

TO OBTAIN SEISMIC SHOCK DIRECTION OF ANY EARTHQUAKE BY USING CRACK MEASUREMENTS

Ozkan ISLER¹

SUMMARY

The scope of this study is that the damage diagnoses performed on the Blocks of Ozyıl Housing Estate, selected at random among the buildings having been damaged in medium level in 1992 Erzincan Earthquake, and Celtiksuyu Regional Boarding Primary School Buildings, having heavily been damaged and collapsed in 2003 Bingol Earthquake, is evaluated with regard to the seismic energy and that with starting here, the shock directions about both earthquakes are determined. In the reinforced concrete load carrying components suffering the structural damage, the most important assumption of this study is that the virtual work carried out by the internal forces creating the fractures and refractions during the earthquake in these components is equalized to the seismic energy. In the Blocks of Ozvil Housing Estate, examined after 1992 Erzincan Earthquake, the fracture inspections have been carried out in all the floors, beams and at the nodal points of the column-beam during the directions (x-x) and (y-y) or (E-W) and (N-S) selected and the virtual work in these directions has been calculated, and the shock direction of the earthquake has also been found with help of the these calculated energy components. As for the examinations performed in 2003 Bingol Earthquake, the measurements having been made in the horizontal directions in the floors destroyed in Celtiksuyu Regional Boarding Primary School Buildings, having collapsed, have been taken into consideration and it has been stated that the work implemented with shifting these floors during the earthquake is equal to the seismic energy, and the shock direction of this earthquake has been inspected. In the earthquakes of 1992 Erzincan and 2003 Bingol, while the shock directions given according to the earthquake records tg θ are 0.80 and 1.96 in order, these values have been found as 0.87 and 1.83 in a very similar way to the fact thanks to the calculation method developed in the study.

INTRODUCTION

The scope of this study is that the shock directions belonging to earthquakes in question are calculated by an analytical method, with the help of the damage diagnoses made after the earthquake. The magnitudes of 1992 Erzincan and 2003 Bingol Earthquakes are 6.8 and 6.4 in order and acceleration records have been written down as 0.40g / 0.50g / 025g and 0.55g / 0.28g / 0.55g, in the (N-S), (E-W) and vertical

¹Prof.Dr., Istanbul Technical University, Istanbul, Turkey. Email: islero@itu.edu.tr

directions. A common feature of the provinces of Erzincan and Bingol is that they both are located on The North-Anatolian Fault line, the most active fault layer of the area.

In the study, the damage diagnoses and measurements made in the Blocks of Ozyil Housing Estate, selected at random among the buildings having been damaged in medium level in 1992 Erzincan Earthquake, and Celtiksuyu Regional Boarding Primary School Buildings, having collapsed in 2003 Bingol earthquake, have been based on.

ASSUMPTIONS

In the study, the assumptions carried out to obtain the shock directions of the earthquake are that: 1) The damages forming in the structural components during the earthquake and/or the works made by the horizontal shiftings forming in the layers are equal to the seismic energy coming to the building ventured, (2) the contributions that the brick walls placed between the reinforced concrete frames have made on the rigidity of the system are neglected, (3) The seismic energy in the vertical direction and the damages caused by it have no effect over the calculations performed on the horizontal plane.

DAMAGE SURVEYING

The fracture widths forming in the nodal points of the beam-column of the reinforced concrete frames and the beams web in the areas near to the support have been measured and recorded in visual determinations in the buildings damaged in the medium level after 1992 Erzincan earthquake. These buildings are those having the concrete skeleton structral system with totally 4 floors, including (basement + ground floor + 2 regular floors).

Celtiksuyu Regional Boarding Primary School Buildings, having quite interestingly collapsed in 2003 Bingol earthquake has been selected as the sample building for this study. No basement exists in this building having a concrete support structural system with 3 floors. The building has interestingly collapsed after the earthquake. In the building that the concrete quality is too bad, all the ground floor columns have completely been broken during the earthquake and the headlining of the ground floor has been destroyed. Only two floors on the upper side have been able to achieve last as heavily damaged. The seismic energy coming from the ground to the building has firstly broken all the ground floor columns and then caused shifting the upper floors in the direction of the shock that the earthquake is effective. The situation plans belonging to these buildings and the structural system plans have been illustrated in the figures 1, 2 and 3.



