THE BEHAVIOUR OF TRADITIONAL BUILDING SYSTEMS AGAINST EARTHQUAKE AND ITS COMPARISION TO REINFORCED CONCRETE FRAME SYSTEMS; EXPERIENCES OF MARMARA EARTHQUAKE DAMAGE ASSESMENT STUDIES IN KOCAELİ AND SAKARYA

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The Marmara Earthquake disaster, which occurred in a geographical region covering almost seven provinces in north-west of Turkey (Kocaeli, Sakarya, Bursa, İstanbul, Bolu, Eskişehir, Yalova) on 17th of August 1999, had caused high loss of life and property. ***(Figure 1)*** A total of 18.373 people lost their lives, 48.901 people were injured, 317.493 dwelling units and 47.412 work places were damaged. (Ministry of Public Works and Settlements, 2000) Almost ten days after the disaster, the technical staff from the Ministry of Public Works and Settlements, General Directorate of Disaster Affairs, Bank of Provinces and General Directorate of Highways were transferred to the disaster area for damage assessment studies.

This study attempts to present the experiences get from Marmara Earthquake damage assessment studies in which the authors took place actively. The paper summarizes the observations of the authors from the damage assessment studies about the behaviour of traditional building systems and reinforced concrete structures against to earthquake in some districts of Kocaeli and Sakarya. According to the result of observations, suggestions are put forward for new construction systems, for strengthening methods of the existing traditional building stock and for physical planning of cities.

INTRODUCTION

The damage assessment studies covered several districts of two different provinces; Kocaeli, being the epicentre of the earthquake, had ***heavily damaged / collapsed*** 35839 residences and 5478 workplaces, ***moderately damaged*** 41100 residences and 5861 work places, ***slightly damaged*** 45111 residences and 6122 workplaces. Sakarya had ***heavily damaged / collapsed*** 24689 residences and 5146 workplaces, ***moderately damaged*** 18406 residences and 3764 work places, ***slightly damaged*** 24423 residences and 2349 workplaces. (Ministry of Public Works and Settlements, 2000) ***(Table 1)***

The damage assessment teams in which the authors participated, determined about 4000 residences and work places of which is, ***8% heavily damaged / collapsed, 13% moderately damaged, 18% slightly damaged, 61% undamaged*** in ***Kocaeli-Gölcük*** region ***(Table 2)***, about 3500 residences and workplaces of which is, 16***% heavily damaged / collapsed, 51% moderately damaged, 22% slightly damaged, 11% undamaged*** in ***Sakarya*** region. ***(Table 3)***

CLASSIFICATION OF CONSTRUCTION SYSTEMS AND DAMAGES

The building stock of the damage assessment study area can be presented mainly by 4 construction systems;

- ***Timber framed structures***

  Hımış

  Bağdadi
- ***Frameless Brick and Masonry buildings***
- ***Reinforced concrete framed structures***
- ***Unframed buildings with planar reinforced concrete bearing elements***

KOCAELİ- GÖLCÜK

In **Kocaeli-Gölcük** the study was carried on three districts; Kavaklı District, Dumlupınar District and Şehitler District. The greatest destruction was seen in ***Kavaklı Distirct,*** which is located in the city center along the seacoast. Reinforced concrete framed buildings are dominant (75%) and ground bearing capacity is low (poor soil condition) in this area.

Reinforced concrete frame systems are known to be one of the most sensitive systems to earthquake loads if they are constructed with adequate engineering, correct construction techniques, proper detailing, inspection and good workmanship. However in this region, most of the above requirements that were not fulfilled, have become the reasons for high damage on reinforced concrete frame structures. The highest level of damage was observed in reinforced concrete frame systems over 5 stories. ***(Table 2b, Table 2c)*** The damage ratios of reinforced concrete frame buildings were less for 1-4 storey buildings in comparison to 5-8 storey buildings. The damage ratio increased as the number of stories increased.

The damages determined in reinforced concrete frame structures were: ***slightly damaged;*** cracks on infill material extended through reinforced concrete frame, damages on cladding connections, ***moderately damaged;*** beam concrete spalling, column concrete spalling, columns out of plump ***highly damaged;*** breaking of column-beam connections, deviation in the vertical building axis, collapse of basement and ground floors (bottom-up collapse), partial or total collapse of the structural system etc.

Not only the low quality concrete, poor detailing and poor construction, but also poor soil conditions, attached pattern settlement, high density, soft-stories at ground floor level were some of the other factors maximizing the level of damage.

The level of damage is less in ***Şehitler District,*** which is much more a rural settlement area. Most of the buildings are settled towards the side of hills. The soil condition is hard and the building stock is made up of 2-3 storey timber framed structures and 3-4 storey frameless brick and masonry buildings by 49% and, 3-7 storey reinforced concrete framed buildings by 51%. Even though the building stock is almost fifty-fifty in reinforced concrete frame structures and traditional systems (covering timber frame structures, masonry and frameless brick buildings), the level of damage is much higher in reinforced concrete frame structures when compared with the traditional style buildings. ***(Table 2a)*** Moreover the number of the deaths (available numbers on the site study) was 287 in RC frame buildings whereas it was only 3 in traditional style buildings.

