Seismic Protection SNCO, Ministry of Emergency situations, Yerevan, gnamalyan@mail.ru
[4] Chief specialist, Yerevan Nakhagits, Yerevan Municipality, analitikarm@yahoo.com
[5] Chief of division at EEC, Western Survey for Seismic Protection SNCO, Ministry of Emergency situations, Yerevan, hayrapetyanv@yahoo.com

area. According to the new map of seismic zonation of Armenia, elaborated at NSSP RA in 1995 and adopted by the Government of the Republic of Armenia, the seismic hazard level for the mentioned area is evaluated by the expected ground acceleration of 0.4g, that correspond to 9 seismic impact on MSK-64 scale.

Terminal 1 of the Yerevan “Zvartnots” international airoport consists of three structures: Departure hall (a building in form of an open ring, with two levels and an open ground floor, used as a parking), Control tower with a lower building of 10m, 5 floors and 2 underground levels and Passageway for the vehicles access, connecting the lower level of the parking to the higher level of the principal building. It was constructed in 1980-es and has cultural significance for RA (see fig. 1).

Figure 1. “Zvartnots” International Airport of RA

This paper discusses one of the structures of airoport: A building in form of an open ring, in the following tasks: observational and instrumental studies of the building, the developing of the building design model, the seismic calculations and proposal of retrofitting.

OBSERVATIONAL AND INSTRUMENTAL STUDIES OF THE STRUCTURE

A building in form of an open ring is a structure standing on two columns, it is broadened in two sides with consoles, with double sloping cover, under which is a parking lot for movable transport. The waiting hall which ground on the columns has 24.4m broadness, is nearly 6.0m height from the ground (-1.65-4.50m) and also has half storey on +7.50m level. The vertex is on 12.5m height from ground.

The building has a view of an unfinished circle in the layout. From the center of the aero-complex 1-56 digital axes are carried from radiuses R1=80.0m and R2=65.6m and made solid bases from M-200 grade of concrete, the distance between internal axe is L=6.437m, external is L=7.850m.

All the bases are glass-shaped. The bases have nearly 4,0x6,0m measure reinforced with reinforcement poles of a II class. The bases of 1-46 digital axes in ring-shaped direction have no bundle with each other, there is a bundle between 47-56 axes, because the walls enclosing underground stories with their basic shutters are becoming bundles having ring-shaped direction.

The constructive scheme of the building presents from itself arranged 1-56 digital axes, frames of combined elements, which are connected with combined bundles in the ring-shaped direction. The columns of frames of combined elements according to the height, have changeable cut 0.4x1.4m below, 0.4x1.0m above. On the +4.15m level columns are united with shutters having changeable cut which on the heads of the columns have 0.4x1.85m, in the middle of flight and in the ends of consoles 0.4x1.05m sectors. On the +4.40m level the shutters are united with sloping columns and sloping shutters, which have 0.4x0.6m sectors. The marked elements are done from 300 grade of concrete and reinforced with reinforcements of AII class. The combined slabs of the cover have 0.45m height (see fig.2).

The structure is divided into 7 sectors. On above mentioned axes combined shutters also on the haunches of the solid ring-shaped beams, metallic insertions are anticipated which let one cover of the ring lean against the one, securing also their free sliding in the ring-shaped direction softening stretches arising from seismic and thermal vibrations.

The bases of the building are boulders with sand aggregates, carbonated clay sands. During the special combination of burdens the calculations are done taking into consideration that the building is in the 8 intensity of seismic zone (Amax=0.2g).

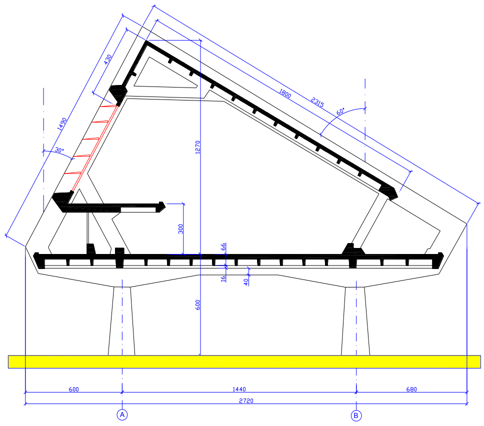

Figure 2. Cross section of the building in form of an open ring

There are damages of different degrees in the reinforced concrete constructions of different sections of the open ring building. Mainly the concrete protective layer of the steel framework of the reinforced concrete constructions have corroded, the steel framework has been laid bare and has been subjected to corrosion of different degrees, the metal supplementary elements do not have an anti-corrosion protective layer and have also been subjected to corrosion of different degrees (see fig.3).