Fig. 1 Situation plan of the Ozyil buildings (Erzincan)

Ozyıl Cooperative blocks, having been damaged in the medium level in the 1992 Erzincan Earthquake, consist of 14 units of buildings totally. The damage diagnosis works have been performed In all the blocks by Isler and Celik [1]. These statistical surveys of the damage diagnosis prepared have then been based for the strengthening works to be performed in these buildings. Of these 14 blocks, the values pertaining to the fracture widths measured in the determinations made visually in nodal points of the beam and columnbeam concerning three blocks selected at random have been showed on the structural system plan sketches in the figures (Fig.4).

The feature of the damage shape forming in the destroyed school building has been found noticeable in its appropriateness to the calculation method presented here and the examinations, inspections and measurements deemed as required have been made on this building damaged heavily. In the measurements carried out, it has been fixed that the destroyed floor liners collapsed by shifting in the ranks of 27.5 cm. and 15cm. in order (average value) in the directions of NS-EW. The condition plan (Fig.5), photos (Fig.6) and the plan sketch showing the shot locations of these photos illustrating the building's collapse situation according to the floors have been shown in (Fig.7,8,9,10).



Fig. 2 Plan of the Ozyil buildings



Fig. 3 Plan of the Celtiksuyu Primary School building







1992 ERZINCAN EARTHQUAKE-OZYIL SINAN BLOCK, DAMAGE SURVEYING



1992 ERZINCAN EARTHQUAKE-OZYIL FATIH BLOCK, DAMAGE SURVEYING

Fig. 4 Cracks with measurements on the Ozyil buildings (in mm.)







Fig. 6 The position of photographs



(F1) (F2) Fig. 7 Horizontal replacements of the first floor and damaged columns after collapse



(F3) Fig. 8 Collapse of the ground floor of Celtiksuyu Primary School



(F4) Fig. 9 Heavy damaged ground floor column at the corner



(F5) Fig. 10 Punching in 1st floor slabs by ground floor columns

THE METHOD OF OBTAINING THE SEISMIC SHOCK DIRECTION

From the point of view of the diagnosis and measurements of the damage having been made on the buildings damaged after any earthquake in this section of the study, the opinion that the seismic shock direction experienced shall be able to determined has been put forth and a simple calculation method developed for this purpose has been given.

It can be stated that the seismic energy leading to the damage is equal to the total of the energy consumed for the damages forming in whole the sructural components of the building and the other words, is equal to the total of the work made by the external forces.

Here, to simplify the calculating technique in the calculation of the total work carried out by the internal forces, the following are also discussed concerning the assumptions that: 1) all the fractures forming in the nodal points of the column-beam is on the beam web, 2) Whole the frame beam dimensions and the load carrying capacities belonging to these concrete beams are equal to each others, 3) the fracture widths measured on the beam web is ell-proportioned to the bending moment creating this fracture, 4) the centers of mass and rigidity are identical. According to this:

Reinforced beam section dimensions: b/h

The fracture width measured in the beam web forming with effect of the bending: Wc

The bending moment causing the fracture in the section: Me

Rotation angle forming in the cracking beam section: $\Delta \theta = Wc/(h/2)$

The virtual work carried out in the cracking beam section: W=Me. $\Delta\theta$ Seismic energy: Es

On condition that $\mu = Me.h/2$ is a fixed value in the proposed calculation method,

Total virtual work:
$$\sum W = \sum Me.\Delta\theta = \sum Mc.Wc/(h/2) = (Me.h/2)\sum Wc = \mu.\sum Wc$$

when the total virtual work is equalized to the Seismic Energy, the formula can be written as $Es = \sum W = \mu \cdot \sum Wc$.

