RESPONSE OF RURAL DWELLINGS TO RECENT DESTRUCTIVE EARTHQUAKES IN TURKEY (1973-1975)

by

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SYNOPSIS

During this century, the seismic activity of Anatolia has been increasing. This paper emphasizes this fact and describes 3 destructive earthquakes which caused losses of lives and damages on structures during 1973 to 1975 (Feb.1, 1974-İzmir, M=5.2; March 27,1975-Gelibolu, M=5.7; Sept. 6,1975-Lice, M=6.9). First, İzmir and Gelibolu earthquakes parameters and characteristics are outlined and the damages on rural dwellings briefly stated. Then, Lice earthquake which caused great damage on rural dwellings is presented in the "standard form" (6). Finally, the design criteria of the prototype low-cost rural dwellings in the region has been discussed.

INTRODUCTION

Based on a statistical analysis using the instrumental records between 1904 to 1970, the "large earthquake" model, and the "Gumbel" distribution the seismic activity of Turkey can be expressed with $\log_{10} n = 3.973-0.654\ M$, where n is the yearly cumulative frequency (4). According to this expression, in Turkey the number of earthquakes with $M \geq 4.3$ is $n \simeq 15$. Another study which analyzes the earthquakes of Turkey between 1900-1970 gives $n = 18$ average value (5). Again, according to statistical analyses, in Turkey an earthquake of average $5.5 \leq M \leq 6$ is expected to occur each year. Below, earthquakes of Turkey given in the C.G.S. report is tabulized :

Year	n(M≥4.3)	M_{max}
1973	21	5.1
1974	22	5.2
1975	32	6.9

As can be seen from the table, during the last 3 years, a seismic activity which is greater than the average has been encountered.

Like in other countries, the earthquakes in Turkey cause damages especially in "low-cost rural dwellings" and the losses in lives are higher than their magnitudes would normally indicate. By the term "low-cost rural dwellings" the authors refer to dwellings that are built; a) without any engineering service, b) by using regional construction materials, c) by the owner himself.

For this reason, the authors have concentrated their studies of documenting destructive earthquakes in Turkey to the response of rural dwellings.

FEB. 1,1975 İZMİR EARTHQUAKE

On Feb.1,1975 (00h.01m.02s) an earthquake with magnitude 5.2, epicenter 38.6°N-27.0°E, and hypocenter 29 km. deep occured at a distance 26 km to İzmir. In this earthquake, 2 persons were killed, 7 injured, 15 dwellings fully

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and 200 partially damaged. Total loss was 3 million U.S. dollars. In the three months 3 aftershocks with $4 \leq M \leq 4.8$ have been recorded.

Since there are no low-cost rural dwellings in the region their damages could not be observed. From other types, 15 masonry dwellings were demolished, (fig.1), the conical roof of the historic clock tower fell off (fig.2), and wall cracks, column and chimney damages, and plaster peel offs were observed in roughly 200 masonry and reinforced concrete buildings.

MARCH 27, 1975 GELİBOLU EARTHQUAKE

On March 27,1975 (05h.15m.06s) an earthquake with magnitude 5.7, epicenter 40.4^{o}N-26.1^{o}E, and hypocenter 10 km deep occured. During this earthquake, 1 person was killed, 7 injured, and 292 houses all being rural dwellings completely demolished. 600 houses of which 85 % are rural dwellings have been partially damaged. Total loss was 6 million U.S. dollars. In the next three months, 5 after-shocks with $4 \leq M \leq 5.3$ have been recorded.

The earthquake caused structural damage mostly in Gelibolu, Labseki and Umurbey. The behavior of rural dwellings of the region during the earthquake have been summarized below :

Rural Dwelling Type	Ratio to Total Rural Dwellings	Demolished %	Damaged %	Undamaged %
Masonry (Brick-Stone)	72	15	22	63
Masonry (Adobe)	25	10	11	79
Others	3	-	2	98

In the region 75 % of the houses are low-cost rural dwellings. The predominant prototype rural dwelling of the region has a heavy roof, thick masonry walls, and one story. The epoxy material of the walls is mud. The earthquake responses are shown in figures 4 and 5.