SAKARYA

In **Sakarya** the study was carried on three districts; Cumhuriyet District, Ozanlar District and Yahyalar District. ***Cumhuriyet District*** is located in the rural area and building stock is mostly made up of ***timber framed structure with different infill materials.*** These timber framed structures fall into two main groups. The first is called ***"hımış"*** where the timber frame is infilled with adobe, stone masonry or brick. The other is ***"bağdadi"*** where the voids between the timber framing elements is filled lighter materials, or with a form of plaster/lime rendering on wooden lath. ***(Figure 2)*** (Ergünay & Gülkan, 1999) Both kinds of timber framed structures are endowed with good earthquake resistance in spite of the fact that they are slightly damaged, moderately damaged and rarely highly damaged. The number of reinforced concrete frame structures were only 7, 2 of which were under construction and 5 of which were highly damaged. ***(Table 3a)***

The damages determined in timber frame structures can be classified as: ***slightly damaged****;* where vertical cracks were mostly placed either at the corners or at the mid of the walls (0.5mm.)**,** ***moderately damaged;*** vertical and horizontal cracks on the walls (2mm.), corner cracking especially at openings, wall deformation, deformation of walls along the wooden beams and separation of walls from the beams, roof separation from wall, ***highly damaged;*** partial collapse in the structural system or total collapse.

It is clear that if these traditional buildings were constructed with adequate engineering, proper material and high quality construction, the damage would be less. High seismic resistance of wooden buildings is the result of lightness and spatial character of the response of elements during earthquakes. (Khaimov & Nurtaev,1999)

Ozanlar and Yahyalar Districts are located in the city centre, mostly made up of co-operatively produced mass-housing buildings. These buildings have very poor construction quality. Therefore the impact of the disaster is very high. The existing traditional building stock was slightly damaged, moderately damaged, undamaged and rarely highly damaged. ***(Table 3b, 3c)***

In the whole earthquake disaster region (especially Kocaeli –Yahyakaptan Mass Housing Area) it was observed that, unframed buildings with planar reinforced concrete bearing

elements were undamaged. Due to their space multibracings and high level of static uncertainty, these systems are less sensitive to errors during erection, more advantageous from the point of view seismic energy dissipation and more stable. (Khaimov & Nurtaev,1999)

RESULTS AND SUGGESTIONS

The results of damage assessment studies in several districts of Kocaeli and Sakarya show that, the traditional buildings, which are timber frame structures, masonry and frameless brick buildings presented good earthquake resistance even though they were made from weak local materials. Especially timber frame structures, were mostly slightly damaged since, they are light and flexible. The damages were usually determined on the infill materials such as, adobe, stone or brick whereas the timber frame structural system stayed stable.

In the study area, Reinforced Concrete Frame Structures presented high level of damage due to low quality concrete, inadequate engineering, incorrect construction techniques, poor detailing, inadequate inspection or observation of construction, lax attitude of authorities in the application of Building Code Requirements.

It should be pointed out that, besides the construction techniques, inappropriate land use decisions, settlement for residential purposes on the risky sub zones, high density areas without enough spaces in between, formation of informal settlement and squatter areas maximised the impact of the disaster.

Taking in to account the results of Damage Assessment Studies the suggestions can be classified in to two groups;

Suggestions for Construction Systems:

- According to the results of damage assessment study; reinforced concrete frame structures presented high level of damage. Under these conditions, it is necessary to examine why reinforced concrete frame structures were applied and still continuing to be applied in such a wide range. Urban Legislation, Building Codes etc. are still continuing to direct the

professionals for the choice of reinforced concrete systems, disregarding the alternative structural systems. The earthquake resistance of traditional buildings (especially timber frame structures) in Marmara Earthquake points out the fact that reinforced concrete frame system should not be seen as the only alternative for contemporary construction systems.

- Reinforced construction systems deserves a fundamental revision and also alternative construction systems should be applied. For new constructions, less vulnerable construction systems should be preferred such as steel frame structures or unframed buildings with planar reinforced concrete bearing elements for high storey buildings and timber frame structures for low-storey buildings.

- Strengthening methods should be developed not only for reinforced concrete frame structures but also for the existing traditional building stock. In the region, traditional buildings were mostly constructed by their owners, without being served any engineering services. In the construction of new timber frame and masonry buildings and also for strengthening of damaged traditional building stock, it is necessary to train public through training programmes such as; use of proper materials, carpentering etc. These training programmes can be supervised by Non Governmental Organisations or Local authorities.

- The observations during the damage assessment studies showed that if the buildings can be constructed with proper material and good workmanship, the resistance to earthquake will be higher. Therefore much more importance should be given for the effective use of technicians and foremen during construction process. The productive power of these people in the construction sector should not be disregarded and training programs should be provided in order to eliminate their lack of technical aspects.

- Site inspections should be conducted at various stages of the construction process. Design and construction details should be complied with Building Codes, Technical regulations and standards.

- It should be taken into consideration that the education of architects and civil engineers is as much as important as correct construction techniques dealing with the earthquake reality. In the current education system, reinforced concrete construction system is taken

as the main focus for building construction. During architecture education, training programs should be provided introducing alternative construction systems. Considering our traditional building culture, the use of timber frame structures should be encouraged. Much more emphasis should be given on the training of students about the development of architectural design of traditional building systems and their implementation.

