Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.VII)

13-2-5

REDUCING EARTHQUAKE LOSSES IN EASTERN TURKEY

Andrew COBURN[1], Robin SPENCE[1], Nejat BAYÜLKE[2], Oktay ERGÜNAY[2]

1 The Martin Centre for Architectural and Urban Studies, University of Cambridge, 6 Chaucer Road, Cambridge CB2 2EB, England
2 Earthquake Research Department, Ministry for Public Works and Housing, Ankara, Turkey

SUMMARY

Eastern Turkey is an area of exceptionally high loss of life in earthquakes and in addition, costs the Turkish Government considerable sums in reconstruction aid to damaged villages. A study of strategies to reduce earthquake losses in Eastern Turkey was undertaken by the Earthquake Research Department of the Ministry for Public Works and Housing in collaboration with the Martin Centre for Architectural and Urban Studies, University of Cambridge. The principal conclusion is that a programme of subsidised strengthening for construction of new village houses can be expected to save twice as much in reconstruction costs over 25 years as the programme costs. In addition to saving economic expenditure it is calculated to save around 3,000 lives.

INTRODUCTION

In the past 80 years, over 50,000 people have been killed by earthquakes in Eastern Turkey; equivalent to 1% of today's population. This severe level of earthquake risk is due to a combination of high seismicity from the intersection of two major fault systems; the North Anatolian Fault and the East Anatolian Fault, together with a predominance of owner-built, weak stone and adobe masonry buildings. Over the next 25 years it is expected that the region will experience at least 8 large earthquakes ($6.0<M<7.0$) and it is highly probable that there will occur a very large magnitude event ($7.0<M<8.0$). These events will take place in a region of rapidly increasing population, likely to double within the 25 years.

Elsewhere in Turkey, housing stock has upgraded to higher-cost, less vulnerable construction with rises in income levels and standards of living. For a number of reasons, these changes have been very much slower in Eastern Anatolia and the prospects for rapid rises in income levels in the immediate future are generally held to be poor.

Earthquake losses could be reduced by helping villagers in the areas of highest risk to build more earthquake resistant houses at low cost. A Government programme could help villagers by training craftsman builders in earthquake-resistant construction techniques, raising public awareness of earthquake risk, and possibly subsidising the additional cost of incorporating strengthening into normal construction. The costs of such a programme could be considerable, so the costs and benefits of any proposal should be carefully considered.

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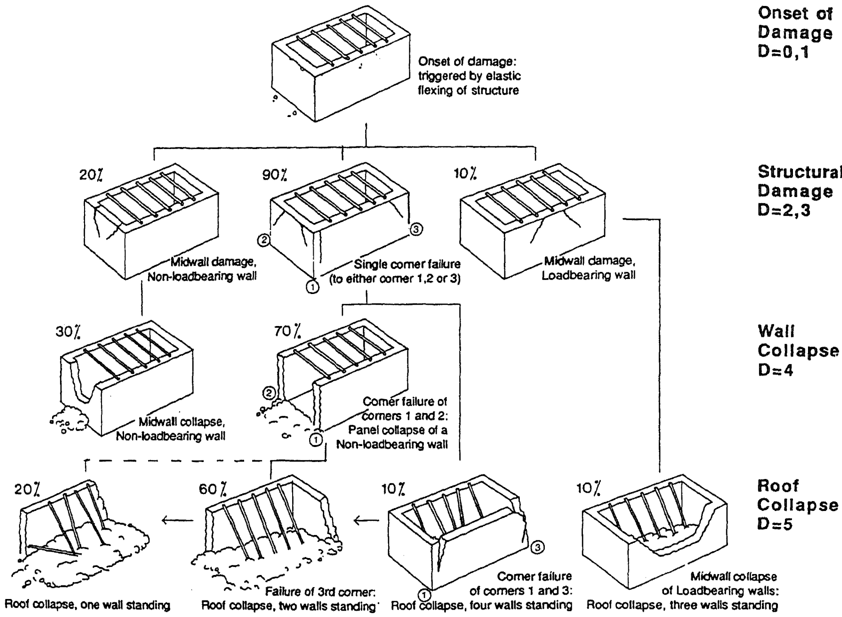