SEPT 6, 1975 LICE EARTHQUAKE

The parameters of the Lice Earthquake has been given in the standard form (Table.1). From Turkey's view, Lice Earthquake is an interesting earthquake. According to 1953 years of statistical informations, an earthquake of this magnitude has not been encountered in the vicinity of Lice. Earthquakes with moderate magnitudes ($M \leq 5.2$) are still continuing and causing structural damage.

The structural damages are located in an ellipse shaped 3200 km2 area whose axes are 50 km long in the E-W and 20 km long in the N-S directions.

93 % of the structures in the region are low-cost rural dwellings. Prototype characteristics determined by surveying 146 typical low-cost rural dwellings are summarized in table I.

The performance of the rural dwellings in the region are given in the table below :

Rural Dwelling Type	Ratio to Total Rural Dwellings	Demolished %	Damaged %	Undamaged %
Masonry (stone)	93	60	32	8
Masonry (adobe)	5	48	45	7
Others	2	-	68	32

Figure 6 shows a reinforced concrete school. Figure 7 shows a low-cost rural dwelling district after the earthquake. Figure 8 displays the wooden roof beam and wall connection detail. Figure 9 shows the damage on a masonry

building. Figure 10 is a view of slightly damaged prototype low-cost rural dwellings and Figure 11 shows a detail from one of the rare buildings which was not damaged.

CONCLUSION

The design of earthquake resistant low-cost rural dwellings is a complex subject with large socio-economic dimensions. Using data gathered from the earthquake results, an emprical solution to the problem can be proposed. In each earthquake, there have been structures which stood up without damage, and these have been sources of hope and courage to the engineers and authorities.

Using the observed earthquake response results of low cost rural dwellings in Gelibolu and Lice, the following constructional criteria can be proposed for the prototype stone masonry dwelling of these regions :

1. It should be constructed on compacted deposits with rigid stone or concrete continuous foundation sitting on a layer of gravel (20 cm thickness).
2. Sizes of masonry stones should be in proportion to each other. Angular stones must be used. Adobe mortar should be stabilized with min 10 % cement.
3. Main walls should be surrounded with reinforced concrete laths.
4. The wooden floor beams should be firmly connected to the concrete laths using metalic tie elements.

The low-cost rural dwellings built applying the above principles with suitable material and workmanship standards, can be accepted as the most economic earthquake resistant structures in their regions.

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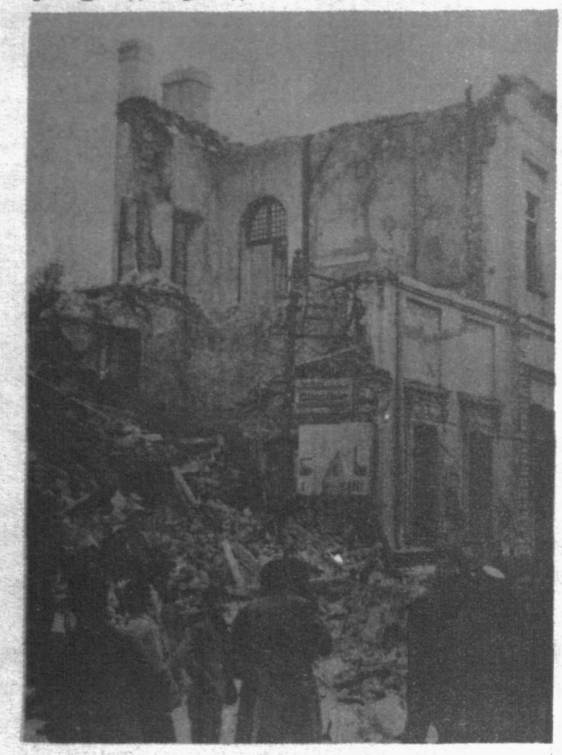
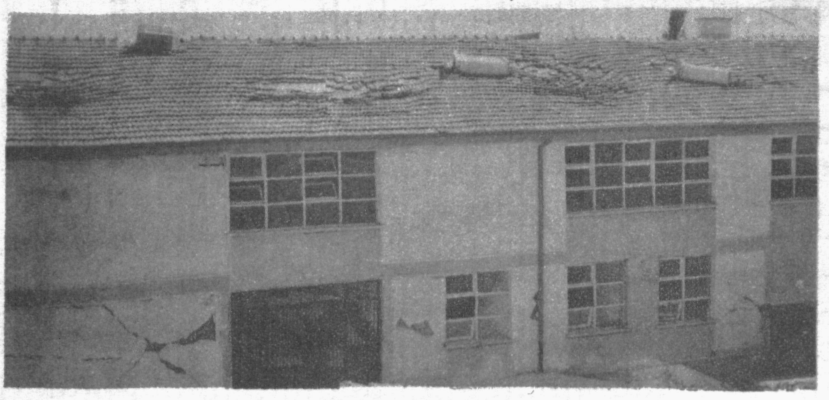
İZMİR EARTHQUAKE - FEB. I, 1974