If the fracture measurements made in the directions of EW-NS or x-y in the beams is stated separately, Seismic Energy's components in the directions of x-y can be written as follows:

 $Esx = \mu . \sum Wcx, Esy = \mu . \sum Wcy.$

On the other hand, if a collapse in the way of shifting has occurred almost all over the building, as in the sample of Celtiksuyu Regional Boarding Primary School Buildings, at this time the work made by the center of mass of the building can be taken into account. In this case,

Total lateral earthquake force coming to the building is: V

If the lateral replacements measured in the directions of EW-NS or x-y are, δx and δy

The components of the Seismic Energy are $Esx = \delta x.V$, $Esy = \delta y.V$.

Finally, θ angle of the seismic shock direction requested to be determined with help of the diagnosis and measurements of the damage can be obtained as, finally

 $tg \theta = Esy/Esx$

EXAMPLES

Seismic shock directions pertaining to both earthquakes have been determined by benefiting from the damage diagnosis records obtained in the Ozyil Housing Estate Blocks damaged at medium level and Celtiksuyu Regional Boarding Primary School Buildings having collapsed, which have been selected during the damage diagnosis works made in the area after the earthquakes 1992 Erzincan and 2003 Bingol. Information showing the damage establishments (fracture widths), concrete quality and the total fracture widths in the directions EW and NS belonging to Ozyil Housing Estate Blocks, and tg θ values calculated for each block have been given as whole in the table (Table.1).

In order to obtain the shock direction occurring in 1992 Erzincan Earthquake, the components in the directions of x and y of the virtual work in the cracking sections are calculated from the table:

tg θ value is calculated to be ratio of: $\sum Wx$ and $\sum Wy$

$$\operatorname{tg} \theta = \sum Wy / \sum Wx \text{ or } \operatorname{tg} \theta = \operatorname{Esy/Esx}$$

Thus, the shock direction of 1992 Erzincan Earthquake is obtained by taking the average $tg \theta$ value obtained for the blocks:

 $\operatorname{tg} \theta = \sum \operatorname{tg} \theta / 3 = (1.04 + 0.59 + 0.97) / 3 = 0.87$

BLOCK NAMES	IHLAS		FATIH		SINAN	
₩ (y) ₩ - E (x) S						
fc (N/mm2)	21,5		11,7		17,3	
	Σtix	Σtiy	Σtix	Σtiy	Σtix	Σtiy
321	10	12	32	33	32	32
	35	35	69	27	47	45
Σti	45	47	101	60	79	77
tgθ= Σtiy/Σtix	47/45= 1,04		60/101= 0.59		77/79= 0.97	

Table. 1 Cracks information of the Ozyil buildings and seismic shock directions

In order to determine the shock direction of 2003 Bingol Earthquake, it is stated that the work done during shifting and collapsing Celtiksuyu Regional Boarding Primary School Buildings is equal to the Seismic Energy and the angle θ of the shock direction concerning this earthquake is obtained:

Ex= V. $\delta x = V.(27.5cm) = 27.5V$ Ey=V. $\delta y = V.(15cm) = 15V$

tg θ =Ey/Ex=27.5/15=1.83

CONCLUSIONS

tg θ value presenting the shocking direction about any earthquake in this study has been obtained by benefiting from the diagnosis and measurement of the damage carried out the damage. For this purpose, an analytical calculation method developed with the acceptance that the Seismic Energy coming to the building is equal to the Virtual work consumed during the damage is also been presented.

The calculation method presented in the study has been applied on the damaged buildings having been examined in 1992 Erzincan and 2003 Bingol Earthquakes and the shock directions calculated for these earthquakes has been found to be tg $\theta = 0.87$ and 1.83.

These shock directions recorded for the same earthquakes have been given as $tg \theta = 0.80$ and 1.97 in turn. As seen, seismic shock directions belonging to both earthquakes can be able to be obtained with a deviation below %9 thanks to the calculating method proposed in the study.

On the other hand, it has clearly been seen that a great part of the damages occur in the first floors of examined buildings and these damages increase also with the decrease of the concrete quality.

REFERENCES

1. Isler,O.&O.C.Celik. "Damage surveys and strengthening of the Ozyil Buildings damaged during March 13, 1992 Erzincan Earthquake", Istanbul Technical University Construction and Earthquake Research Center, Technical Report, 1992.