STRUCTURAL INVESTIGATION OF TIMBER HOUSES AT SÜLEYMANİYE AND ZEYREK

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Introduction

The Urban Regeneration of Historical Peninsula Project (İstanbul) has been started about ten months ago. One of the major goal of this project is to renovate timber buildings in the regions of Süleymaniye and Zeyrek (Figure.1.). The assessment of these buildings has to be completed before the construction phase. Structural investigation is the main part of this assessment process and requires multi-disciplinary action and time. It is also important that information about the capacity and condition of the structural frame should be accurate and meaningful so that decision of whether the frame has the capacity to carry structural loads after the renovation or new structural framing is necessary. In this project, we are applying modern tools and methods in order to get better assessment procedures and save project cost and time.

Assessing Timber Buildings

Assessing building condition includes following major activities:

- Reviewing existing construction documents
- Field investigation
- Probing and exploratory demolition
- Testing materials
- Analyzing existing framing (structure)
- Making an evaluation – Evaluation Report

During the assessment process, first crucial step is to find out whether the existing structural frame satisfactory or not. If the existing frame satisfies necessary conditions then architectural restoration work can start without any intervention to the frame. If this not possible, decision has to be made for a new structural framing. In this case, existing frame has to be demolished and new construction starts from foundation up to the roof (Figure .2.).

In each phase, explained above, building frame analysis or analysis and design processes are repeated . Analysis and design activities are the main and important part of the assessment and evaluation processes, therefore better methods and more advanced techniques should be used to get accurate results in acceptable project time periods.

In this paper, the method being used for analysis and design of structural frames will be explained.

Analysis and Design of Structural Frames

The example building architectural details (elevation & typical floor plan) are shown in Figure 3. This building does not exist at the site, but all the architectural recordings and documents are available. It will be a new construction rather than renovation.
Three different structural framing (Model 1 , Model 2 and Model 3) is considered to test the mathematical representation of structural frames and their behaviors in static and dynamic loading. Side views and isometric pictures of these models are shown in Figures 4, 5, 6.

Decisions for the initial member sizes were made looking at the architectural drawings and from engineering experiences. Vertical and earthquake loads are taken in compliance with Euro - Code and Turkish Design Codes (Figure 7. Earthquake Spectrum Diagram).

STAAD.Pro 2005 computer program is used for the analysis and timber design processes. This program is chosen especially to test the traditional timber structural frames with respect to AITC (American Institute of Timber Construction) , Euro Code 5 (Design of Timber Structures) and Turkish Codes. Once the existing or the proposed frame constructed geometrically in digital and graphic environment, program run-time is minimal (less then a minute 9 for analysis and design phases. It is possible to find the best structural configuration for a new frame or the alternative solutions for renovation of existing frame in reasonable time.

Model 1, Model 2 and Model 3 were analyzed and design under same static and dynamic loading conditions.

Summary of results are given in following figures :

- Figure 8. For different models, frequencies and periods in different modes.
- Figure 9. Summary Table : Frequency, period and maximum displacements for different models.
- Figure 10.1 & 10.2. Deflected mode shapes (x & z directions) for Model 3.
- Figure 11.1 & 11.2. Member stress ratios (beams & columns) for Model 3.
- Figure 12. Final Member Sizes (Model 3.).

Result of the final analysis show that Model 3 has responded structural forces better than other models. It is not necessary to make analysis reaching this conclusion. The main purpose of this approach is to show the evolution of the structural framing in three dimension and also, to demonstrate, studs and bracing elements contribution to the total stiffness of structural frame.

Conclusions

Result of the study can be summarized as follows:

- Traditional timber construction techniques have many advantages in earthquake safe design. During an earthquake, timber structures will be subject to less inertial forces, because of their light construction weight compared to reinforced concrete structures.

- Energy dissipation capacity and overall ductility are high enough in the properly constructed traditional timber structures in Turkey to resist earthquakes.
- Existing structural frame is much better represented by the mathematical model.
- Aging and other member defects can be considered.
- Gives more & accurate information about the dynamic behavior of frame.
- Soil effects are included.
- Behavior of the frame: more & accurate results.
- Can give better ideas during the restoration process.
- Save time & manpower.
- Better design for new structural framing.