Figures : 1 2 3 4 5

GELİBOLU EARTHQUAKE - SEPT. 6, 1975



Figures :

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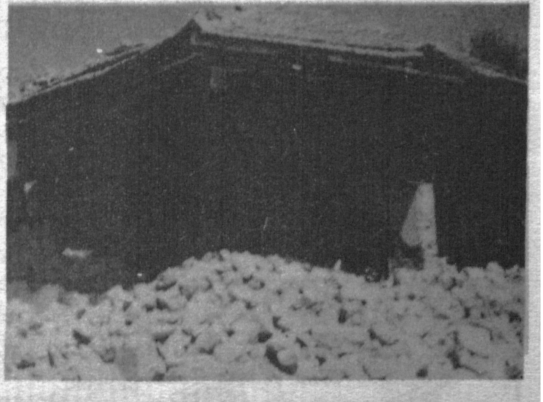


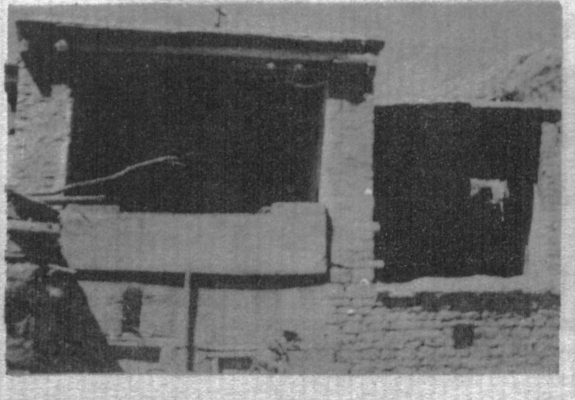
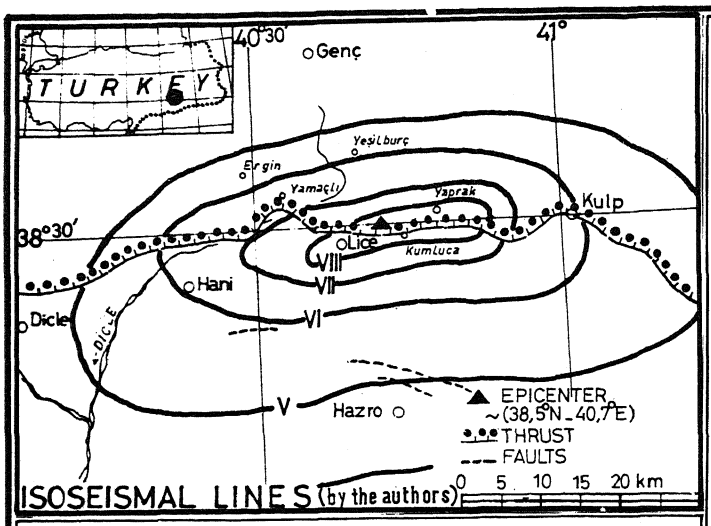


