SEISMIC ASSESSMENT AND REHABILITATION
OF
EXISTING BUILDINGS
(SEISMIC ASSESSMENT)

NATO-SfP977231

<u>Project Co-directors:</u>

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PROGRESS REPORT #2

prepared by

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0.0 LIST OF ABBREVIATIONS

TUBITAK: The Scientific and Technical Research Council of Turkey.

METU: The Middle East Technical University, Ankara, Turkey

METU/EERC: METU/Earthquake Engineering Research Center, Ankara, Turkey

ITU: Istanbul Technical University, Istanbul, Turkey

BU: Bogazici (Bosphorus) University, Istanbul, Turkey

KU: Kocaeli University, Izmit, Turkey

GDDA: General Directorate of Disaster Affairs, Ankara, Turkey

GSRT: The Greek General Secretariat for Research and Technology, Greece

CERTH: Center of Research and Technology, Thessalonica, Greece.

FORTH/ICE-HT: Foundation for Research and Technology – Hellas, Institute of Chemical Engineering and High Temperature Chemical Process, Patras, Greece

IZIIS: Institute of Earthquake Engineering and Engineering Seismology (IZIIS), University St. Cyril and Methodius, Skopje, Macedonia

UT at Austin: The University of Texas at Austin, Austin, TX USA

0.1 CO-DIRECTORS

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0.2 END-USERS

- Participating institutions
- Engineering profession
- Municipalities
- Ministry of Construction and Resettlement of Turkey and similar ministries of the participating countries.

1. GENERAL

To reduce loss of life and property from future earthquake hazards, comprehensive risk-based preparedness programs of mitigation must be developed. Experience has shown that lives can be saved, damage to property can be reduced and economic recovery can be accelerated significantly by promoting initiatives that incorporate effective screening, prevention and mitigation measures. The success of these initiatives can be ensured by taking preventive measures to reduce catastrophic losses from natural disasters through structural and nonstructural interventions at the local level.

The present project is related to the seismic evaluation and retrofitting of existing buildings in Turkey and Greece. It is intended to transfer, adapt and implement and/or develop innovative technologies and methodologies for both countries.

The collaborating institutions in the proposed project will be:

1. The Scientific and Technical Research Council of Turkey (through SERU[1] and METU)
2. The Greek General Secretariat for Research and Technology (through CERTH and FORTH/ICE-HT)
3. The University of Texas at Austin, Texas, USA
4. The Institute of Earthquake Engineering and Engineering Seismology (IZIIS), University St. Cyril and Methodius, Macedonia.

The Scientific and Technical Research Council of Turkey is responsible for the planning, coordination and is the co-sponsor of the proposed project. The project co-coordinators are as follows:

1. Prof. Güney Özcebe, NPD, SERU-METU, Ankara, Turkey
2. Prof. Mihail Garevski, PPD, IZIIS, Skopje, Macedonia
3. Prof. Michael N. Fardis, FORTH/ICE-HT, Patras, Greece
4. Prof. K. Pitilakis, CERTH, Thessalonica, Greece
5. Prof. James O. Jirsa, University of Texas at Austin, Austin, Texas, USA

[1] Please refer to Section 2 for abbreviations.

2. PROJECT ACTIVITIES TO DATE IN CHRONOLOGICAL ORDER

1 December 2000	Issue date of the "Grant Letter"
1 January 2001 to 1 May 2001	Organization of the institutions within the NATO country (TURKEY) accomplished; "The Scientific and Technical Research Council of Turkey" issued a matching national grant letter.
25 May 2001	A "Press Conference" was held in Ankara-Turkey with the participation of representatives from all partner countries.
25 May 2001 to 28 May 2001	An organizational Coordination Meeting and Workshop were held in Antalya-Turkey.
29 May 2001	The Turkish branch initiated research activities in two sub-projects. The titles of these projects are "The Seismic Vulnerability Assessment of Existing Buildings" and "Seismic Retrofit of Existing Buildings"
1 June 2001	Effective starting date of NATO-SfP977231

3. TECHNICAL PROGRESS

3.1 ANNEX 3a: Milestones, Deliverables and Schedule of SfP977231

MILESTONES	MONTHS	3	6	9	12	15	18	21	24	27	30	33	36	
1. ASSESSMENT														
1.1 Screening		■	■	■										
1.2 Preliminary evaluation		■	■	■	■									
1.3 Final Evaluation			■	■	■	■	■							
2. RETROFITTING TECHNIQUES														
2.1 System behavior improvement				■	■	■	■	■	■					
2.2 Member strengthening						■	■	■	■	■				
2.3 Research with new materials		■	■	■	■	■	■	■	■	■				
3. TYPICAL APPLICATONS							■	■	■	■	■			
4. MONITORING						■	■	■	■	■	■	■	■	
5. TRAINING						■	■	■	■	■	■	■	■	
					Preliminary assessment methodology				Final evaluation methodology		Retrofit methodology		Evaluation of the proposed methodologies	**Deliverables**
			Progress Report # 1		Progress Report # 2		Progress Report # 3		Progress Report # 4		Progress Report # 5		Final Report	**Reports**

3.2 Progress before the Effective Starting Date (1 January 2001 -1 June 2001)

As mentioned in Section 2, the major activities prior to the effective starting date of the current project were towards organizational activities and the obtaining of national funds. The Turkish branch of the project team prepared and submitted the necessary documents and obtained a matching fund from the Scientific and Technical Research Council of Turkey (TUBITAK). The entire project activities in Turkey are grouped under four sub-projects. The projects supported by TUBITAK are named as follows:

1. Development of Seismic Vulnerability Assessment Methodologies
2. Development of Retrofitting Techniques for Existing Structures
3. Typical Applications and Instrumentation
4. Continuous Education Project in Earthquake Engineering

Brief information and the abstract of each project can be found in Appendix A. The financial tables showing the overall Turkish budgets of these projects can also be found in the same appendix.

A TUBITAK research unit, named as the "Structural Engineering Research Unit" (SERU) has been established to coordinate and conduct research activities in this area in Turkey. Among the sub-projects listed above, the first two will be carried out with the joint efforts of three national universities. The third and the fourth sub-projects in the list will be carried out in the Middle East Technical University (METU). The project activities in these sub-projects have been initiated and will be introduced in the next section.

After getting the TUBITAK grant, the official announcement of the project in order to inform the public was made by arranging a press conference on 25 May 2001 at the TUBITAK headquarters. The representatives of all partner countries (Turkey, Macedonia, Greece and USA) attended this press conference.

The project co-directors along with the representatives of participating Turkish universities participated in the coordination (organization) workshop in Antalya-Turkey during 25 May to 28 May 2001. At the end of this very fruitful workshop the general principles along with the responsibilities of each partner country were defined. The details of this meeting can be found in the meeting minutes presented in Appendix B.

3.3 Progress after the Effective Starting Date (1 June 2001 – 30 April 2002)

3.3.1 Progress in the activities of the Turkish Branch

The R&D activities in three sub-projects, namely "Development of Seismic Vulnerability Assessment Methodologies" and "Development of Retrofitting Techniques for Existing Structures" and "Continuous Education Project in Earthquake Engineering – Dissemination of Knowledge", were initiated.

I. Development of Seismic Vulnerability Assessment Methodologies:

It is intended to three develop separate of assessment methodologies to assess the seismic vulnerability of low- to medium-rise RC frame or dual buildings of ordinary importance. These are namely:

- Initial Screening Methodology
- Preliminary Evaluation Methodology
- Final Evaluation Methodology.

Considerable progress has been reported in the R&D activities in the first two items. However, activities in the third item were started with some delay. The major reason for this delay was the extension of the field work to gather detailed information on the collapsed buildings. For this reason a comprehensive survey was carried out in the archives of Düzce Municipality to collect as much information as possible from the design drawings of the collapsed buildings. Moreover, comprehensive soil explorations were also performed to understand the characteristics of the soils at the sites where massive collapses were occurred during November 12, 1999 Düzce earthquake.

The progress report for this sub-project is presented in Appendix C1.

II. Development of Retrofitting Techniques for Existing Structures:

The activities in this sub-project are underway in three leading research laboratories of Turkey. The two basic approaches chosen for the seismic retrofitting of the existing undamaged reinforced concrete building structures were:

- Strengthening of the existing hollow brick masonry infills by CFRP
- Strengthening of the existing hollow brick masonry infills by using precast panels.

a) Strengthening of the existing hollow brick masonry infills by CFRP

In all three laboratories, R&D activities towards developing strengthening methodology by using CFRP have been started. In the Structures Laboratory of the Middle East Technical University, the first phase of the experimental work, which is consisted of 6 testing of single-bay-two-story RC frames, have been recently completed. The test specimens included those weaknesses that were commonly observed in the existing structures in Turkey. These attributes include RC frames with strong-beams and weak-columns, beam-column joints with no ties, frames members with insufficient confinement reinforcement with hoops having 90 deg bents at the ends, column longitudinal bars with insufficient lap-length, poor concrete quality, etc. The findings of this experimental study were very promising. It was observed that the base shear capacity of the week frame with hollow-brick masonry infills can be increased up to 2.3 times by proper and as well as economical use of CFRP strips. Analytical investigations towards the development of re-design criteria for CFRP strengthening are currently underway.

In addition to the experimental work that is underway in the METU, two parallel research programs were initiated at the Structures Laboratories of the Istanbul Technical University and the Bogazici University.

The details of these studies are presented in Appendix C2.

The second phase of the experimental study on the strengthening of hollow-brick masonry infills with CFRP will be launched soon in the Structures Laboratory of the METU. In this phase of the study, it is intended to use a 3-bay-2-story model RC frame as the test specimen. As in the first phase the test specimen will incorporate those weaknesses that are commonly observed in the existing structures in Turkey.

b) Strengthening of the existing hollow brick masonry infills by using precast panels:

Strengthening of the existing hollow brick masonry infills by using precast panels will be studied only in the Structures Laboratory of the METU. The details of this phase of the experimental work have been established. The experimental set-up is constructed and 6 one-bay-2-story RC frames incorporating the weaknesses commonly observed in existing structures were already produced.

The progress report for this sub-project is presented in Appendix C2.

III. Typical Applications and Instrumentation:

The activities in this sub-project are expected to take start towards the end of 2002.

IV. Continuous Education Project in Earthquake Engineering:

This subproject was planned to include a program of extensive publication of research and professional results suitable for engineering application, two national/international workshops and engineer training sessions including distance learning techniques. Preparatory work dealing with the subproject is proceeding satisfactorily in accordance with the decisions taken at the Coordination Workshop in Antalya for the NATO Project [May 25-28, 2001].