Suggestions for Physical Planning of Cities

- In order to diminish the negative effects of earthquakes, the earthquake problem must be directly related to the physical planning of cities, the policies of urbanization , land use, density usage, pattern of settlement.

- The application of preventing policies, plans and measures should be facilitated through legislation. Central and Local Government should assume greater initiative in such legislation in the field of prevention particularly regarding land use and other aspect of physical planning. (Şengezer,1999)

- To minimize the impact of the earthquake, the most appropriate way of using the available land should be provided, risky zones with poor soil conditions should be avoided for housing areas .

- High density areas should be broken down into smaller sub zones separated by green spaces. Studies should be made to define the optimum density and the optimum number of stories to minimize the damage.

- Usage density should be kept as low as possible in high risk areas. Measures should be put into affect about settlement patterns and arrangement of buildings relative to each other, division of land blocks .

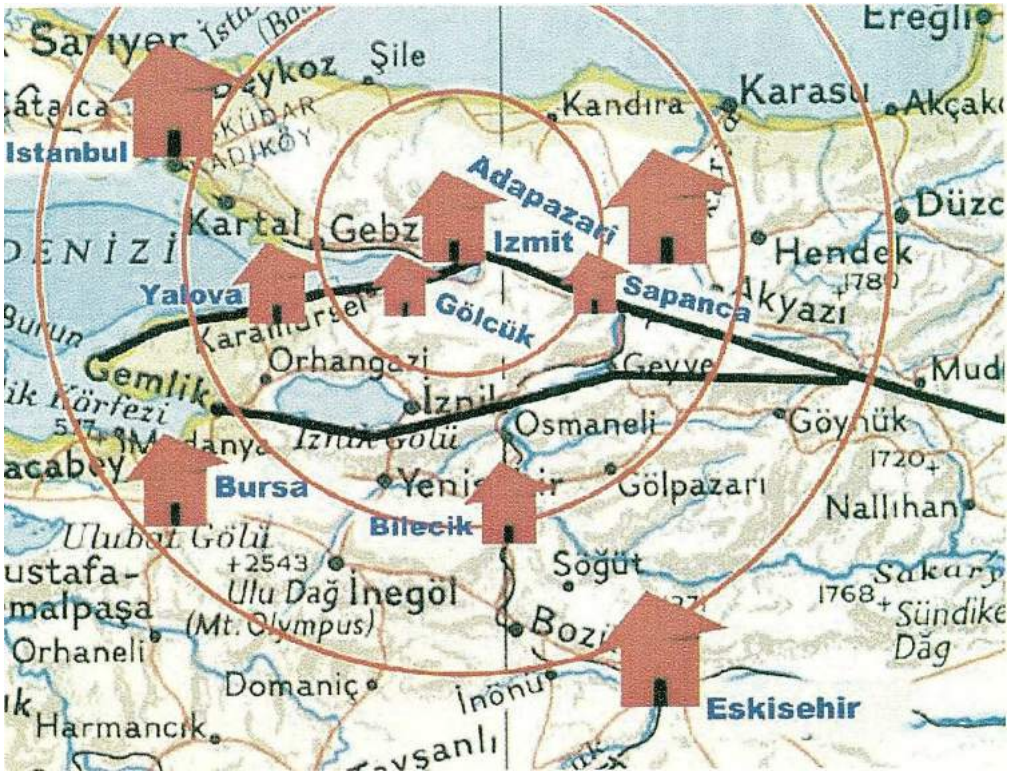

Figure 1. The epicenter of Marmara Earthquake

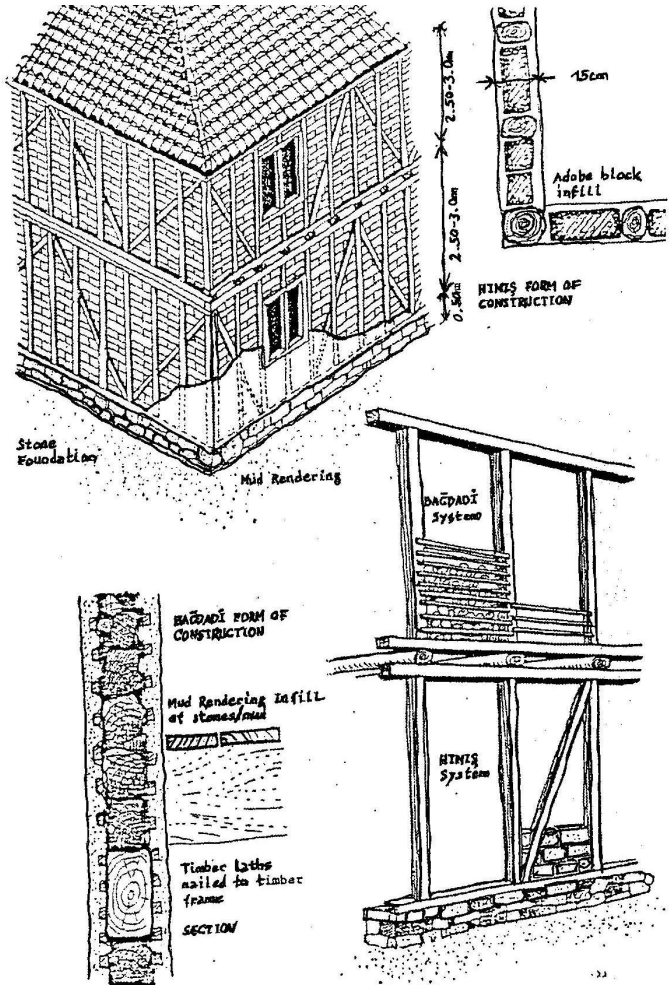

Figure 2. Timber Frame Structures (Hımış, Bağdadi)