Figure 1. Historical Peninsula - İstanbul

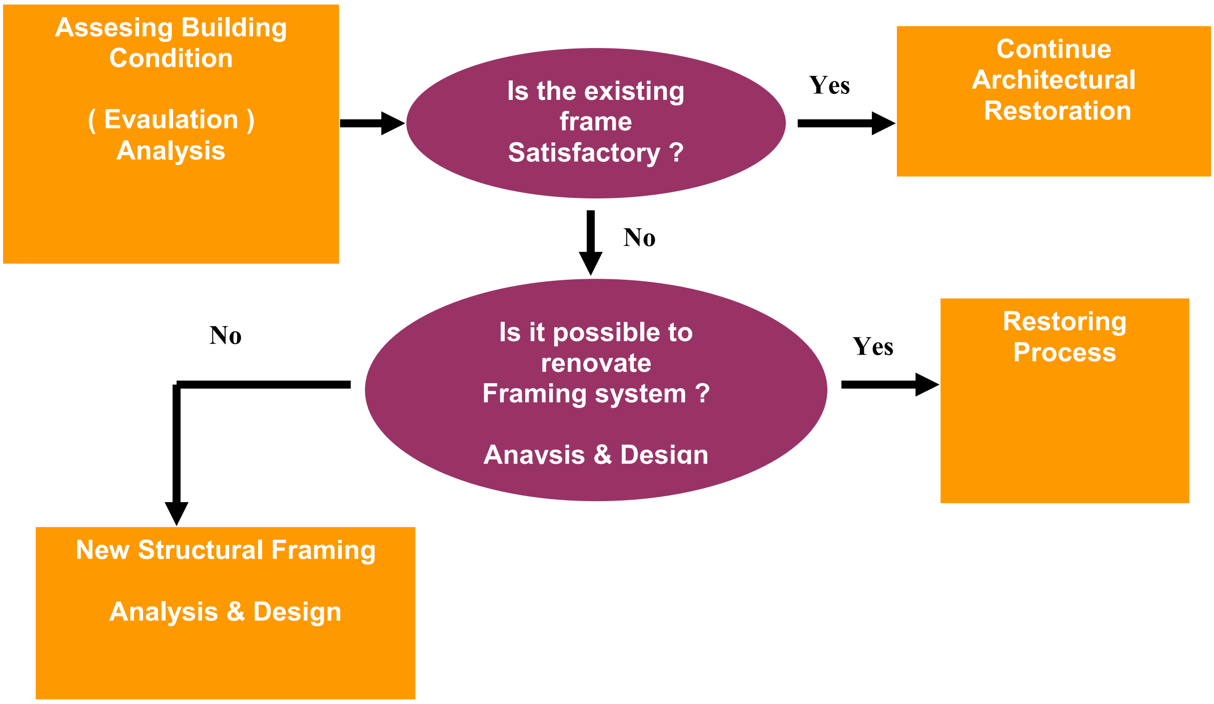


Figure 2. Assessing Timber Buildings, Analysis & Design

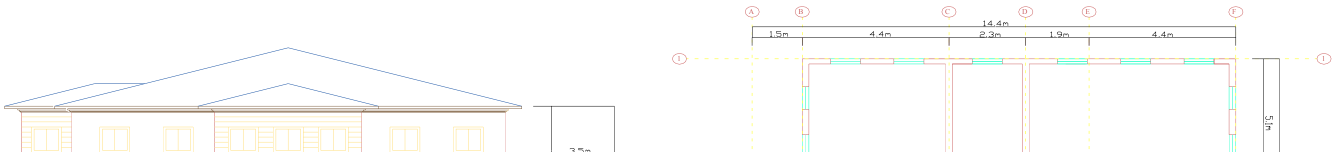
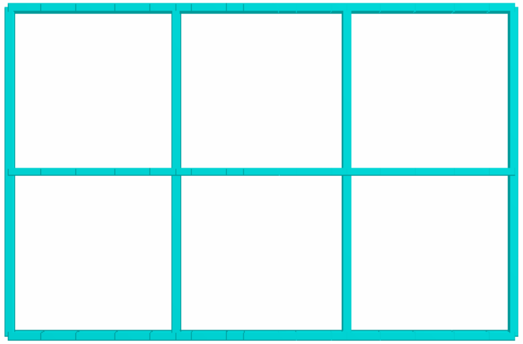
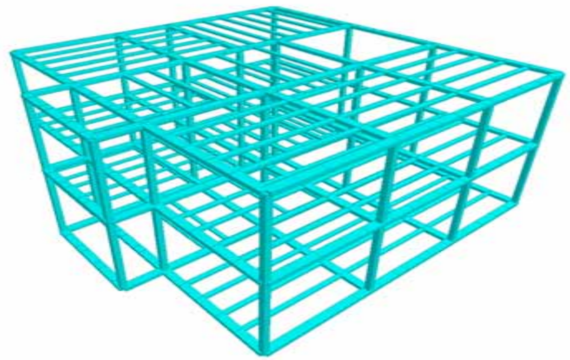