The progress report for this sub-project is presented in Appendix C3.

3.3.2 Progress in the activities of the Macedonian Branch

The major contribution of the Macedonian Branch is limited to the shaking table tests of model structures. At least two shaking table test sequences are planned. The first test will be made on a typical structure displaying common weaknesses encountered in real life. The test specimen will be 1 /2 or 1/3 scale of the original building. In the following sequence, structure(s) rehabilitated by the methodologies developed in the present project will be tested to understand the actual improvements in the seismic performance.

Although the experimental studies that are underway in METU Ankara and FORTH/ICE-HT Patras are still in their initial stages, steps have been made towards the experimental work to be carried in IZIIS, Skopje. In addition currently available instruments in IZIIS, new measuring and monitoring systems are needed for the shake table tests. These systems are identified and Prof. M. Garevski, the Director of IZIIS and the PPD of SfP977231, has recently started the bidding process. The instrumentation necessary for the tests will be acquired in the summer of 2002.

Moreover, in 2002 the development of the test model will be conducted and possibly one shaking table test will be performed in order to study the performance of the original weak structure.

The summary report presented by Macedonia is included in Appendix D.

3.3.3 Progress in the activities of the Greek Branch

There are two partner institutions from Greece. These institutions are CERTH-Thessalonica and FORTH/ICE-HT-Patras. Greek institutions are taking responsibility in the first three sub-projects. These are namely "Development of Seismic Vulnerability Assessment Methodologies", "Development of Retrofitting Techniques for Existing Structures" and "Typical Applications and Instrumentation".

I. Progress of the FORTH/ICE-HT-Patras:

The FORTH/ICE-HT-Patras is participating in the first two sub-projects. The R&D activities towards the development of practical seismic vulnerability methodologies appear to be progressing well in conformity with the work schedule. In this context, it has been recently reported that an initial screening methodology was developed for Greece along the lines of FEMA 154 (ATC-21): "Rapid visual screening of buildings for potential seismic hazards: A Manual" (1988). According to the progress report of FORTH/ICE-HT Patras, the development of the methodology is practically complete and it was briefly presented in Appendix E, without any background or justification.

In Patras, the R&D activities towards the preliminary and final investigations are still underway. These activities appear to be running in line with the work plan.

In the context of developing new rehabilitation methodologies, the details of the experimental program were established. Two series of column tests were planned. The objective of the first series is to investigate the effect of the retrofitting technique on the strength and deformation capacity of non-seismically designed column elements. Whereas in the second series, the focus will be on the effect of insufficient lap-splicing on the performance of columns in non-earthquake-resistant buildings. The behavior of such column elements will then be improved by applying innovative retrofitting techniques that can be applied on the existing buildings without disrupting the service. The details of the experimental program can be found in the progress report of Patras, which is presented in Appendix E.

II. Progress of the CERTH-Thessalonica:

The CERTH-Thessalonica will share responsibility together with METU-Ankara in the third sub-project. Although the Thessalonica group was allocated the total amount of funds in their budget for the purchase of equipment, it appears that no R&D activities within the framework of "Sub-Project 3: Typical Applications and Instrumentation" have been initiated as yet. No progress was reported by the CERTH for the period of 01.11.2001-30.04.2002.

3.3.4 Progress in the activities of the US Branch

The University of Texas at Austin has no R&D budget; therefore, no R&D activities have been assigned to this institution. However, the US project co-director is acting as an advisor and participating in the activities under "Training of the Young Scientists". Within the scope of this item Dr. M. Onur Sonuvar, a young scientist from METU, started his postdoctoral studies in the Ferguson Structural Laboratories at the University of Texas at Austin. Onur Sonuvar's financing is provided partly by Turkey (through the use of national budget) and partly by UT at Austin.

The US project co-director Prof. J. O. Jirsa visited the Middle East Technical University during the last week of March 2002. The purpose of the trip was to overview the progress of the project studies up to that date. During the visit, both sides exchanged views and ideas and discussed the results of the tests that were performed in the Structures Laboratory of the METU within the framework of the NATO SP project. These discussions led to the necessity of testing some other specimens simulating the tension and compression performance of the diagonal strut with the CFRP dowels and sheets. Devising of the test specimens to get a better idea of the local behavior of the critical zones of the strut will be made in late May 2002. These tests will be conducted during the visit of Prof. U. Akyuz as young trainee at the University of Texas at Austin. The initial intentions are such that, the tests will be performed in the Ferguson Structural Laboratories at the University of Texas at Austin in the summer of 2002. Local funding necessary for this experimental program will be arranged by Prof. J. O. Jirsa.

3.4 Accomplishments

Considering the timetable given in the project plan, NATO-SfP977231 is proceeding as scheduled with a slight delay in the development of vulnerability assessment methodologies. As explained in Appendix C1, the major reason of the delay was the difficulties encountered during the field work. This phase of the study is now over and the data gathered from the fieldwork is processed and made ready for the analysis.

3.5 Milestones for the Next Six Months

At the end of the next six months, it is expected to develop the screening and preliminary assessment methodologies for the seismic vulnerability assessment of existing buildings.

3.6 Involvement of the Young Scientists

Please refer to Appendices C1, C2 and C3.

3.7 Listing of Major Travel

- Prof. Mihail Garevski (PPD) participated the IPR Workshop that was held in Moscow on 15-16 March 2001.
- Prof. M. Garevski (PPD), Prof. K. Talaganov participated the 8th East Asian Conference on Structural Engineering and Construction, Singapore, 5-7th December 2001
- Prof. Ugurhan Akyuz (investigator) participated FRP Composites in Civil Engineering, Hong Kong, 12-15 December 2001.
- Prof. James O. Jirsa (co-director) visited the METU Ankara-Turkey, 18-27 March 2002
- Prof. Guney Ozcebe (NPD) visited Department of Civil Engineering of the University of Ottawa and gave a seminar on the experimental work that was carried out in the Structures Laboratory of the METU on Repair and Strengthening of RC Structures (including the experiments that were made within the framework of NATO SfP977231) and participated the Spring Convention of the American Concrete Institute that was held in Detroit, MI, 17-26 April, 2002

3.8 Visit by Experts

Prof. Mete Sozen of Purdue University came to METU for 2-day stay in July 2001.

3.9 Visibility of the SfP Project

SfP-977231 is in its initial phase. Until now, only one MSc thesis was completed.[2] Currently, 9 MS and 2 PhD students are working towards their degrees.[3]

3.10 Technical and Administrative Difficulties

As mentioned in Paragraph 3.1.2, one of the two Greek partners the CERTH-Thessalonica is expected to contribute to the third sub-project "Typical Applications". Although the Thessalonica group was allocated the total amount of funds in their budget for the purchase of equipment, it appears that no R&D activities within the framework of "Sub-Project 3: Typical Applications and Instrumentation" have been initiated as yet. No progress was reported by the CERTH for the period of 01.11.2001-30.04.2002.

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[2] Pay, A. C., "A New Methodology for Seismic Vulnerability Assessment of Existing Buildings in Turkey", MSc Thesis, Department of Civil Engineering, METU, August 2001, Ankara

[3] These figures includes the graduate students in the Turkish Chapter of the project.

4. SUMMARY REPORT

SUMMARY REPORT

SfP - 977231 SEISMIC ASSESSMENT

SfP Title: *SEISMIC ASSESSMENT AND REHABILITATION OF EXISTING BUILDINGS*

Project Co-Directors:

(NPD) *Prof. Güney Özcebe*

(PPD) *Prof. Mihail Garevski*

Prof. Michael N. Fardis

Prof. James Jirsa

Approval Date: *1 December 2000* Effective Starting date: *1 June 2001*

Duration: *3* years; expected completion by *31 May 2004*

Information about the SfP Project through Internet: *Information about the SfP Project will be available at http://www.seru.metu.edu.tr in a very short time.*

Major Objectives

- *To develop seismic vulnerability assessment methodologies for existing buildings.*
- *To develop seismic rehabilitation methodologies for existing (undamaged) buildings.*
- *To make sample applications of the developed methodologies.*
- *Dissemination of results, engineer training (classroom/internet), researcher training (on the job).*

Overview of Achievements since the Start of the Project until 31 October 2001

- *On May 25, 2001 a press conference was held iin TUBITAK Headquarters in Ankara with the participation of Prof. N. K. Pak, Prof. G. Ozcebe (NPD), Prof. M. Garevski (PPD), Prof. M. N. Fardis and Prof. J. Jirsa (project co-directors).*

- *A coordination workshop was held in Antalya-Kemer on 26-28 May 2001. All project partners except Prof. K. Pitilakis of CERTH-Thessaloniki participated in this workshop.*
- *R&D activities in Sub-project 1: Development of Seismic Vulnerability Assessment Methodologies and Sub-projet 2: Development of Retrofitting Techniques for Existing Structures were started. These activities include:*
  - *Literature survey studies: These studies were completed.*
  - *Studies on initial screening and preliminary evaluation: The work towards the development of Screening and Preliminary Assessment Methodologies is nearly half-way through.*
  - *Strengthening of the existing hollow brick masonry infills by CFRP: System strengthening tests on one-bay-two-story twin RC frames (having non-seismic design) with brick masonry infills have been completed. In this regard, a considerable achievement has been obtained.*
  - *Strengthening of the existing hollow brick masonry infills by Precast panels: The tests on system strengthening by using one-bay-two-story RC frames (having non-seismic design)with brick masonry infills have been started.*
  - *Strengthening of the existing hollow brick masonry infills by CFRP: system strengthening tests on three-bay-two-story RC frames (having non-seismic design) with brick masonry infills have been continued*
  - *The experimental programs that will be undertaken by the Turkish partner institutions is planned*
  - *As of 30 April 2002, two young scientists were sent to USA to carry out postdoctoral studies. Research Assistant Onur Sonuvar has been pursuing studies at the University of Texas at Austin since August 2001 and Research Assistant Erdem Canbay is at Purdue University since February 2002.*

Milestones for the Next Six Months

- *SfP Project will be made public through Internet at http://www.seru.metu.edu.tr*
- *Development of screening and preliminary evaluation methodologies are is expected to finish, (METU-PATRAS).*
- *Strengthening of the existing hollow brick masonry infills by CFRP will be continued on one-bay two-story single weak frames and on the three-bay two-story weak frames (METU, ITU, KU, BU).*
- *Strengthening of the existing hollow brick masonry infills by using precast panels (METU).*
- *Testing of members and subassemblies for seismic strengthening will be started (PATRAS).*
- *Shaking table tests will be planned. If possible reference frame will be cast and tested (IZIIS, SCOPJE, FYROM)*
- *Training of young scientists will be focused. Future plans for similar training and academic experience include sending Assistant Professor Dr Uğurhan Akyüz in the summer of 2002 (using NATO funds) for a period of three months to the University of Texas, to be followed by a similar period for Dr Şevket Özden of Kocaeli University.*

Implementation of Results

During the period 1 March 2001 to 30 April 2002 one MSc thesis was completed (in METU). In the Turkish Branch of the SfP Project currently, 7 MS and 4 PhD students are working towards their degrees.