DAMAGE ASSESSMENT RESULTS

23.05.2000

	DAMAGE CLASSIFICATION					
	COLLAPSED/ HEAVILY DAMAGED		MODERATELY DAMAGED		SLIGHTLY DAMAGED	
PROVINCE	**RESIDENCES**	**WORKPLACES**	**RESIDENCES**	**WORKPLACES**	**RESIDENCES**	**WORKPLACES**
BOLU	2334	219	6099	902	5736	837
BURSA	141	3	571	25	940	68
DÜZCE	16666	3873	10968	2573	10124	1422
ESKİŞEHİR	90	21	167	18	314	22
İSTANBUL	3051	447	15102	2510	14065	1943
KARABÜK	0	0	76	0	99	1
KOCAELİ	35839	5478	41100	5861	45111	6122
SAKARYA	24689	5146	18406	3764	24423	2349
YALOVA	13895	751	14540	1159	11879	1885
ZONGULDAK	91	1	286	4	691	8
TOTAL	**96796**	**15939**	**107315**	**16816**	**113382**	**14657**

* The figures cover the damage of 12 November 1999 Bolu-Düzce Earthquake, as well.

SOURCE:

Ministry of Public Works and Settlement, General Directorate of Disaster Affairs, Crisis Management Center.

Republic of Turkey, Ministry of Public Works and Settlement, General Directorate of Disaster Affairs.

Table 1.

DAMAGE ASSESSMENT RESULTS IN ŞEHİTLER, KAVAKLI, DUMLUPINAR DISTRICTS OF GÖLCÜK(KOCAELİ)						
	Heavily damaged/ Collapsed	**Moderately damaged**	**Slightly damaged**	**Undamaged**	**Total Residences + Workplaces**	**The Ratio of Reinforced Concrete Structure (RC) to Traditional Structures (TS)**
ŞEHİTLER	64	75	213	1251	**1603**	**49% TS 51% RC**
KAVAKLI	195	300	161	599	**1255**	**25% TS 75% RC**
DUMLUPINAR	61	145	346	590	**1142**	**18% TS 82% RC**
TOTAL	**320**	**520**	**720**	**2440**	**4000**	**32% TS 68% RC**

Table 2

DAMAGE ASSESSMENT RESULTS IN CUMHURİYET, OZANLAR, YAHYALAR DISTRICTS OF SAKARYA						
	Heavily damaged/ Collapsed	**Moderately damaged**	**Slightly damaged**	**Undamaged**	**Total Residences + Workplaces**	**The Ratio of Reinforced Concrete Structure (RC) to Traditional Structures (TS)**
CUMHURİYET	8	122	320	150	**600**	**92.5% TS 7.5% RC**
OZANLAR	257	653	260	130	**1300**	**30% TS 70% RC**
YAHYALAR	295	1010	190	105	**1600**	**20% TS 80% RC**
TOTAL	**560**	**1785**	**770**	**385**	**3500**	**37% TS 63% RC**

Table 3.