Figure 3. Side View & Typical Floor Plan , Dr. Emin Bey Konağı

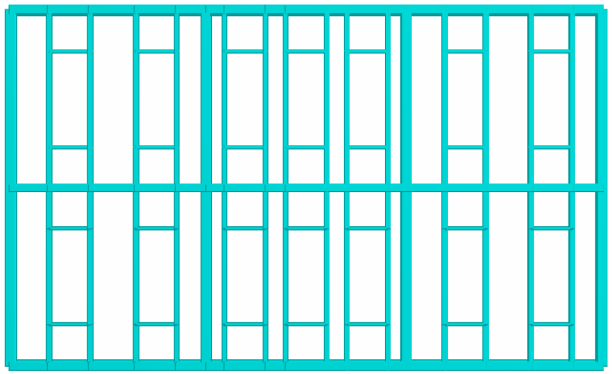


Side frame



Isometric View

Figure 4. Model 1. Frame



Side Frame

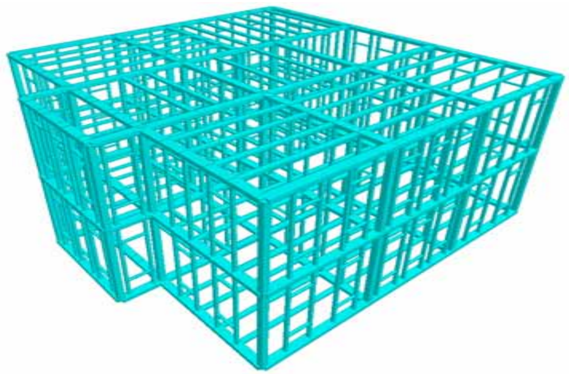
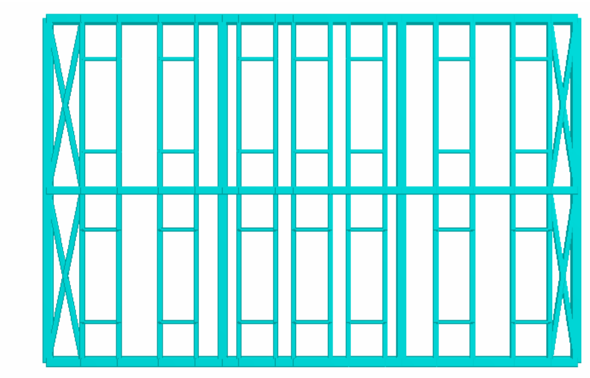