Overview of Patents or Patent Applications

N/A

NATO Consultant

There is no NATO consultant assigned to this project.

Additional Collaborating Institutions

- ISTANBUL TECHNICAL UNIVERSITY
- KOCAELI UNIVERSITY
- BOGAZICI (BOSPHORUS) UNIVERSITY

Abbreviations:

TUBITAK - The Scientific and Technical Council of Turkey

METU - The Middle East Technical University

ITU – Istanbul Technical University

KU: Kocaeli University

BU: Bogazici (Bosphorus) University

APPENDIX A: ABSTRACTS OF THE SUB-PROJECTS – TURKISH CHAPTER

- SPONSORING INSTITUTIONS
- THE SCIENTIFIC AND TECHNICAL COUNCIL OF TURKEY
- MIDDLE EAST TECHNICAL UNIVERSITY
- ISTANBUL TECHNICAL UNIVERSITY
- BOGAZICI UNIVERSITY
- KOCAELI UNIVERSITY

Project Code and Title: ICTAG I574: Development of Seismic Vulnerability Assessment Methodologies	
Principal Investigator: Prof. Dr. Güney Özcebe	Telephone: (312)210 24 61
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ABSTRACT

The evaluation of seismic safety of existing buildings is one of the matters that are being investigated by the researchers especially in countries of high seismic risk. In recent years, efforts have begun to establish methods to evaluate the seismic safety of buildings to determine risks and to suggest strengthening of existing buildings.

The observations made after the recent earthquakes demonstrated that, the buildings become less vulnerable to earthquakes with the developments in the earthquake engineering, the changes in design methods, the availability of new materials and the developments in the construction technologies. Damage statistics from recent earthquakes indicated that only a fraction of the existing buildings suffered severe earthquake damage while the remaining larger fraction did not create any life-safety hazard. Therefore, in the seismic vulnerability assessment, the main thrust should be directed towards the identification of the buildings, which create life-safety threats. Rather simple procedures are desirable to "screen-out" the majority of safe buildings. In cases where some deficiencies were detected, more detailed and sophisticated methods may be utilized.

Serious and systematical research in the area of seismic vulnerability assessment of buildings has been realized only in the last two decades. The methodologies found in the literature are not applicable world wide due to the differences in the quality of the materials of construction, in the local construction practices, in the locally common architectural patterns etc. Therefore, rapid and yet reliable rehabilitation methodologies for Turkey must be developed.

A reliable seismic evaluation method, which reflects the actual performance of the structure consist of three phases. These are; (a) a rapid screening based on simple tools, (b) a more refined evaluation process and (c) the final evaluation stage.

The first screening is an essential part of the study. It is in this level where the gigantic size of the existing building stock is handled and those found inadequate are identified as life-safety hazard. This step requires identification of structural attributes that can be deemed as hazardous from the point of view of seismic safety. The cities affected by the 17 August 1999 Marmara earthquake and 12 November 1999 Düzce Earthquake provide an open laboratory for this purpose. In this study, the plan is to include basic building data (damage level, number of stories, framing type, footprint, critical member sizes, location coordinates) for as many building as possible. The correlation between the damage distribution and the site conditions will also be studied. Availability of these data, focused on specific locations of heavy, medium and/or light damage, will provide a rich and useful database to test and develop methods for assessment of earthquake vulnerability in Turkey. Once the database is constructed, a rapid first-level screening index will be established to screen-out the safe buildings. This index will preferably be based on strength considerations and the expected earthquake intensity at the site.

Later somewhat more refined and yet simple indexes will be developed to perform second and third level screening. While doing this, critical use of the established database will be made in conjunction with the current codes, i.e. the Turkish code of reinforced concrete practice (TS500-2000) and Turkish seismic code.

Keywords: Life-safety, seismic vulnerability, earthquake resistance, rapid screening, vulnerability assessment

Project Code and Title : ICTAG I575: Development of Retrofitting Techniques for Existing Structures	
Principal Investigator: Assist. Prof. Dr. Ugurhan Akyüz	Telephone: (312)210 54 59
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ABSTRACT

The seismic repair and/or strengthening philosophy generally consist of a) system behavior improvement and b) member repair/strengthening. Although these two general approaches can be applied separately in some cases, they generally are combined. In the system behavior improvement technique, the general philosophy is to introduce a new lateral load resisting system, which will increase the lateral strength and the lateral stiffness of the existing system, which is generally a non-ductile frame with inadequate lateral stiffness. This principle relies on the safety of the existing structure under gravity loads. Various techniques based on this principle have been developed and applied in the past. Among them, the most widely used technique is the formation of new stiff walls through infilling some bays of the existing frame with reinforced concrete infills. In general, the new stiff elements are placed in such a manner as to minimize the floor torsion. Use of infilled frames as a method of seismic behavior improvement for existing structures is presently a very common application in Turkey. This approach was first proposed following the pilot tests made by the METU staff on the infilled frames, and was gradually established in practice on the basis of the underlying experimental research. In addition, the column jacketing is among the commonly used repair/strengthening techniques in Turkey. The efficiency of the method was investigated by a number of test series concentrating on various aspects of the problem.

All these techniques are applicable at the cost of a certain discomfort to the occupants and, the application of these techniques in the rehabilitation of undamaged buildings may not very practical. In the scope of this research project, the development of new strengthening techniques is one major achievement. For this purpose experimental research programs will be initiated. In these research programs the use of new materials in system and member rehabilitation will be studied. It is intended to perform quasi-static tests on model frame structures, aiming at the investigation of the post intervention seismic behavior of frames retrofitted with various techniques to be proposed.

Besides overall system behavior improvement, repair and/or strengthening of some reinforced concrete elements is sometimes required if their capacities are not sufficient to meet the strength demand of a major earthquake. In the past, many methods were proposed for strengthening of R/C members. Depending on the desired earthquake resistance, the type of elements and their connections members can be repaired and/or strengthened by epoxy injection, by jacketing or fiber reinforced plastics (FRP) or carbon fiber (CF) wrapping.

Another objective of the proposed study is to develop alternative and yet feasible member strengthening techniques for structures in service.

At the end of these studies, rapid and yet reliable rehabilitation methodologies for Turkey will be developed.

Keywords: Earthquake, reinforced concrete, repair, strengthening, earthquake resistance, earthquake safety, lateral load resisting system

Project Code and Title :

ICTAG I576: Typical Applications and Instrumentation

Principal Investigator: Prof. Dr. Haluk Sucuoglu	Telephone: (312)210 54 80
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ABSTRACT

The methodologies developed for the seismic vulnerability assessment of existing buildings will be applied to a group of state owned buildings. Those buildings identified as seismically vulnerable will be classified according to their structural parameters, types of weaknesses they display, and the geotechnical parameters at the site. One building in each group, not exceeding 5 will be rehabilitated by using the rapid retrofit techniques and methodologies, which will also be developed in this study.

Structural engineering deals with the safe and economic design of structural systems. To this end the engineer must tackle the important task of representing physical reality as a mathematical abstraction that will permit him to predict with confidence the way that the assembly of components will behave when subjected to external effects. The word “behavior” encloses a number of connotations. First, the deformations caused by the effects must be calculated so that steps can be made to limit them to acceptable levels. Similarly, forces, stresses, or long-term strains must all be calculated, or the strength of individual members must be determinable so that these can be compared with analysis results. Analysis, on the other hand, depends on a number of simplifying assumptions because otherwise even simple structures would require lengthy and expensive calculations.

For earthquake ground motions this situation is even more complicated because of the additional sources of uncertainty such as three-dimensional effects, influence of “non-structural” components, and spatial variability. For improved understanding of dynamic structural response, engineers have three recourses:

- Build computer models of variable complexity and conduct numerical experiments, leading to identification of important modalities of response,

- Build scaled laboratory models, subjecting them to static or quasi dynamic or even true dynamic loads, matching observations against numerical predictions,

- Place sufficient measuring devices on full-scale structures, and record their response when subjected to the real experiment that an earthquake is. This way, the correctness of any theory or idealization can be calibrated.

For this reason, the incorporation of the building seismic monitoring component into the project proposal is considered as being necessary.

Keywords: Earthquake, reinforced concrete, repair, strengthening, earthquake response, seismic monitoring, instrumentation

Project Code and Title: ICTAG I577: Continuous Education Project in Earthquake Engineering	
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ABSTRACT

All research projects possess, produce or provide an educational content. The upward distillation of knowledge leads to wisdom; the filtering down of knowledge leads to know-how. The vital function of a University is indeed the development and discovery of knowledge through research, but it can be stated without much argument that the most important duty of a University is to make the spin-off from this knowledge immediately and freely available to the community. The imparting or transfer of technical knowledge, initially as research-oriented information or, after proper processing, as know-how, calls for expertise at different levels. The Middle East Technical University Project Team is specially equipped for this task of continuing education in both English and Turkish. The members of the Project Team have impeccable research credentials and extensive experience over the years in teaching students, practicing engineers, technical managers and building contractors possessing differing backgrounds of competence and technical responsibility.

It is suggested that the dissemination of research results from the present project be conducted in the following formats:

- Individual lectures, seminars, short refresher courses and training workshops on the latest methodologies and techniques for the seismic assessment and rehabilitation of buildings
- The preparation of desktop-published course material explaining and illustrating salient items of the Turkish and other contemporary earthquake codes; structural behavior during earthquakes; damage assessment for urban and rural structures; rehabilitation techniques as developed from experimentation and research, etc.
- Broadcasting of systematized knowledge relating to the seismic amelioration of structures and buildings of different types by means of compact discs, video films, the Internet and television channels [if possible].