Figure 3. Damages of the reinforced concrete members

- There are damages of different degrees in the reinforced concrete constructions of different sections of the open ring building (frames, beams connecting frames to each other, inserted floor and roof slabs, cantilever constructions, reinforced concrete handrails, and etc.). Mainly the concrete protective layer of the steel framework of the reinforced concrete constructions have corroded, the steel framework has been laid bare and has been subjected to corrosion of different degrees, the metal supplementary elements do not have an anti-corrosion protective layer and have also been subjected to corrosion of different degrees (see fig. The damages have occurred because of during the exploitation of the building (about 30 years) the reinforced concrete constructions have been periodically subjected to humidity which has brought to the freezing-melting process in case of negative temperature during winter resulting in corrosion of concrete.
- Water removal from atmospheric precipitations is not organized in a proper way in the building.
- The construction works have not been carried out with sufficient quality.
- The concrete protective layer of the steel framework doesn't have enough thickness.
- Longitudinal steel framework is placed with large distance- with a 35-40cm step.
- In separate reinforced concrete constructions the concrete doesn't have a satisfactory grade of solidity.

It should be noted that the strong and considerable damages in reinforced concrete constructions (the decomposition of the concrete protective layer of the steel framework, the general proportionate and local disproportionate corrosion of steel framework and supplementary metal elements, and etc.) have occurred mainly on the first floor and on the level of the roof of the first floor.

- The zone of thermal-movement joints has been subjected to considerable damage.
- The functional importance of thermal-movement joints has been violated in the factual constructive solutions of the building.
- In the assembly junctions of sloping supports of reinforced concrete frames, the concrete protective layer of the steel framework has decomposed, the steel framework has been laid bare and has been subjected to general strong corrosion.

According to the structure the medium value of the results of the testing by destructive and non-destructive methods is 280-330 kg/cm^2.

The assessment of dynamic characteristics of the building performed on the base of microtremor measurements. The values of the periods (T) of the building own vibrations in X, Y, Z directions are: Tx = 0.29sec., Ty = 0.37sec., Tz = 0.1sec.

DEVELOPING OF THE BUILDING DESIGN MODEL AND SEISMIC CALCULATION

Building is modelled as special frame. Columns and beams are modelled as linear elements, walls and floors slabs as shell elements (see fig.4).

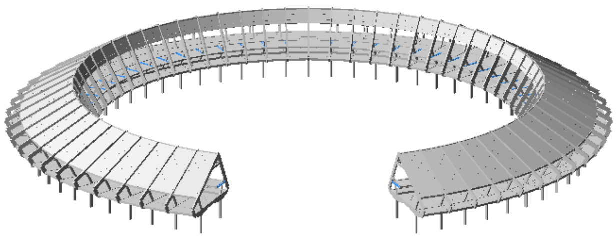

Figure 4. Special design model

Seismic calculation of the building has been performed by LIRA version 9.6.

According to RABC II-6.02-2006 the design value of the horizontal seismic load Ski, applied at a point k, which corresponds to the ith mode of the building's or structure's free oscillations, is determined by the following formula:

$$S_{ki} = k_0 k_1 k_2 k_3 A Q_k \beta_i \eta_{ki} \qquad (1)$$

where A is the dimensionless coefficient of seismicity indicating the ratio of a given settlement's design ground acceleration to the gravitational acceleration (A=0.4), k_1 is the structure permissible damage coefficient, k_2 is the structures importance coefficient, k_3 is the soil-structure interaction coefficient, ko is the dimensionless coefficient of soil conditions (k0 = 1.0, for soil category II), Q_k is the weight that induces inertial force, and is deemed to be concentrated at the point k, η_{ki} -is a dimensionless coefficient depending on the ordinates of the free oscillation mode Xki and concentrated weights values Qk, β_i is the "dimensionless dynamic coefficient corresponding to the ith mode of a given building's or structure's free oscillations.

In the calculation we accepted: $k_1 = 0.5$, $k_2 = 1.0$, $k_3 = 1.0$.

The following 4 preliminary versions were designed for the one section:

A. columns are fixed to the base and the slabs connect to beams with hinges
B. columns are fixed to the base and the connection between slabs and beams are rigid
C. columns are neither fixed nor hinge to the base and the slabs connect to beams with hinges
D. columns are nor fixed nor hinge to the base (k=0.7), and the connection between slabs and beams are rigid.

Table 1 shows some details of above mentioned final calculation results.

To give more realistic assessment of the spatial work of the construction during earthquake it is necessary to consider it completely and not as separate block. There was accepted that columns are neither fixed nor hinge to the base and the connection between slabs and beams are rigid.

Table 1. Results of Calculation

Case	Periods for first 5 shape modes (sec)	Max displacement (mm)		Max reinforcement			
		X direction	Y direction	Symmetric		Asymmetric	
				%	sm2	%	sm2
A	1.0895; 0.6136; 0.5789; 0.4230; 0.4228	239.0	130	13.6	489.0	4.55	219.0
B	1.0478; 0.5325; 0.5125; 0.3588; 0.3588	228.0	98.5	9.94	358.0	4.54	225.0
C	1.2189; 0.6641; 0.6280; 0.4233; 0.4230	268.0	141.0	9.75	351.0	6.12	219.0
D	1.1783; 0.5850; 0.5640; 0.3589; 0.3460	256.0	115.0	9.13	323.0	4.52	78.5

It should be noticed that according to the RABC II-6.02-2006 codes the area of the longitudinal reinforcement of eccentrically compressed elements shall constitute no more than 4% of the element's cross-section for class A-I, A-II, A-III reinforcements. In this case the reinforcement composed 9.13-13.6% .