Figure 5. Model 2. Frame


Side Frame

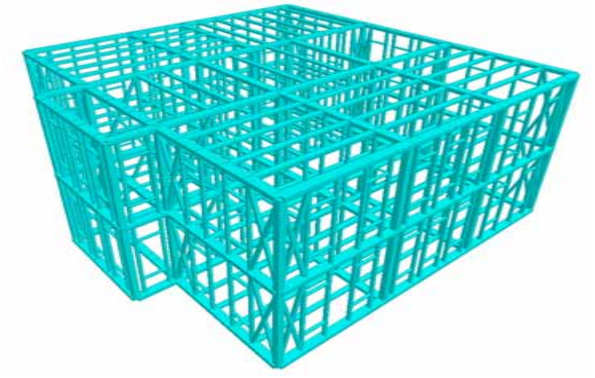


Figure 6. Model 3. Frame

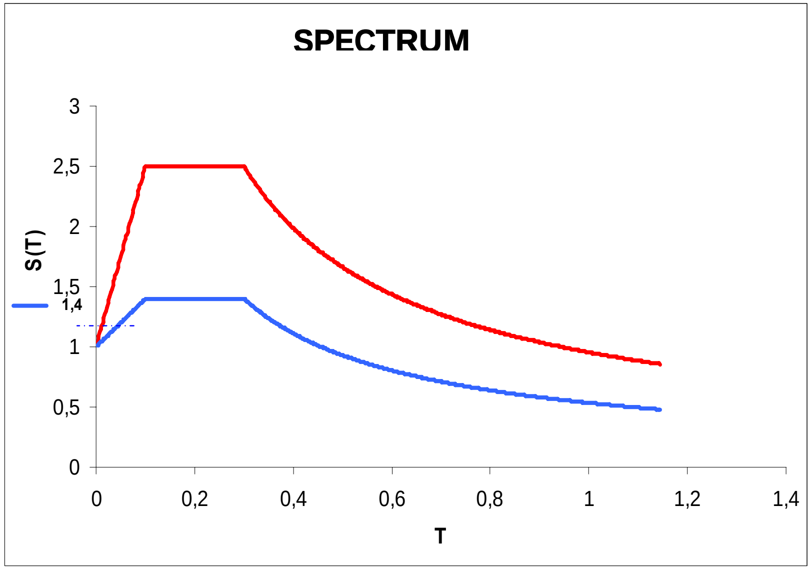


Figure 7. Earthquake Spectrum Diagram

MODEL 1		
MODE	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	1.662	0.60176
2	1.669	0.59929
3	1.677	0.59629
4	1.844	0.54227

MODEL 2		
MODE	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	1.711	0.58455
2	1.726	0.57951
3	1.762	0.56740
4	1.990	0.50247

MODEL 3		
MODE	FREQUENCY (CYCLES/SEC)	PERIOD (SEC)
1	1.711	0.58454
2	1.726	0.57949
3	1.763	0.56721
4	1.990	0.50245

Figure 8. Modes & Periods

			DISPLACEMENT (mm)		
	Frequency cycle/sec	Period sec.	Max X	Max Y	Max Z
MODEL 1	1.662	0.602	100.78	15.28	112.50
MODEL 2	1.711	0.585	59.40	8.95	65.31
MODEL 3	1.711	0.585	44.03	8.62	46.89

Figure 9. Frequency, Period, Max. Displacement.

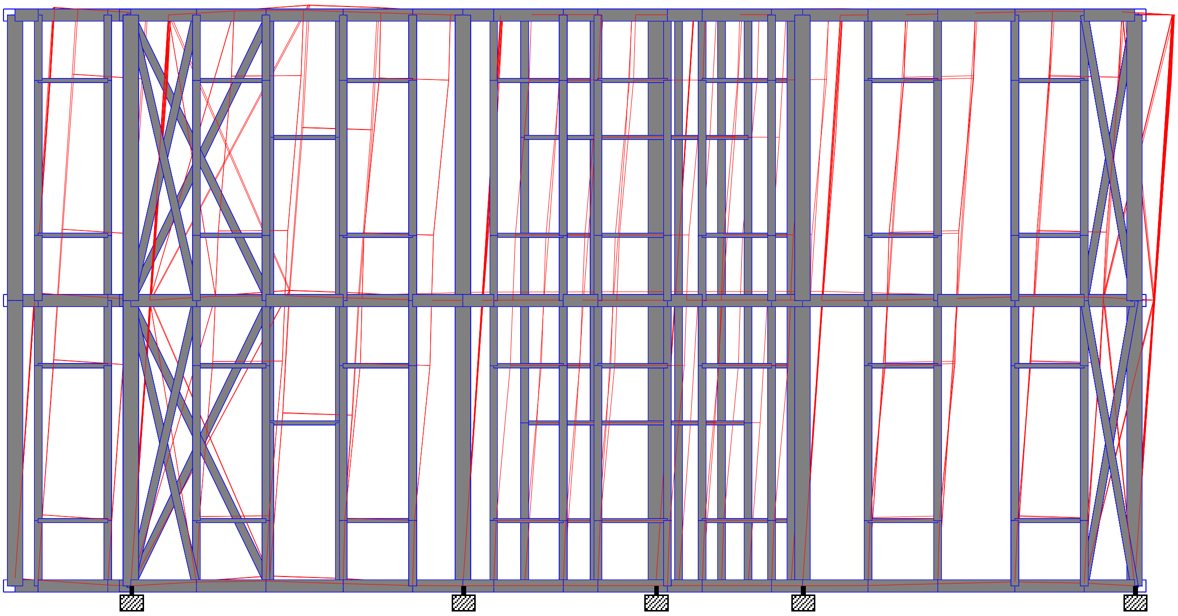


Figure 10.1. Deflected Mode Shape (X direction)