It is expected that after some trial runs, the continuing education activities could develop into formal programs leading to evaluation of student performance and possible award of certificates of proficiency.

Keywords: Earthquake, reinforced concrete, earthquake engineering, continuing education, internet based education, asynchronous education

APPENDIX B: SUMMARY MINUTES

SUMMARY MINUTES OF THE DELIBERATIONS OF THE COORDINATION WORKSHOP FOR NATO PROJECT SfP977231

Entitled

SEISMIC VULNERABILITY ASSESSMENT AND RETROFITTING OF EXISTING REINFORCED CONCRETE BUILDINGS

ANTALYA, TURKEY

MAY 25-28, 2001

Introduction

The abovementioned NATO project consists of four sub-projects, each of which is further divided under various item headings. Details of the contents of each sub-project are given in the Appendix to these minutes, along with topical points for examination, which were compiled by the participants of the projects for detailed discussion during the deliberations of the Coordination Workshop. The minutes given below comprise the final consensus reached and decisions taken for the implementation of each sub-project after an extensive interchange of ideas during the sessions of the Coordination Workshop for the sub-projects and item headings. As a memory refresher, it is recommended that the Appendix be read first and that the minutes be examined subsequently.

The list of persons who participated in the Coordination Workshop is given below in alphabetical order of surname:

5. Ugurhan Akyuz [Turkey]
6. Erdem Canbay [Turkey]
7. Ugur Ersoy [Turkey]
8. Michael Fardis [Greece]
9. M. Garevski [Macedonia]
10. Polat Gulkan [Turkey]
11. Alper Ilki [Turkey]
12. James O. Jirsa [USA]
13. Faruk Karadogan [Turkey]
14. Guney Ozcebe [Turkey]
15. Sevket Ozden [Turkey]
16. Haluk Sucuoglu [Turkey]
17. Tugrul Tankut [Turkey]
18. S. Tanvir Wasti [Turkey]

PROJECT 1:

DEVELOPMENT OF SEISMIC VULNERABILITY ASSESSMENT TECHNIQUES

Scope:

Structural System

Frame + Wall (mixed) RC Buildings

Occupancy

Residential and Office Buildings (I=1)

Height

Low- and Mid-rise Buildings

Performance Criterion:

Life Safety (the building should not collapse and should remain stable enough to prevent life loss).

Item 1: Initial screening

The initial screening is intended to identify buildings that, on the basis of past experience, require further study.

Side Walk Survey: (check-list)

1. Soft story
2. Number of story
3. Irregularities in plan
4. Irregularities in elevation
5. Adjacency
6. Short column
7. Number of bays
8. Redundancy
9. Visible condition
10. Topography

Item 2: Preliminary evaluation

This is the stage to conduct a closer examination in order of priority, of various groups established in the initial screening stage.

This stage is oriented toward utilizing correlations based on the geometry of vertical load-bearing members. Data available from the METU/Purdue investigations in the Bolu/Düzce area should prove to be useful in this respect.

Item 3: Final evaluation

This "Final Evaluation" stage consists of in depth condition evaluation and assessment of selected buildings. Analysis results should be used to check member strength and drift (or deformation) control criteria.

The Turkish and Greek teams will formulate separate proposals. The proposals will later be merged in to one final document. Prof. M. N. Fardis will coordinate the work of the Greek team.

PROJECT 2:

REHABILITATION METHODOLOGIES

1. Three step approach:

    1. System behavior improvement
    2. Member strengthening
    3. Research with new materials

    Life safety (the building should not collapse and should remain stable enough to prevent life loss) is the main performance criterion for rehabilitation of the existing R/C residential structures.

2. a) Jacketing of columns using conventional and innovative materials, other rehabilitated component tests, 3D structure tests. (Greek Institutions, to be coordinated by Prof. M. Fardis)

b) Infilled frame tests, column-jacketing tests, infill wall with CFRP, post tensioning tests. (3 universities in Turkey)

c) Intend to contribute, but they have to find funds. (USA)

3. Column jacketing (Patras, Turkish universities)

4. Local strengthening techniques

a) connection

b) lap-splice (Patras, Turkish universities)

5. Shake table tests. Turkish universities will first decide on the static test program. Then, they will get in contact with the Macedonia group for shake table test.

PROJECT 3:

TYPICAL APPLICATIONS AND MONITORING OF REHABILITATED STRUCTURES

Number of buildings: 3

Location of the buildings: Bolu/Yalova [tentative]

General Directorate of Disaster Affairs [GDDA] co-operation

Type of the buildings: one mid-rise (5-6 floors), method 1

one mid-rise (5-6 floors), method 2

one low-rise (2-3 floors), method 1

at least one with a soft story

Type of the Instrumentation: to be determined later

Greek contribution:

The Principal Investigator of Sub-Project 3 (Haluk Sucuoglu) will contact the Thessalonica team and coordinate the monitoring activities.

PROJECT 4:

TRAINING/DISSEMINATION OF RESULTS

Item1: Dissemination of results

2 workshops (International/National) : 40 to 50 participants, mainly researchers concerned and a limited number of qualified engineers, to discuss research results and related issues. The objective of the workshops is to gather the experts in this field and discuss the outcomes of the project and get recommendations for the progress of the project.

Publication of such technical documents as may be suitable for the purposes of this project.

Item2: Engineering training (Classroom)

Short and long courses may be organized within the framework of the University Continuing Education Center.

Item3: Engineering training (Internet)

Contact should be established with Audio Visual Research Center (GISAM) and the Computer Center at Middle East Technical University with the objective of producing instructional material in CD format. Explore possibilities of instruction via the Internet (a pilot short course on the assessment and rehabilitation of RC buildings to be produced either for the internet or in CD format)

Item4: Researcher training (on the job)

Exchange visits by young researchers to and from Institutions participating in the NATO Project. Encourage participation of post docs and PhD students in ongoing research in partner Institutions and in fieldwork.

APPENDIX C: PROGRESS REPORTS OF THE TURKISH BRANCH

- C1: Progress report of Sub-Project 1
- C2: Progress Report of Sub-Project 2
- C3: Progress report of Sub-Project 4

APPENDIX C1: SUB-PROJECT 1 - DEVELOPMENT OF SEISMIC VULNERABILITY ASSESSMENT METHODOLOGY – 2nd PROGRESS REPORT

C1.1 INTRODUCTION

In Turkey the part of the building stock, which comprises structures failing to comply with the current code requirements, is enormous in size. Recent earthquakes have revealed the deficiencies of existing buildings with respect to the seismic performance by resulting in serious damage and casualties. Seismic upgrading of the existing building stock is therefore an urgent need in order to reduce the catastrophic losses in human lives, material damage, disruption of the business and economy. The identification of deficient buildings and the mitigation of their potential hazards are very important and remains a difficult task because of the huge size of the building stock which is located in high seismic risk regions of Turkey.

The objective of this investigation is to develop a methodology, which will make possible the rational, practical and economic evaluation of the seismic performance of existing buildings in Turkey.

C1.2 SEISMIC VULNERABILITY PRINCIPLES

The foremost task in the development of a reliable seismic evaluation method is to delineate the priority decisions. These decisions determining the level of detail of the evaluation principle will depend upon the importance of the structure, the allocated budget, the time factor and some other auxiliary constraints. While screening a large building stock, budget and time restrictions appear to be the most deciding factors.

As explained in Section 3, the scope this investigation is limited to low-to-mid-rise frame or frame-wall type structural systems. The residential and/or office buildings falling in this category will form the subject matter of the investigation. The aimed performance criterion is selected as *"Life Safety Performance Level"*. This is the performance level in which the building should not collapse and should remain stable enough to prevent life losses resulting from partial and/or total collapse.

In view of the size of the population of the buildings that require investigation, the assessment procedure will be carried out in three steps. As a result, the methodology being developed in this research project will have three phases. These are as follows:

1. Initial Screening Phase
2. Preliminary Evaluation Phase
3. Final Evaluation Phase

C1.2.1 Initial Screening

The first phase aims at the rapid initial screening of the buildings. It is in this phase where the huge existing building stock will be inspected and classified on the basis of seismic vulnerability. This step requires the identification of structural attributes that are deemed to be hazardous from the point of view of seismic safety. On the basis of past experience such attributes may be listed as:

- Presence of soft story
- Presence of irregularities in plan and/or elevation
- Presence of short columns
- Adjacency to other buildings
- Number of stories
- Number of bays
- Redundancy
- Visible conditions
- Topography

It is important to note that this list may be revised, as needed depending on the results of the statistical analyses that will be performed in this phase of the sub-project.

In this phase of the project, methodologies for data collection, interpretation and evaluation will be developed. The aim of initial screening is to eliminate a portion of the buildings in order to obtain a manageable stock size for the analyses of the second phase.

The city of Düzce affected by the 17 August 1999 and 12 November 1999 earthquakes provided an open laboratory for this purpose. The major activities planned for the first 12 months were:

- to carry out a detailed literature survey
- to assemble the basic building data (such as damage level, number of stories, framing type, footprint, critical member sizes, location coordinates) for as many buildings as possible
- to develop methodologies for the preliminary investigation.

The literature survey has been accomplished and a considerable number of US and Japan sources were also included. As a part of the literature survey, methodologies developed in USA and Japan were studied and the applicability of these methodologies to Turkish building practice were investigated.

As mentioned in the Project Plan and in the 1st Progress Report, a major step in the project activities was to assemble as much building and geotechnical data as possible before starting the analytical work. For this purpose a detailed field investigation in Düzce was started as mentioned in Progress Report 1. In this investigation in addition to the basic building data mentioned above, detailed material investigation were also performed. Moreover, the parameters known to be eminent on the seismic vulnerability of the buildings were also identified for each building.

More than 421 buildings were investigated during the field survey. Together with the earlier data present in the METU-EERC library the final size of the sample group is now over 575 buildings. The preliminary analysis indicated that the data gathered during this field investigation satisfactorily represents the building stock of the earthquake stricken region. A complete list of gathered data items can be seen on the data summary form provided in Appendix C1.1.

This phase of the study was completed with a 3-month delay. This delay was mainly due to the unforeseen difficulties encountered during the field work.

To be able to study the correlation between the damage distribution and the site conditions in the city of Düzce after November 12, 1999 Düzce earthquake of Mw=7.2, a detailed geotechnical investigation was also required. Within this context, a comprehensive geotechnical survey of the Düzce City was carried out. This activity had the following major goals (a) to assemble the geotechnical data available from the archives of the Düzce municipality, (b) to investigate the adequacy of the gathered data to identify the soil structure of the town and (c) to carry out further geotechnical investigation if necessary. These studies were completed successfully.