TABLE . I



TURKEY

LİCE

SEPTEMBER 6, 1975

Time (GMT)	:	09.22.27
Epicenter	:	38,5°N-40,7 E
Depth of hyp	:	16 km
Magnitude	:	7,4 ATH (LV) 6,8 UPP 6,9 (Average)
Acceleration(*)	:	350 gal
Energy	:	$5,63 \times 10^{21}$ Erg.
Feeling area	:	21×10^{4} km2
After shocks	:	6 after shocks in the first 3 months ($4 \leq M \leq 4,6$)

Earth movements(*):
Horizontal displacement of about 10 cm observed in the thrust, on the North of Lice, Pieces of miocene limestone (in the W-E direction), 1 to 4 tons, observed to be broken.

LIST OF DAMAGES :

Lives lost	:	2338 people
Injured	:	4657 people
Demolished	:	5381
Damaged	:	7023
Total loss		21×10^{6}

Structural damages have been increasing due to earthquakes which occured in 1976.

GEOLOGICAL AND TECTONIC STRUCTURE :

The south is undifferentiated marine miocene On the north, a zone of upper cretaceous (W-E dir). of 5 to 30 km.width and undifferentiated metamorphic series take place successively.

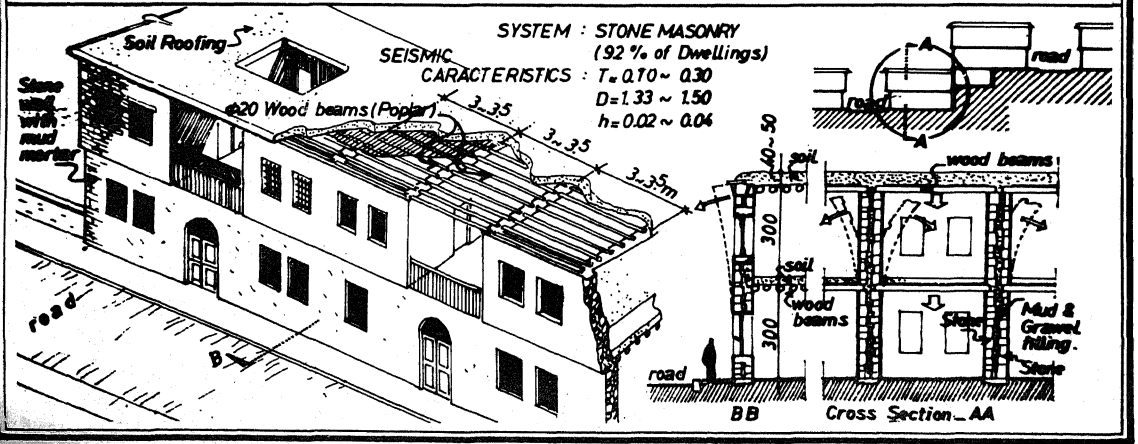
On the north a long thrust, born from Alpide belt, extends in E-W dir. a zone which the eugeosyneline has been pushed over the miageosyneline. On the south; small, motionless faultings exist, from cracks in miocene limestone.

SEISMIC ACTIVITIES : (Summarized from Ref.1)

Year	Epicenter	Magnitude	I_0(MM)
12.11.1934	39,0N-41,0E	6,0	VII
28. 3.1954	39,1N-41,0E	7,0	IX
7. 7.1957	39,0N-40,5E	6,5	VIII
22. 5.1971	38,8N-40,5E	7,0	IX

$\log_{10} N = 4,30 - 0,54\ M$ / $(35^{o}-39^{o})N-(38^{o}-45^{o})E$
N: Number of earthquakes in 1973 years (Ref.2)

TYPICAL RURAL DWELLING IN THE REGION:



(*) Observed by the authors in the region.