DAMAGE TO TRADITIONAL BUILDINGS

Analysis of the performance of weak masonry buildings (1) in earthquakes indicates that their extreme vulnerability is the result of lack of integrity of the walls; inadequacy of bonding between walls at corners; lack of connection between roofs and walls, and absence of rigidity in the roof plane. Damage, initiated at inherent planes of weakness, quickly develops to collapse. Based on these observations, a spectrum of alternative strengthening proposals L1-L9 was drawn up, of increasing cost with increasing resistance to earthquake forces, and suitable to increasing levels of organisation and technological capability on the part of the builder.(3)

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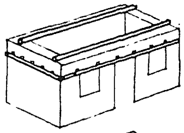
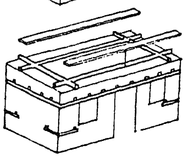
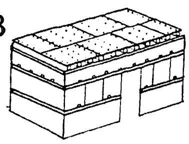
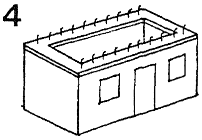
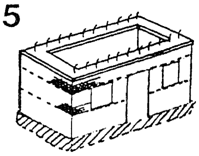
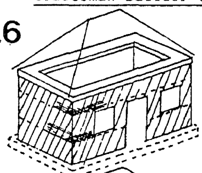
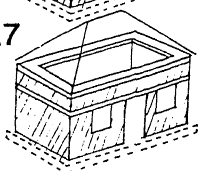
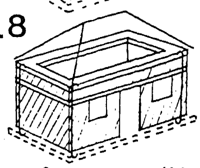
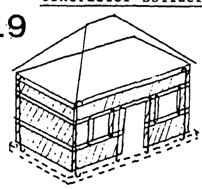
Level of building operation required:		Owner Builder or Craftsman Builder	Approximate Additional Cash Cost (materials only) (TL 1983)	As % cost of House Type: A	B	C
C	L1 	● Single horizontal timber hatil at lintol level. ● Sturdy wall-plate 10 x 10 cm, running length of loadbearing wall with all roof beams nailed securely to wall plate. ● All good building practices and annual maintenance from table 2, (A).	30 000	10%	6%	-
C	L2 	● Single horizontal timber hatil at lintol level. ● Sturdy wall-plate with tie across non-loadbearing wall. ● Timber corner reinforcements at cill level. ● Planks nailed across roof beams. ● Good building practices and annual maintenance from table 2, (A).	45 000	15%	9%	-
C	L3 	● Three horizontal hatils; eaves, lintol cill levels. ● Plywood sheeting or boarding nailed across roof beams. ● Good building practices and annual maintenance from table 2, (A and B).	120 000	40%	23%	-
		Craftsman Builder only				
D	L4 	● Thin reinforced concrete ringbeam (10 cm x 60 cm, 2 ϕ 12 bars with ϕ6 bars @ 40 c.c) ● Steel straps cast into ringbeam for fixing roof beams or trusses. ● Good building practices and maintenance from table 2, (A and B).	50 000	-	9%	4%
D	L5 	● Thin reinforced concrete ringbeam ● Two horizontal courses of light reinforcement (2 o10 bars or expanded metal mesh) laid in thin courses of cement mortar. ● Foundations of large boulders in cement mortar. ● Plywood sheeting or boarding nailed over roof. ● Good building practices, table 2, (A and B).	150 000	-	28%	12%
		Craftsman Builder (or Contractor Builder)				
D	L6 	● Substantial reinforced concrete ringbeam, (20 x 60cm, 4 ϕ12 bars with ϕ6 stirrups @ 30cm) ● 1.6 cement:sand mortar throughout. ● Two horizontal courses of light reinforcement. ● Reinforced concrete foundations. (Table 2 measures less critical) (Lightweight pitched roof assumed)	270 000	-	51%	22%
D	L7 	TURKISH BUILDING CODE SPECIFICATION (ERI 1975) ● Substantial reinforced concrete ringbeam. ● 1:2:6 cement:lime:sand mortar throughout ● Reinforced concrete lintol beam, as ringbeam. ● Reinforced concrete foundations.	350 000	-	66%	28%
D	L8 	● Substantial reinforced concrete ringbeam. ● Reinforced concrete lintol beam. ● Vertical reinforcement, in concrete at corners. (ϕ16 bar anchored to foundations and ringbeam in 10 cm cavity filled with concrete). ● Reinforced concrete foundations. ● 1:2:6 cement:lime:sand mortar.	400 000	-	-	32%
		Contractor Builder only				
E	L9 	● Reinforced concrete roof slab cast monolithically with substantial reinforced concrete ringbeam. ● Two horizontal reinforced concrete wall beams, as ringbeam, at lintol and cill levels. ● Vertical reinforcement at corners, full height. ● Vertical reinforcement at edges of openings between cill and lintol beams. ● Reinforced concrete foundations ● 1:2:6 cement:lime:sand mortar	500 000	-	-	40%