At the end of the activities explained above, two sets of databases were compiled: These are namely (i) structural and performance characteristics database and, (ii) site characterization and geotechnical engineering databases. To be able to assess the share of soil structure interaction on the overall observed damage, the findings of these two databases were decided to be presented and assessed within global information system framework. The construction of the GIS framework is expected to finish by June 2002. The details of the construction of GIS framework are explained in Appendix C1.2.

In the mean time, investigations towards the rapid first-level screening index are in progress. This index will preferably be based on building attributes, which can be collected within half an hour (per building) at the most. Later, somewhat more refined and yet simple index will be developed to perform second and third level screening based on strength considerations and the expected earthquake intensity at the site. While doing this, critical use of the established database will be made in conjunction with current codes, i.e. the Turkish code of reinforced concrete practice (TS500-2000) and the Turkish seismic code.

A detailed summary of what has been achieved in these studies so far is presented in Appendix C1.3.

C1.2.2 Preliminary Evaluation

At this stage, a closer examination of those buildings designated for further investigation at the end of the initial stage will be performed. This stage is oriented toward utilizing correlations based on the geometry of vertical-load-bearing structural members (columns and RC infill walls) and non-structural members (masonry infill walls), and some other factors relevant to the seismic safety of the structural systems.

At the end of this stage only a certain (preferably small) portion of the entire building stock will be categorized as buildings, which require further detailed investigations in third phase.

Until now, an MS dissertation was completed in METU. This study was supervised by Guney Ozcebe who is also the NPD of the NATO-SfP977231 and the PI of the present sub-project. In this master's study, an attempt was made to propose a new methodology to predict the seismic vulnerability of reinforced concrete structures by performing a statistical analysis (namely discriminant analysis) based on a number of structural parameters selected on the basis of observations and engineering judgment. The available data in the library of METU-EERC was used to calibrate the model parameters. The proposed method was subsequently applied to the available data collected after the 1992 Erzincan earthquake.

The most recent test of the proposed method was made after 4 February 2002 Afyon-Sultandağı earthquake of Mw=6.1. This earthquake hit a rural area of Afyon City. The METU teams were at the earthquake site immediately after the earthquake to make a detailed investigation on heavily damaged buildings. Almost all heavy damage cases were reached (all together 21 RC buildings, ranging from 2 story to 5 stories). The data gathered from this field survey is available at http://www.metu.edu.tr/home/wwweerc. Analytical investigations made on this database indicated that the proposed method is able to predict 67 percent of all heavy damage occurrences. The method apparently fails to predict the structural failures associated with soft-story formation since the soft-story formations were not available in the database, which was used in its derivation.

The initial indications are such that, the proposed method seems to be a promising assessment tool. However, it is obvious that more refinements and calibrations need to be made. This refinement phase has already been initiated and expected to come to an end as of 31 December 2002.

C1.2.3 Final Evaluation

The evaluation phase will consist of detailed condition evaluation and assessment of the buildings. The analyses in this phase will be based on the as- built data obtained from field investigations. This includes the floor plans, member sizes, concrete and reinforcement grades and the reinforcement available in the RC members. Structural analyses will be performed by using as built member sizes and material properties. Analysis results will be used to check strength and drift control criteria. In the strength checks again the as-built sizes and reinforcement of the members and the measured concrete strength will be used.

The R&D activities of the Turkish Branch have recently been commenced. The progress in these activities will be reported in the 3rd Progress Report.

C1.3. PROGRESS EVALUATION

C1.3.1 Accomplishments

The work outlined in the timetable given in the project plan, this sub-project is proceeding as scheduled. However, due to the difficulties encountered in the field work, the field data collection was completed several months later than the anticipated time. This caused a slight delay in the analytical work of this sub-project. This phase of the study is now over. The data gathered from the field has been processed and, the analytical and the statistical investigations are started.

C1.3.2 Future Plans

The sub-project appears to be progressing well in conformity with the work plan. However it may be necessary to shift the work schedule by 3 - 5 months due to the reasons explained in item C1.3.1.

C1.3.3 Young Scientists

In the Turkish branch of the present sub-project several young scientists were employed. Until now, one MS student (Mr. Ali Cihan Pay) finished his MS thesis under the PI of the present sub-project in August 2001. His thesis is entitled "A New Methodology for Seismic Vulnerability Assessment of Existing Buildings in Turkey". Mr. Pay is now pursuing his studies in Purdue University toward his PhD degree in Civil Engineering under the supervision of Prof. R. Frosch.

As of 1st progress report one assistant professor, two researchers and one MS student were actively participating in the research activities. One of these researchers had obtained his PhD degree in civil engineering in the Summer of 2001 and has departed for the University of Texas at Austin (a partner institution) as a postdoctoral fellow. Another PhD student had completed his doctoral work in December 2001 and went to Purdue University as a postdoctoral fellow in February 2002. Two MS student (Mr. Volkan Aydogan and Mr. Serdar Soyoz) are currently working toward his MS degree and taking part in the "Development of Preliminary Investigation Methodology" phase of the present sub-project.

During the period of 1 November 2001 – 30 April 2002 2 new PhD students (Mrs. Nazan Yilmaz Ozturk and Mr. Ilker Kazaz) joined the project team and their thesis work will be related with the assessment methodologies. During this period two new young faculty members joined the

Civil Engineering Department of the METU. These young scientists are invited to take part in the project activities. One of them (Dr. Kemal Onder Cetin, PhD in Civil Engineering, University of California, Berkeley) is a geotechnical engineer and he will be in charge of GIS framework applications. Dr. Ahmet Yakut, having completed his PhD studies at Department of Civil Engineering of the University of Texas at Austin, worked for two years in a Boston based insurance company where he obtained valuable expertise on seismic risk assessment of reinforced concrete buildings. He will be actively involved in the development of final assessment methodologies to evaluate the seismic vulnerability of the existing structures.

Prof. G. Ozcebe of METU is in touch with a young scientist from Institute of Geophysics and Geology, Moldavian Academy of Sciences. Dr. Anton Zaicenko's applied to the Scientific and Technical Research Council of Turkey (TUBITAK) for the NATO PC-B fellowship. His application was approved by TUBITAK and he was awarded 800 USD/month to cover his living expenses in Turkey. He will also receive partial coverage of 250 USD for the travel expenses. Dr. Zaicenko will be visiting METU between 25 May 2002 and 20 June 2002. Dr. Zaicenko is especially. During his stay in the Middle East Technical University, Dr. Zaicenko will be working together with METU team towards the development of seismic vulnerability assessment methodologies for the existing buildings.

C1.3.4 Travel

The Organizational Workshop of NATO-SfP977231 was hosted by Turkey. The workshop was held on 25-28 May 2001. The travel and accommodation expenses of participating project co-directors were met by using NATO funds.

C1.3.5 Proposed Changes

No change of plans is proposed at this stage.

APPENDIX C1.1: Sample Form Used in Field Work

TÜBİTAK - ODTÜ

Structural Engineering Research Unit

Orta Doğu Teknik Üniversitesi, İnşaat Mühendisliği Bölümü, 06531, Ankara

Tel: (312)210 24 51, Faks: (312) 210 11 93

İÇTAG I574

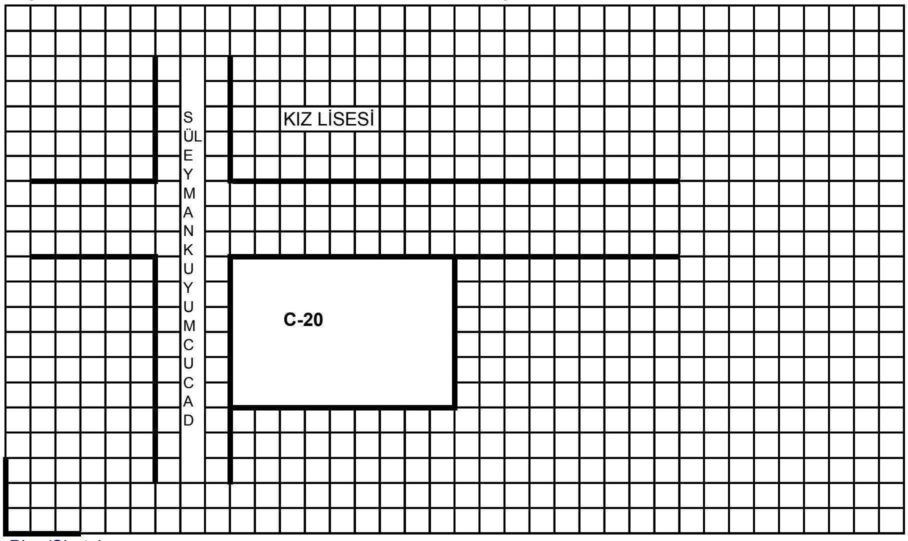
DEVELOPMENT OF METHODS FOR ASSESSING SEISMIC VULNERABILITY

1. GENERAL INFORMATION

Building Reference No.	C-20	**Investigation Date :**	20 / 9 / 2001
Address Information	: KÜLTÜR MAH. SÜLEYMAN KUYUMCU CAD MAH.KUYUMCUZADE APT.		
Construction Date:	/ / 1994	**Date of Project**	/ /
Building Coordinates	: E 344950 - N 4523075		
Investigating Team	: MEHMET YERLİ - HARUN ŞEHİTOĞLU		

View 1

View 2



Plan/Sketch

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2. BUILDING INFORMATION

Stories	Number of Repetitions	Story Height (m)	Floor Plan Area (m²)	Remarks			
Basement	1	3	647				
Ground	1	3.5	665				
Mezzanine							
Normal Storey	4	3	665				
Overhang Storey							
Any increase in storey number due to change of population density in municipal construction regulations?				Yes		No	X

Location :	Detached	X	:hed corner building		ding in row of housing	
	Building on sloping land?	Yes			No	X

Irregularity						
					Yes	No
In plan						
In sectional elevation						
A1 :	Torsional irregularity					X
A2 :	Slab irregularity					X
A3 :	Extensions present in plan					X
A4 :	Axes of load bearing members not parallel					X
B1 :	Resistance (weakness) irregularity					X
B2 :	Stiffness (soft storey) irregularity				X	
B3 :	Irregularity in vertical members					X
How many continuous frames in both principal directio		X-direction	1		Y-direction	2