We have got following comparative values for complete structure. Natural periods for the10 modes are the followings: 1,181; 0,895; 0,719; 0,719; 0,639; 0,584; 0,519; 0,429; 0,359; 0,350 sec.

It should be noticed that according to RABC II-6.02-2006 codes for the displacement calculation the k1 = 1.0. On the fig. 5 is shown displacements along X direction.

Maximum displacement along X direction in level +3.5m, Δ =7.965sm, in level +8.1m, Δ=4.585sm, In level +17.1m, Δ=6.012sm.

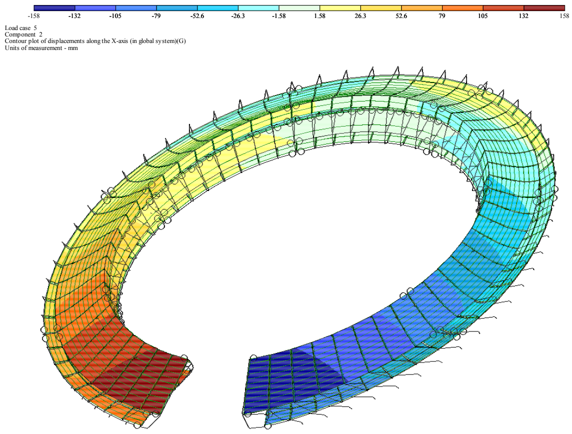

Figure 5. Displacements along X direction

The presented values show that along X, Y directions the drift values are greater than 1/200 accepted value. It should be noticed that large displacements and forces arise on the edge flights which means that open ring could be closed as a retrofitting type.

In the table 2 are presented the analyses of the frame reinforcement according to designed and needed calculation shown on the fig 6.

The results of table 2 are shown, that reinforcement is not enough for the columns about 2.2-4.1 times and for the beams – 2.1-2.4 times.

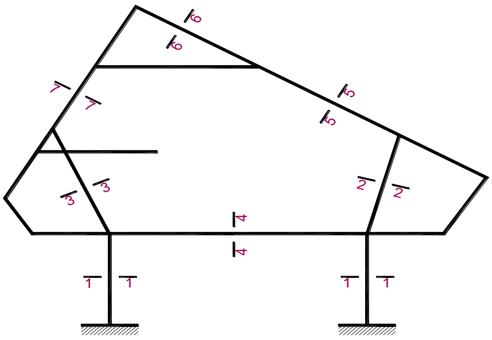

Figure 6. Schematic section of structure

Table 2. Reinforcement of each Section

	Section	Sectoin of the reinforcement according to design (sm^2)	Sectoin of the reinforcement according to calculation (sm^2)	Ratio reinforcement (design / calculation)
1	3	4	5	
1	1 – 1	85.7	351.4	4.1
2	2 – 2	71.9	163	2.2
3	3 – 3	75.8	81.7	1.0
4	4 – 4	68.7	163	2.4
5	5 – 5	129.6	123	1.0
6	6 – 6	105.3	81.7	1.3
7	7 – 7	58.4	123.0	2.1

CONCLUSIONS

The results of seismic calculations are shown, that reinforcement of the columns is not enough about 2.2-4.1 times and for the beams - 2.1-2.4 times. The presented values show that along X, Y directions the story drift values are greater than accepted 1/200 value. It should be noticed that large displacements and forces arise on the edge flights. This means that open ring could be closed as a retrofitting solution.

The degree of seismic vulnerability of the building is estimated as medium.

The results of the instrumental study show that the factual concrete strength (grade) of the constructions of building is close to the design strength.

Add the seismic capability through building rigidity increase. It is proposed to complement the spetial frame of the building with reinforced-concrete rigid diaphragms or steel bonds as shown in proposed scheme (see the proposed installation dots of rigid diaphragms).

The rehabilitation of the building may include employing of special systems of seismic protection, such as interactive ties and structures that can increase damping factor of structure (For example SISTEM DC90). It is neseccary to increase natural periods of structure more then 2.0 sec. To reach this aim is proposed to apply seismic isolation system with the laminated rubber bearings on the level +3.5m.

REFERENCES

Balasanyan S, Manukian A (1994) Seismic risk on the territory of the city of Yerevan, Armenia, Issues in Urban Earthquake Risk, Kluwer Academic Publishers, NATO ASI Series, Series E: Applied Sciences, Vol.271, 167-182.

Earthquake resistant construction design codes (2006) RABC II-6.02-2006

Khlghatyan Z (2006) The estimation of buildings vulnerability and experience in application of modern seismic protection systems in Armenia, *Internationalni Nauchno-Struchi Skup. Grade-vinarstvo-Nauka i Praksa. Kniga 1*, Zabljak, 309-316.

Khlghatyan Z (2005) Khachatryan A, Seismic calculations and the dymamic experiments of LRB isolators of the new terminal of Yerevan "Zvartnots" interna-tional airport, *International Conference on Earthquake Engineering*, Macedonya, Skopje, 5-14.

Reconstruction of Buildings and Structures, Recovery and Reinforcement (2000), RABC I-4.02