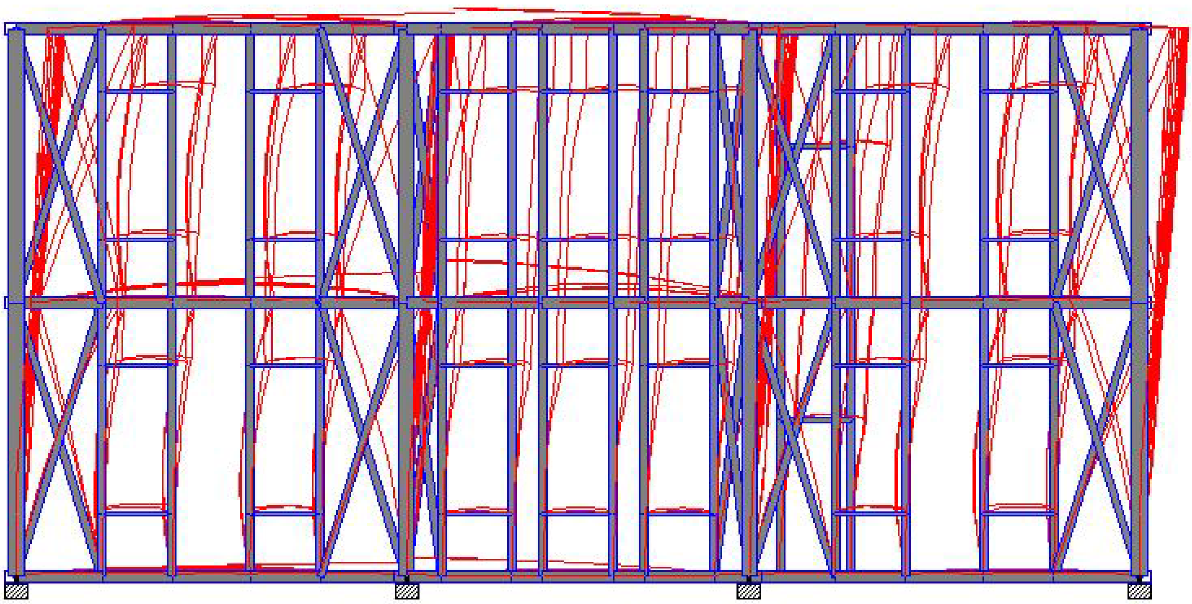


Figure 10.2. Deflected Mode Shape (Y direction)

	Beam #	Design Property	Ratio	Ay cm2	Az cm2	Ax cm2	Iz cm4	Iy cm4	Ix cm4
1. KAT	974	300X150	0.824	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121
	1001	300X150	0.874	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121
	960	300X150	0.957	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121
	895	300X150	0.543	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121
2. KAT	1655	300X150	0.823	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121
	1682	300X150	0.888	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121
	1641	300X150	0.910	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121
	1582	300X150	0.270	382.500	382.500	450.000	8.437.500	33.750.001	23.174.121

Figure 11.1. Member Stress Ratios (Beams)

	Col #	Design Property	Ratio	Ay cm2	Az cm2	Ax cm2	Iz cm4	Iy cm4	Ix cm4
1. KAT	794	200X200	0.816	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335
	801	200X200	0.981	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335
	800	200X200	0.744	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335
	788	200X200	0.498	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335
2. KAT	1490	200X200	0.391	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335
	1497	200X200	0.462	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335
	1496	200X200	0.347	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335
	1484	200X200	0.053	340.000	340.000	400.000	13.333.333	13.333.333	22.533.335

Figure 11.2. Member Stress Ratios (Columns)

	Member size	Member size
COLUMNS		**20/20**
MAIN BEAMS		**15/30**
FLOOR BEAMS		**10/18**
STUDS (Vertical)		**10/10**
BRACINGS		**10/10**

Figure 12. Member Sizes

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