Construction joint with neighbouring buildings :	Yes		No		Unclear	

Floor levels with neighbouring buildings :	Same		Different	

3. PROPERTIES OF LOAD-BEARING SYSTEM

Type of Load-bearing system:	**Reinforced Concrete Frame**	
	Reinforced Concrete Frame + Shear Wall	X

Infill wall material:	**Manufactured hollow brick**	X
	Manufactured solid brick	
	Concrete block	
	Kiln-fired brick	
	Lightweight concrete brick or panel	
	Other (explain):	

Basement wall material:	**Stone masonry (pointed or rubble)**	
	Reinforced concrete wall	X
	Kiln-fired or manufactured solid brick	
	Concrete block	
	Other (explain):**BRICK WALL**	

Slab System:	**Beam-slab floor (BASEMENT)**	X
	Concrete joist hollow tile slab (NORMAL STOREY)	X
	Unfilled concrete joist slab	
	Flat slab	
	Other (explain):	

Summary of Material Test Results

Order	Rebound hammer test		Ultrasonic Measurement Test	
No.	**Member**	**Hammer reading**	**Member**	**Sonic pulse speed (km/sec.)**
	9I	34-32-34-35-34-35-35-36-34-35		
	23J	36-34-35-36-34-36-35-36-34-35		
	22M	36-35-37-38-38-36-36-37-37-37		
	20N	37-36-38-38-36-38-37-36-38-38		
	6F	37-36-35-38-36-37-36-37-36-36		

Design Strength, fck : 27.00		**MPa**	**Test conducted by:**		**Team 1**		
Elastic Modulus, Ec :		**Gpa**	**Date :**				
Grade of Steel in Building:*	**S220 (St I)**	X	**S420 (St III)**			**S500 (St IV)**	
Type of reinforcement:*	**Plain**	X				**Deformed**	

*If possible to establish.

(1) Ground Floor Plan Area	:	665.00	m^2
(2) Total Floor Area of Building (except basements)	:	3325.00	m^2
(3) Sum of Ground Floor Column Cross-sectional Areas in X-Direction	:	9.41	m^2
(4) Sum of Ground Floor Column Moments of Inertia in X-Direction	:	0.96	m^4
(5) Sum of Ground Floor Column Cross-sectional Areas in Y-Direction	:	3.53	m^2
(6) Sum of Ground Floor Column Moments of Inertia in Y-Direction	:	0.09	m^4
(7) Sum of Ground Floor Shear Wall Cross-sectional Areas in 'X' Direction	:	0.38	m^2
(8) Sum of Ground Floor Shear Wall Moments of Inertia in 'X' Direction	:	0.11	m^4
(9) Sum of Ground Floor Shear Wall Cross-sectional Areas in 'Y' Direction	:	0.72	m^2
(10) Sum of Ground Floor Shear Wall Moments of Inertia in 'Y' Direction	:	0.19	m^4
(11) Sum of Ground Floor Infill Wall Cross-sectional Areas in 'X' Direction	:	6.10	m^2
(12) Sum of Ground Floor Infill Wall Cross-sectional Areas in 'Y' Direction	:	8.36	m^2

X' Direction Index	SUM	[0.5(**3**)+(**7**)+0.1(**11**)] / **2** =	**0.00171**	GROUND	[0.5(**3**)+(**7**)+0.1(**11**)] / **1** =	**0.00856**
Y' Direction Index		[0.5(**5**)+(**9**)+0.1(**12**)] / **2** =	**0.00100**		[0.5(**5**)+(**9**)+0.1(**12**)] / **1** =	**0.00499**

Slenderness Ratio Limits for Ground Floor Columns 'UPPER'	: d_{top} = **0.13**	H/d_t = **26.94**
Slenderness Ratio Limits for Ground Floor Columns 'LOWER'	: d_{bottom} = **0.06**	H/d_b = **60.62**

4. SYSTEM, WORKMANSHIP AND GENERAL QUALITY EVALUATION

Evaluation Item		Notes and Explanations	Points 0=bad 5=good
Overview of Building Present Quality			**4**
Material Quality	Concrete		**4**
	Steel		**3**
	Infill		**4**
System Defects	Short Column		**5**
	Soft Storey		**5**
	Weak Storey		**5**
Any axial connection problem in Column/Beam joints?			**3**
At least two spans in both principal directions?			**5**
What is the probability of a hammering effect with neighbouring buildings?			**5**
Does the architecture vary greatly from storey to storey?			**5**
Is there discontinuity in infill walls?			**5**
Is there a corrosion problem in the building?			**5**
Is there a discontinuity in the vertical load-carrying members?			**5**
Is the horizontal load resisting system adequate?			**3**

APPENDIX C1.2: Screening Methodology – a Walk-Down Survey Procedure for the Seismic Risk Assessment of Building Structures

A walk-down survey procedure must be based on simple structural and geotechnical parameters that can be observed easily during a street walk. The parameters that are selected for representing building vulnerability in this study are the following:

- P1: The number of stories above ground (1 to 6)
- P2: The minimum number of bays in both directions (1 to 5)
- P3: Presence of a soft story (Yes or No)
- P4: Presence of an added story (Yes or No)
- P5: Presence of significant irregularity in building plan (Yes or No)
- P6: Presence of heavy overhangs, such as balconies with concrete parapets (Yes or No)
- P7: Apparent building quality (Good, Moderate or Poor)
- P8: Local soil conditions (Stiff, Moderate or Soft)

Each parameter reflects a negative feature of the building system under earthquake excitations on a variable scale. Evaluating the correlation between observed building damage and parameter variation by using the building data compiled from Düzce assesses the weight of each parameter in expressing the seismic vulnerability. It is intended to develop a linear combination rule for the selected parameters in order to predict the damage distribution displayed by the collected data as good as possible. Once such a combination rule is developed, it will be possible to rate the seismic risk of reinforced concrete building structures in the highest seismic hazard zone of Turkey by employing a simple walk-down survey procedure. The proposed method bears some similarities with the seismic evaluation procedure developed in FEMA-178 (1989). However it is believed that it provides a broader description of seismic risk for the multistory reinforced concrete buildings in Turkey in the mentioned seismic zone, which do not conform to the requirements of modern seismic design and construction codes.

The objective of developing a risk scale for existing buildings is to provide a simple tool, which can be easily implemented by both the building owners and the public administrations. If an individual building falls on the high-risk part of the scale, then a more detailed evaluation will be deemed necessary. The risk scale is an ordering of the negative points constituting the seismic vulnerability of a building. The scale will be divided into low, moderate and high-risk levels. Low-risk buildings do not require a further evaluation, but moderate and high-risk buildings are subjected to more detailed evaluation procedures that will be developed in the later stages of this project.

Each vulnerability parameter is evaluated separately in the following sections. If the damage distribution in the collected building data is found sensitive to one of the parameters, then that parameter will be retained. Otherwise it will be deleted from the parameter set.

Building Data from Düzce

A total of 421 buildings were surveyed in Düzce within the scope of the project. All of these buildings survived the 17 August 1999 Kocaeli and 12 November 1999 Düzce earthquakes with some levels of damage. Building damages were classified in four grades, namely none, light, moderate and severe. A building with light damage can be occupied with minor repairs after the earthquake whereas a moderately damaged building requires structural repairs. If there is severe damage, then such a building must be strengthened to upgrade its seismic capacity. Out of 421 surveyed buildings, 60 were undamaged, 150 were lightly, 145 were moderately and 66 were severely damaged.

In a more recent survey program, design documents for another 70 buildings were retrieved from the archives of the Düzce Municipality. These buildings were either collapsed, or erased due to their very severe damage after the Düzce Earthquake. Project teams are currently working on these documents for classifying their characteristics. At this stage, they are not employed in the building data. However their implementation in the following stage will not create any difficulty since their damage grades fall on the extreme end of the damage scale.

The Number of Stories (P1)

Field observations after the 1999 Kocaeli and Düzce earthquakes revealed that there is a very significant correlation between the number of stories and the severity of seismic damage. If all buildings were conforming to seismic design codes, then such a distribution would not occur, and a uniform distribution of damage would be expected. However if the majority of buildings in the earthquake stricken region lack this basic property, then increasing number of stories increase seismic forces linearly whereas seismic resistance does not follow in adequate proportions. Accordingly, damage increases almost linearly with the number of stories. After the two earthquakes in 1999, damage distribution for all 9685 buildings in Düzce is obtained with respect to the number of stories (Sucuoğlu and Yılmaz, 2001). The results are shown in Figure 1 below, where the number of damaged buildings is normalized with the total number of buildings at a given story number. It can easily be observed from Figure 1 that damage grades shift linearly with the number of stories. As the number of stories increase, the ratio of undamaged and lightly damaged buildings decrease steadily whereas the ratio of moderately and severely damaged buildings increase in an opposite trend. This is a clear indication that the number of stories is a very significant, perhaps dominant parameter in determining the seismic vulnerability of typical multistory concrete buildings in Turkey. A similar result was also found by Pay (2001).

A similar investigation is conducted on the 421 surveyed buildings in Düzce, to check whether the surveyed building data represents Düzce building inventory. The results are shown in Figure 2. The trend in this figure is quite similar to that in Figure 1, except a difference in 4 and 5+ stories. Since most of these buildings were erased in Düzce before the data for 421 buildings were compiled, they are not well represented in the data. Enrichment of data with the 70 collapsed and/or removed buildings will correct this difference.