IMPULSE TABLE TESTING

Dynamic tests on full-scale buildings incorporating the strengthening proposals was conducted using a specially designed *impulse table.* (2) The table has plan dimensions of 5m x 6m, and can impart an initial acceleration of 2.0g to a test building weighing 40t.with controllable peak amplitude and frequency. The total cost of the table and equipment constructed in Ankara in 1985/86 was US$21,000. The comparative performance, in terms of damage level, of three test houses, L0 (unstrengthened masonry), L3 (timber ring beams) and L5 (concrete ringbeams) subjected to identical series of impulses of increasing amplitude, is shown in Figure 4.

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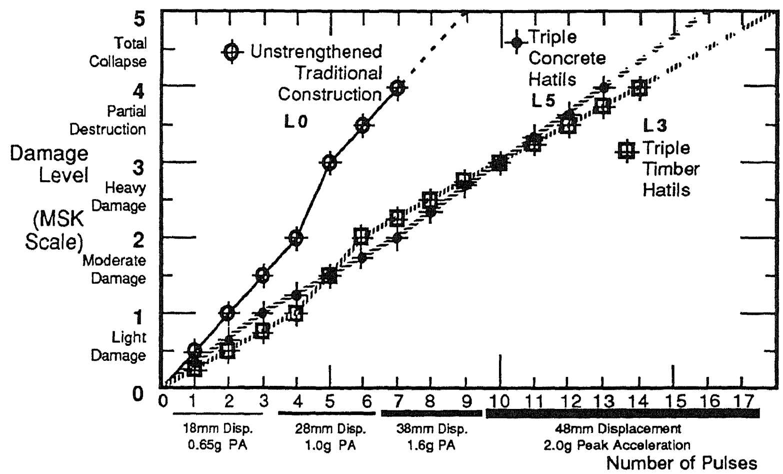

EVALUATION OF COSTS AND BENEFITS OF STRENGTHENING

The results of these tests and relative damage data from past earthquakes has been used to define the vulnerability of each strengthened building type. In a seismic risk model *DEPREM,* the expected earthquake activity over the next 25 years is combined with their resultant expected damage to determine the cost-effectiveness of strengthening the 1 million houses in Eastern Anatolia to different levels. The least overall economic cost, summing up all strengthening costs and reduced earthquake reconstruction costs, is that achieved by using the strengthening technologies L4 and L5.(5) In these cases the overall cost is lower than if no strengthening programme had been undertaken. Thus investment in stronger buildings over a 25 year period will save considerably more in saved reconstruction costs than the initial costs of strengthening. Applied to the high risk areas generally, it would also save over 3,000 lives during this period.

These estimates are based on expected average values, and are subject to a high degree of uncertainty. Uncertainty levels have been determined at each stage of the analysis and for the whole analysis using Discrete Event Simulation Techniques. For the traditional buildings, there is a 73% probability that the actual losses will be within +/-50% of the average predicted losses. For strengthed building types the confidence limit is 40% probability of being within +/-50%, and for loss of life estimates, only 10-20% of being within +/-50%.