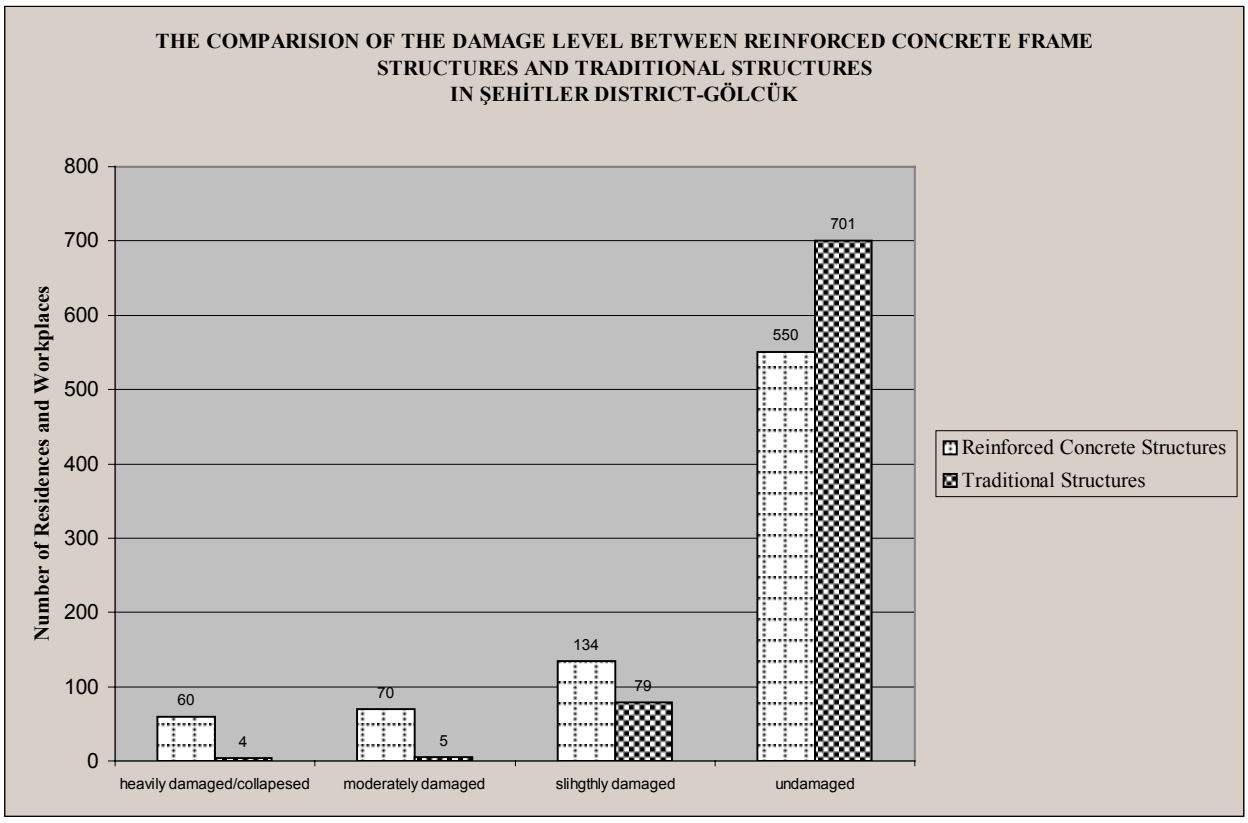

Table 2A.

Reinforced Concrete Structures:814
Traditional Structures:789
Total:1603

<u>ŞEHİTLER DISTRICT:</u>

- ***Location:*** Located near to Rural Area of Gölcük.
- ***Damage Assessment:*** 1603 Residences and workplaces
- ***The ratio of Reinforced Concrete Structures(RC) to Traditional Structures (TS): 49% TS 51% RC***

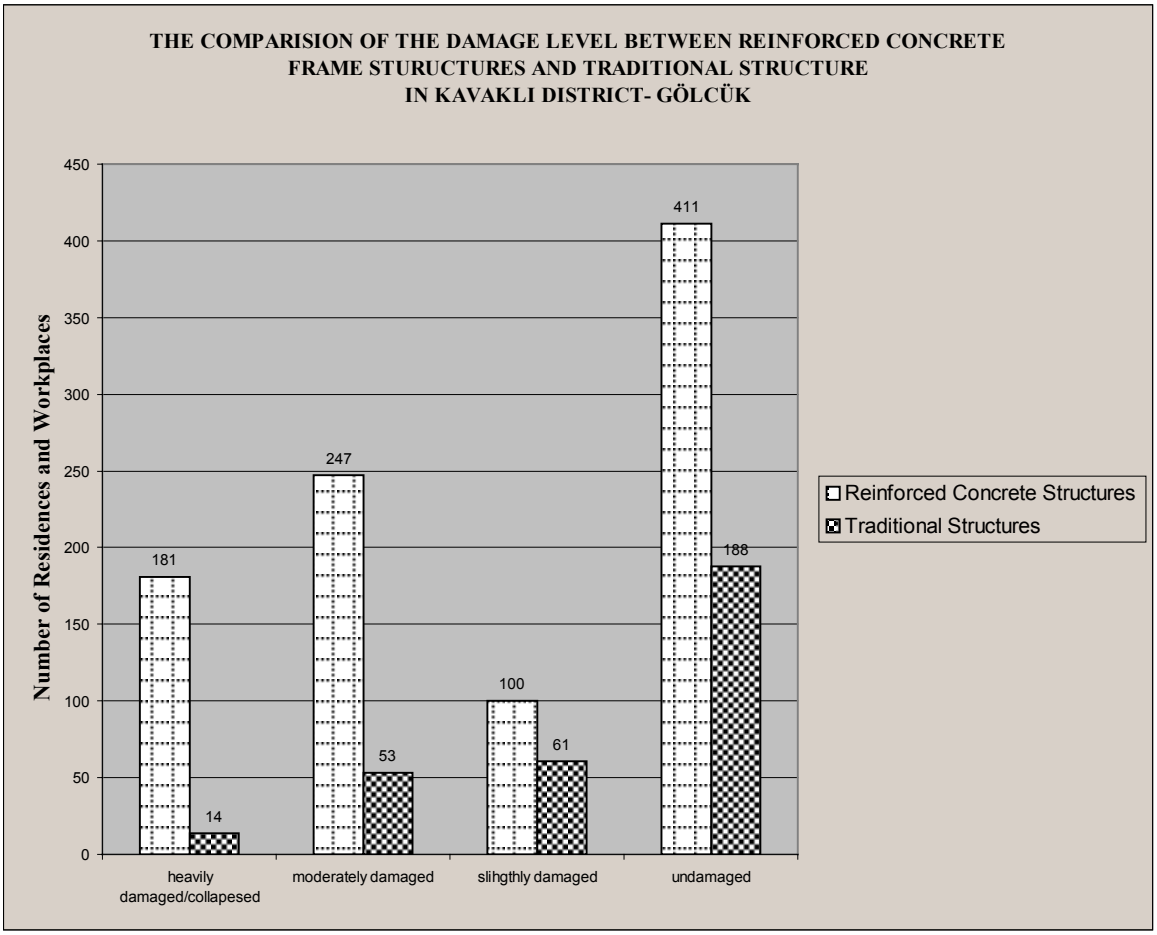

Table 2B.