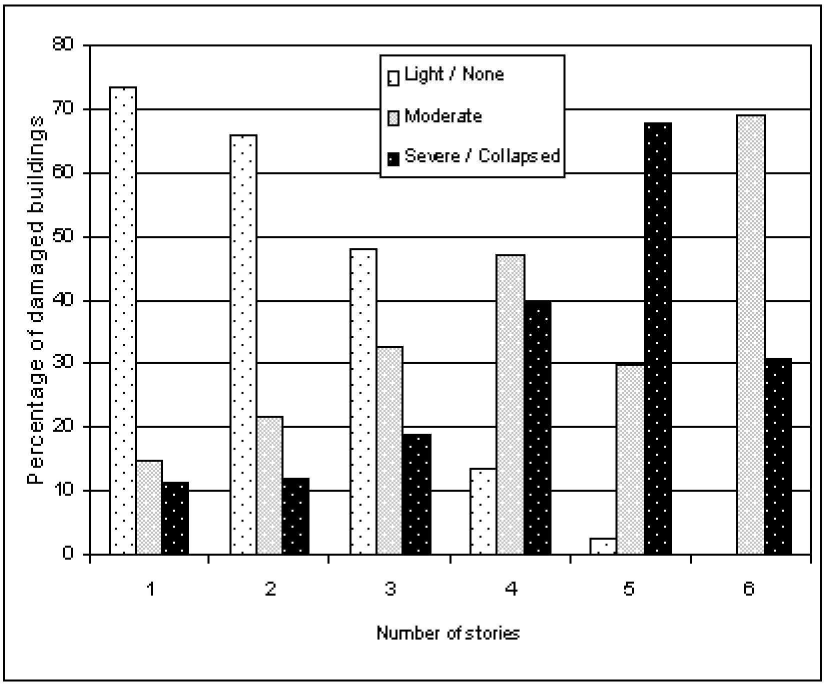


Figure 1. Damage distribution in Düzce after the 1999 earthquakes, with respect

A different presentation of damage distribution with the number of stories is obtained by grouping the buildings with respect to the number of stories, and then calculating the percentage of buildings in each story group according to their damage grade. The distribution obtained is shown in Figure 3, where the sum of ratios for a given number of stories at different damage grades is 1.0. This figure also indicates increasing damage trends with the increasing number of stories very clearly. Therefore this parameter requires attention perhaps more than the other parameters.

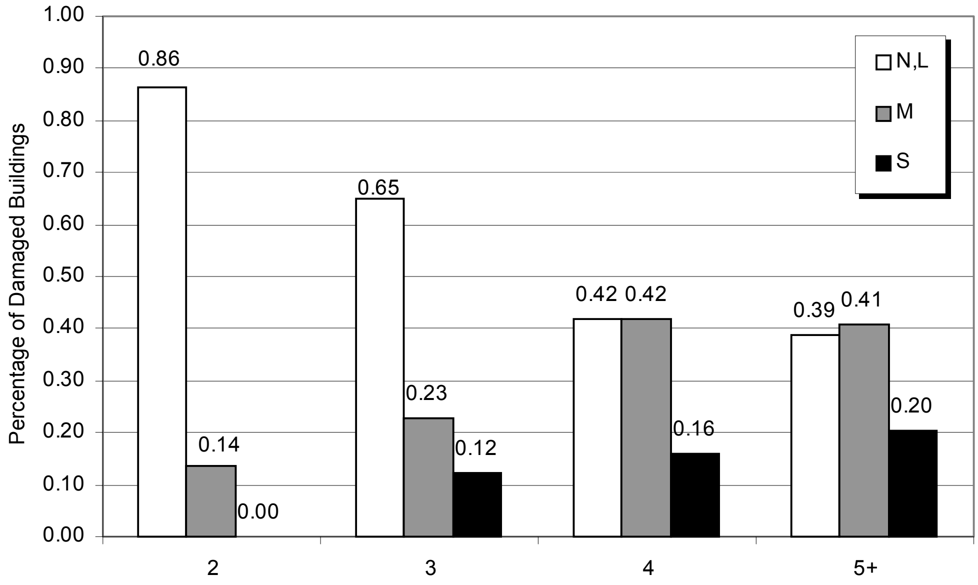


Figure 2. Damage distribution with the number of stories for the 421 buildings in Düzce data

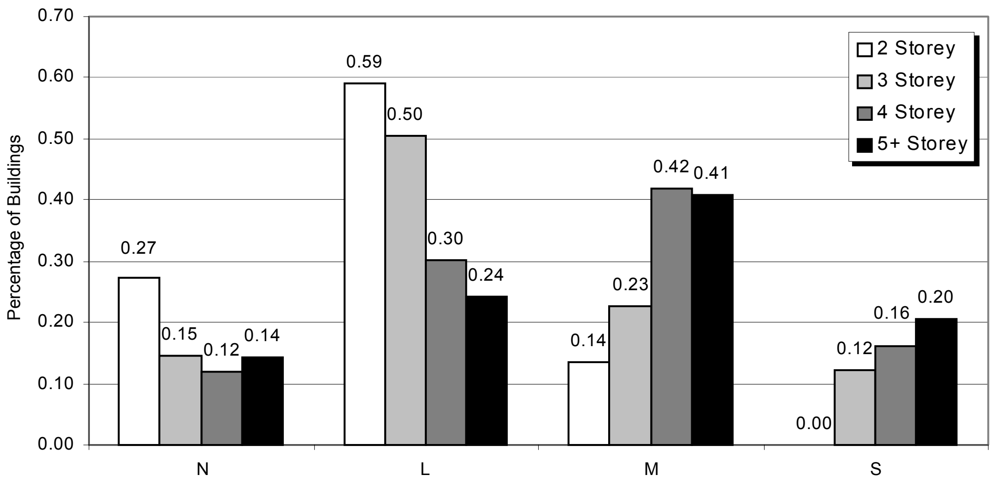


Figure 3. Distribution of damage normalized for each story group

The Minimum Number of Bays (P2)

In a building frame system, as the number of bays increase, redundancy of the structure increases. This is a positive feature, because an even redistribution of internal forces can be achieved after damage starts during an earthquake ground excitation. Hence, the internal forces released from a damaged component can be received by the undamaged components if there is sufficient redundancy. In fact, at least three spans is necessary for a sound earthquake resistant frame design.

The data compiled from 421 buildings is first classified with respect to the damage grade and minimum span number, and then grouped separately for 2+3 and 4+5 story buildings in order to eliminate the effect of the number of stories on damage. The results are shown in Figure 4, where each ratio represent the percentage of buildings in each damage category normalized with respect to the total number of buildings with a minimum span number.

It can be observed from Figure 4 that there is no clear trend for the effect of the minimum number of bays on damage. It was expected that damaged building ratios would increase as the minimum number of bays decrease. This is not the case in Figure 4. Perhaps this parameter has lost its importance among the other parameters which are more influential on damage vulnerability. Accordingly, it is decided to delete this parameter from the parameter set.

Presence of a Soft Story (P3)

Soft story usually exists in a building when the ground story has less stiffness and strength compared to the upper stories. This situation mostly arises in buildings located along the side of a main street. The ground stories which have level access from the street are employed as a street side store, or a commercial space whereas the upper stories are occupied by residences. These upper stories benefit from the additional stiffness and strength provided by many partition walls, but the commercial space at the bottom is left open between the frame members for customer circulation. Besides, the ground stories may have taller clearances and a different axis system causing irregularity. The compound effect of all these negative features from the earthquake engineering perspective is identified as a soft story. Many buildings with soft stories were observed to collapse due to a pan-caked soft story in the past earthquakes all over the world.

Among the 421 surveyed buildings, 203 buildings had soft stories. These buildings are grouped with respect to the damage grades and the number of stories, then their number is normalized relative to the total number of buildings in each group. The results are presented in Figure 5. For all storey numbers, it is evident that the buildings with soft stories exhibit higher damage grades compared to those with no soft stories. Notably, almost all severely damaged buildings have soft stories. This is an important observation because if a building with a soft story is vulnerable to seismic damage, it is very likely that this damage will be either moderate or severe, especially when the number of stories exceed two. It can be decided that damage distribution among buildings with soft stories does not change significantly with the number of stories. Therefore parameter P3 can be assessed independently from the parameter P1.

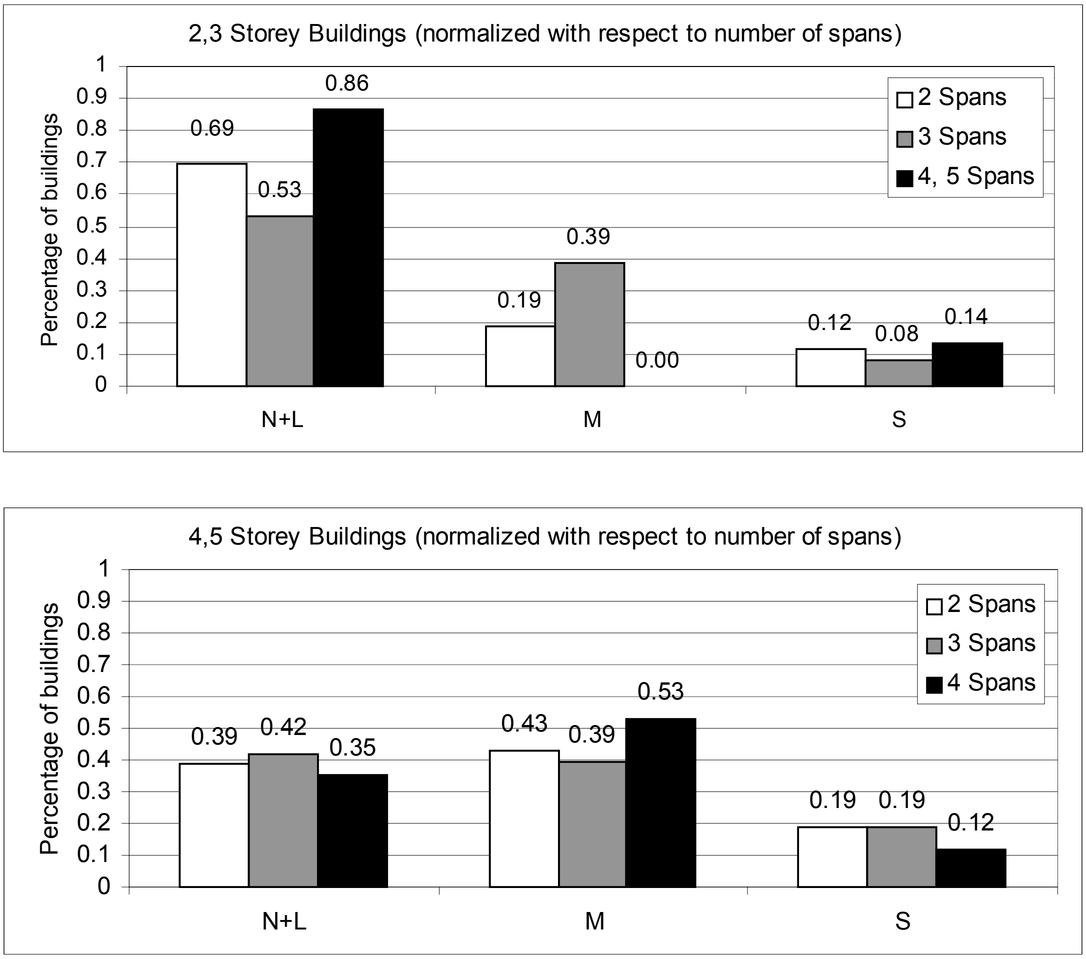


Figure 4. Correlation of damage with the minimum number of spans. Data is normalized with respect to the total number of buildings with a given span number.