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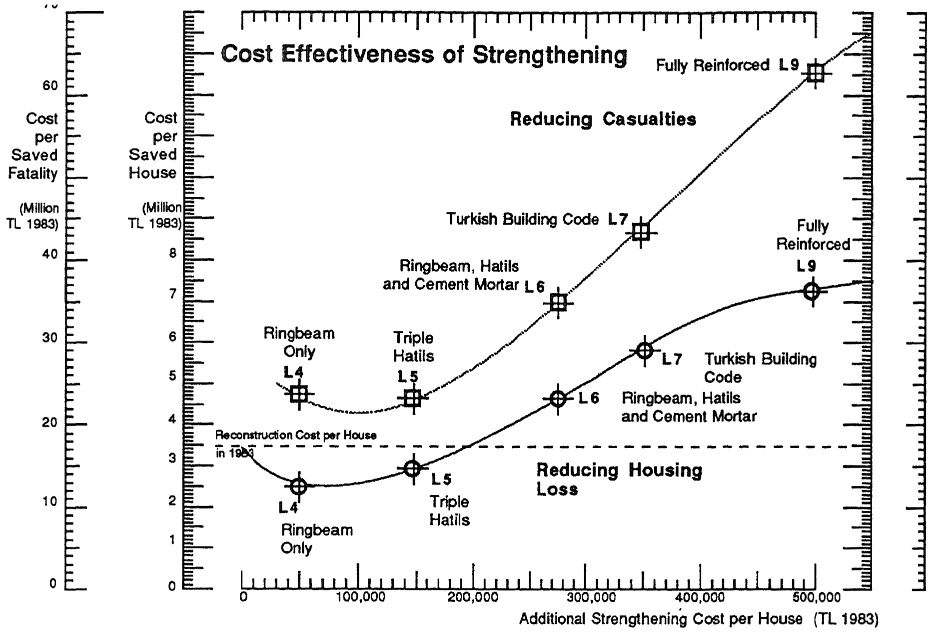

ALTERNATIVE FUTURE SCENARIOS

A variety of alternative scenarios were analysed based on varying assumptions on future population growth, economic growth, rate of new construction, and extent of government intervention. In each case estimated future losses of housing were calculated over a 25 year period(6). A builder training programme, D, if effective in pursuading owners to pay for their own strengthening costs, could stop earthquake losses increasing significantly. But only an additional government subsidy, E, for house strengthening could effectively reduce the current loss rate of 2,600 houses per year.

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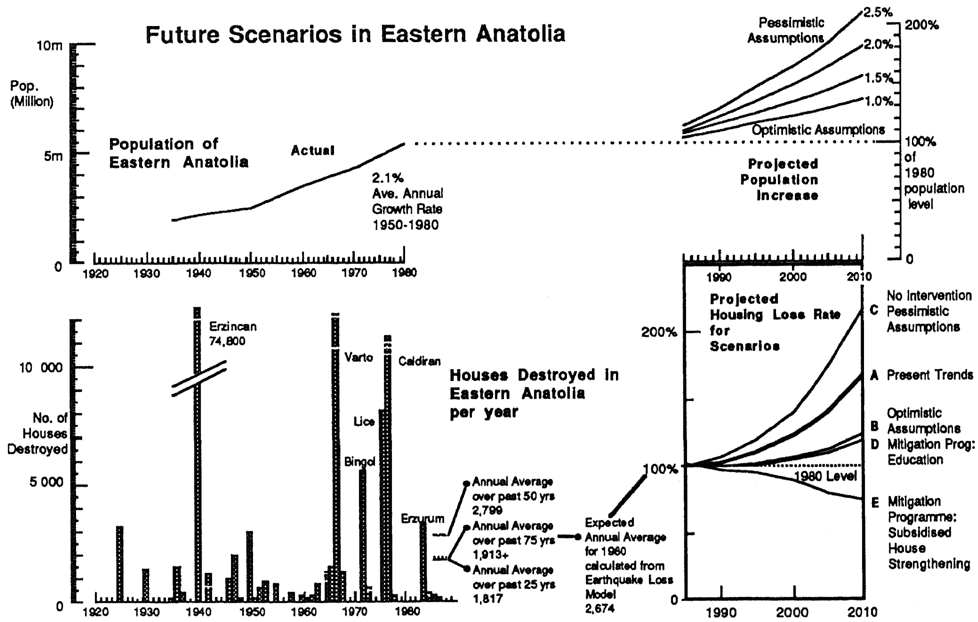

FUTURE STUDIES

An approach similar to those described above is currently being used to develop a computer model for future loss estimations, and applications to urban and regional case studies are in progress in Bursa (Turkey), Campania (Italy) and Mexico City.

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