Reinforced Concrete Structures:939
Traditional Structures:316
Total:1255

KAVAKLI DISTRICT:

- ***Location:*** Located in the city centre along the seacoast having poor soil conditions
- ***Damage Assessment:*** 1255 Residences and workplaces
- ***The ratio of Reinforced Concrete Structures(RC) to Traditional Structures (TS): 75% RC 25% TS***

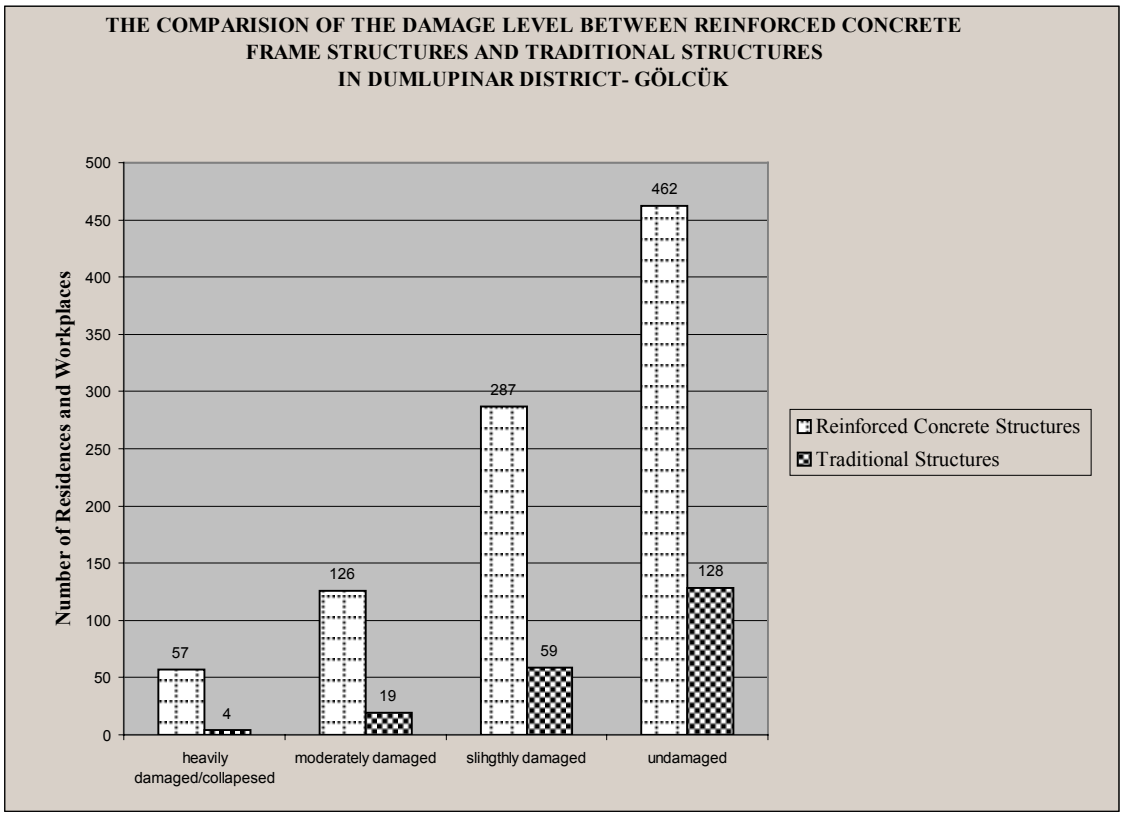

Table 2C.

Reinforced Concrete Structures:932
Traditional Structures:210
Total:1142

DUMLUPINAR DISTRICT:

- ***Location:*** Located in the city centre.
- ***Damage Assessment:*** 1142 Residences and workplaces
- ***The ratio of Reinforced Concrete Structures(RC) to Traditional Structures (TS): 82% RC 18% TS***

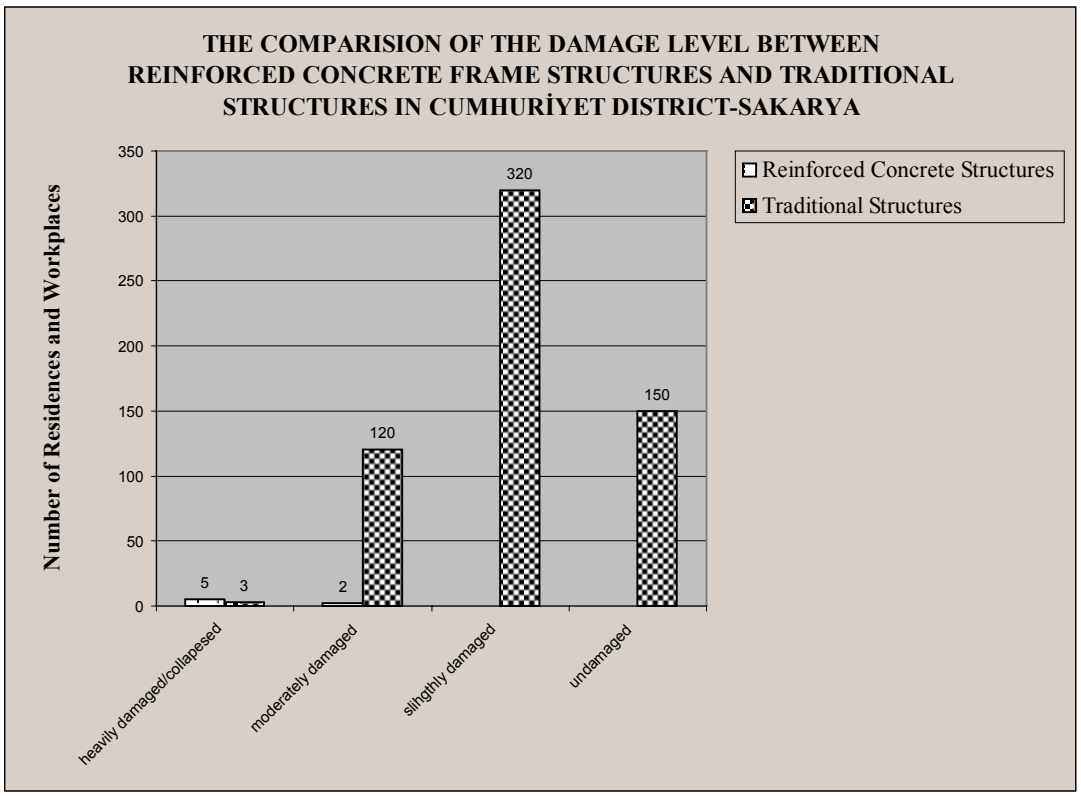

Table 3A.

Reinforced Concrete Structures:7
Traditional Structures:553
Total:600

CUMHURİYET DISTRICT:

- ***Location:*** Located in the Rural Area of Sakarya. There were only (7) Reinforced Concrete Structure Buildings (2 of them under Construction) and (3) of them were highly damaged
- ***Damage Assessment:*** 600 Residences and workplaces
- ***The ratio of Reinforced Concrete Structures(RC) to Traditional Structures (TS): 92.5% TS 7.5% RC***

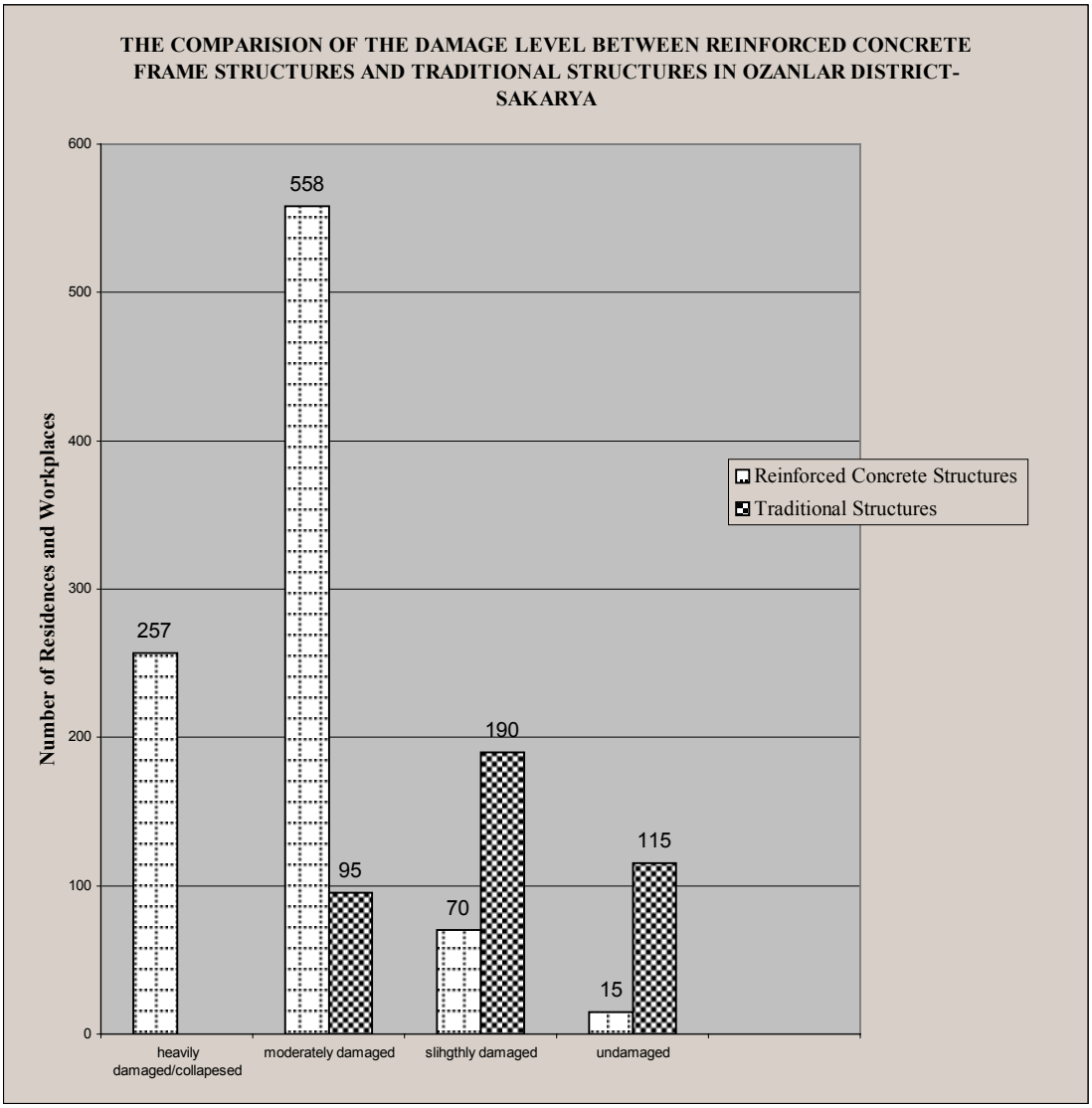

Table 3B.

Reinforced Concrete Structures:900
Traditional Structures:400
Total:1300

OZANLAR DISTRICT:

- ***Location:*** Located in the city centre having mostly co-operative mass housing and some traditional buildings
- ***Damage Assessment:*** 1300 Residences and workplaces
- ***The ratio of Reinforced Concrete Structures(RC) to Traditional Structures (TS): 70% RC 30% TS***

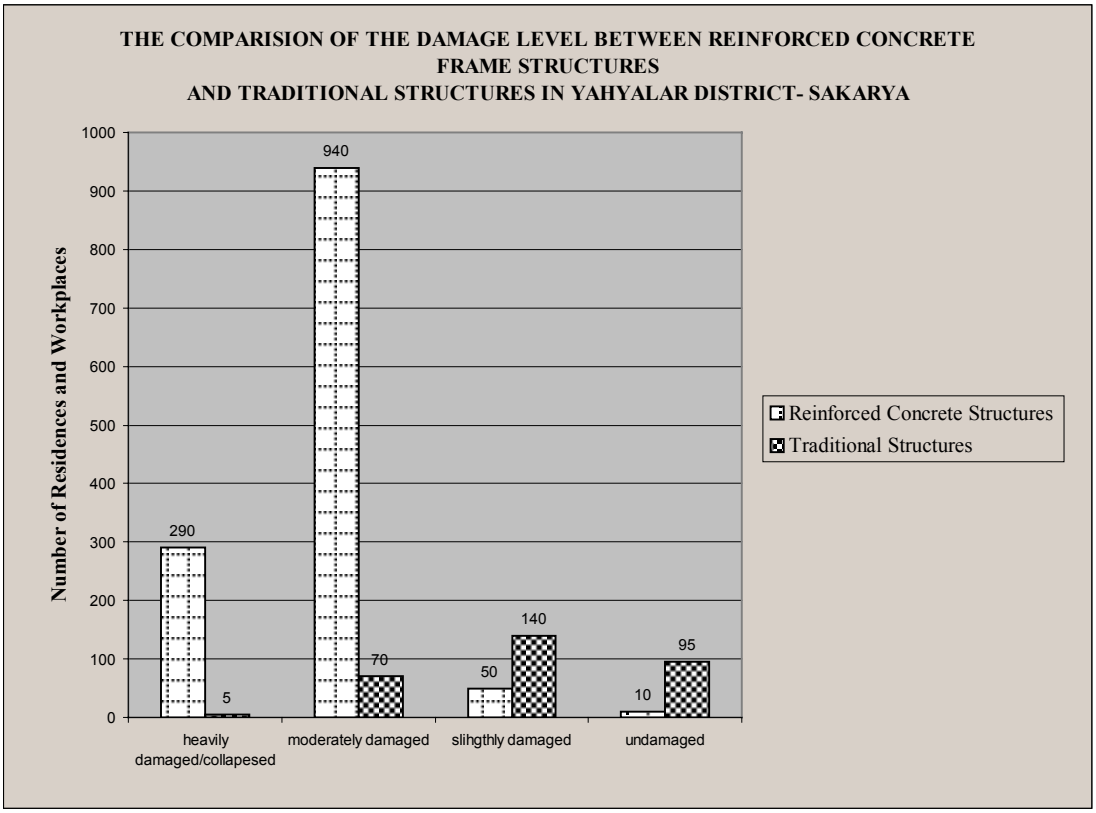

Table 3C.

Reinforced Concrete Structures:1290
Traditional Structures:310
Total:1600

YAHYALAR DISTRICT:

- ***Location:*** Located in the city centre having mostly co-operative mass housing and some traditional buildings
- ***Damage Assessment:*** 1600 Residences and workplaces
- ***The ratio of Reinforced Concrete Structures(RC) to Traditional Structures (TS): 80% RC 20% TS***

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