Presence of an Added Story (P4)

A story may be added to an existing building either illegally, or legally by a construction permit on increasing the height limit in a district due to revisions on the development plans. In such a case, the existing building must be upgraded to a higher seismic resistance level in order to carry the increased seismic forces during an earthquake. However this is usually not done. Hence, the seismic vulnerability of a building increases significantly due to an added story.


2 Storey- Normalized with respect to story type (19 buildings)
Building Ratio
1.0
0.8
0.6
0.4
0.2
0.0
0.20
0.50
0.80
0.25
0.00
0.25
0.00 0.00
N
L
M
S
No
Yes


3 Storey-Normalized with respect to story type (115 buildings)
Building Ratio
1.0
0.8
0.6
0.4
0.2
0.0
0.14
0.09
0.59
0.39
0.21
0.27
0.06
0.25
N
L
M
S
No
Yes


4 Storey- Normalized with respect to story type (129 buildings)
Building Ratio
1.0
0.8
0.6
0.4
0.2
0.0
0.11
0.16
0.39
0.21
0.44
0.40
0.06
0.24
N
L
M
S
No
Yes


5+ Storey- Normalized with respect to story type (126 buildings)
Building Ratio
1.0
0.8
0.6
0.4
0.2
0.0
0.17
0.13
0.41
0.19
0.38
0.44
0.03
0.24
N
L
M
S
No
Yes

Figure 5. Correlation of damage with the presence of a soft story

There were no added stories among the one and two story buildings of the surveyed building stock. Besides, there were no undamaged buildings with an added story, and damage distributions were similar for 3 and 4 story buildings. Accordingly, the data is reduced for brevity as given in Figure 6. A difference between the damage distributions of 3+4 story, and 5 story buildings can be observed in this figure. Three or four story buildings with added and no added stories do not exhibit different damage distributions. However added stories make a difference in the damage levels of five story buildings. There is a tendency of increase in the severely damaged buildings.

The effect of added stories on damage is less than that expected initially. A more consistent trend will be likely obtained after the 70 collapsed buildings are added to the building data. Added stories may be more effective in increasing the damage in buildings with number of stories larger than four.

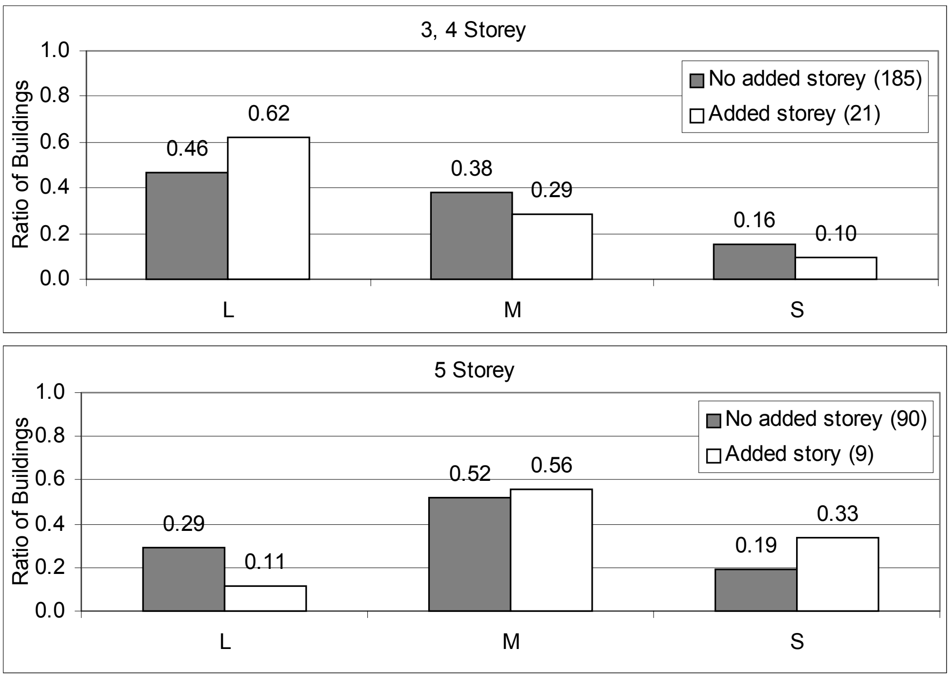


Figure 6. Correlation of damage with the added stories

Presence of Significant Irregularity in Building Plan (P5)

Irregularity in building plan is deviation from a rectangular plan having orthogonal axis systems in two directions. Such deviation from plan regularity leads to irregularities in stiffness and strength distributions, which in turn increase the risk of damage localization under strong ground excitations. In earthquake resistant design, regularity in plan is encouraged.

The results obtained from the survey data are presented in Figure 7, separately for each number of stories. Irregularity in plan does not influence damage distribution in 2 story buildings. In 3, 4 and 5 story buildings, those with irregular plan have a larger share among the severely damaged buildings than ones with regular plan. Therefore plan regularity should be considered as a parameter in determining the seismic risk of buildings taller than 2 stories. However, additional data on collapsed buildings may produce the correlation between damage and plan irregularity more accurately.

Presence of Heavy Overhangs (P6)

Heavy balconies in multistory reinforced concrete buildings shift the mass center upwards, accordingly increase seismic lateral forces and overturning moments during earthquakes. This is the case especially in balconies with large overhanging cantilever spans enclosed with heavy concrete parapets. Since this building feature can easily be observed during a walk-down survey, it is included in the parameter set.

The distribution of damage in buildings with and without heavy overhangs is presented in Figure 8. The building ratios are obtained by normalizing the number of buildings in each category with respect to the total number of buildings with or without overhangs for each number of stories. Almost all of the undamaged buildings are free of heavy overhangs. However, there is no consistent trend in the damage distribution of 2 and 3 story buildings regarding the presence of overhangs. On the other hand, the ratio of moderately and severely damaged 4 and 5 story buildings with overhangs are significantly more than those without overhangs. Accordingly, this parameter should be considered in the seismic risk assessment of buildings having more than 3 stories.

Apparent Building Quality and Local Soil Conditions (P7 and P8)

These two parameters are currently being evaluated by using the surveyed building data. apparent building quality depends on several objective (measurable) and subjective factors. Quality of materials and workmanship, corrosion and maintenance conditions are among these factors. A measure of quality must be developed first by using the observations on the surveyed buildings. Then correlation of this quality measure with damage will be assessed.

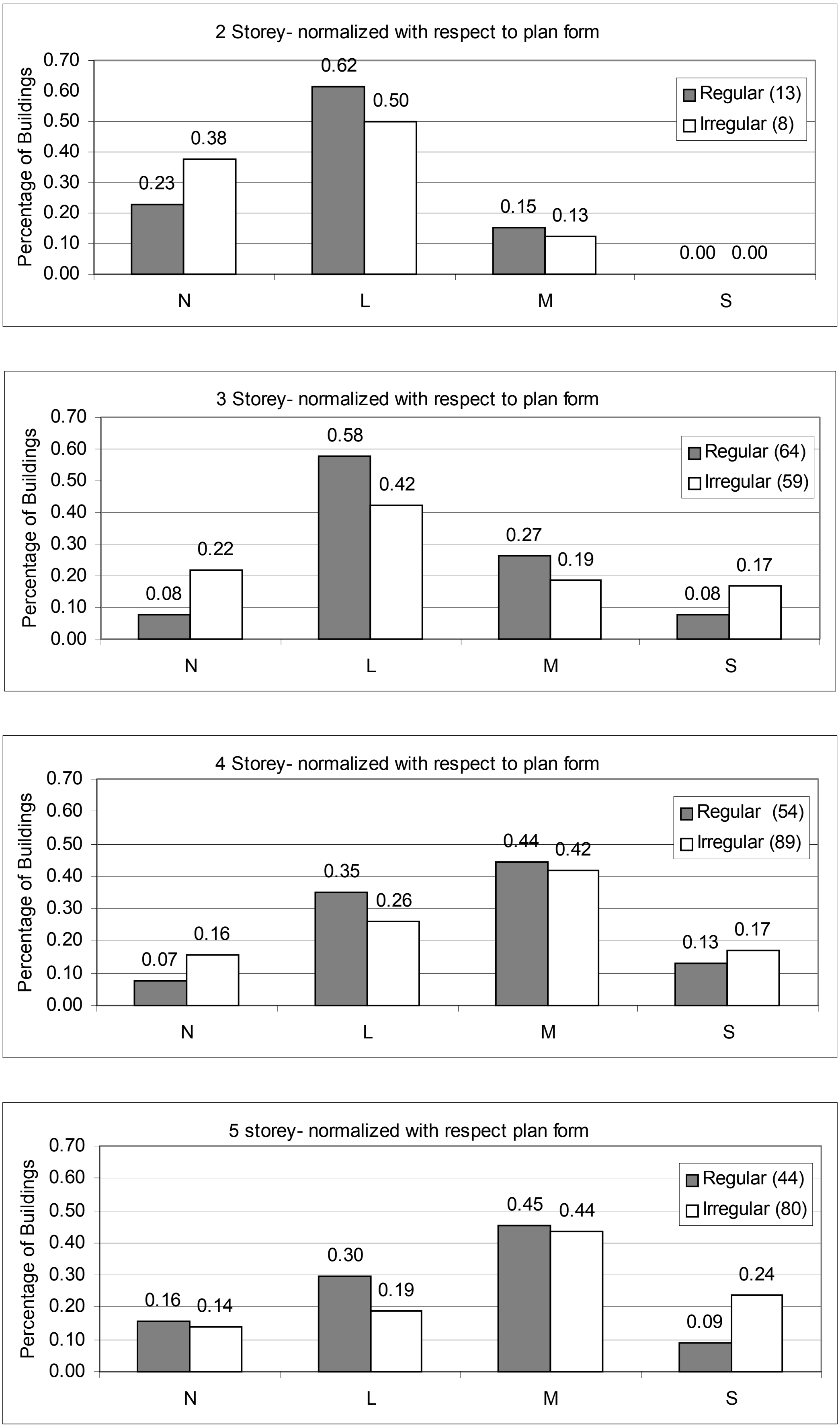


Figure 7. Correlation of damage with the plan form

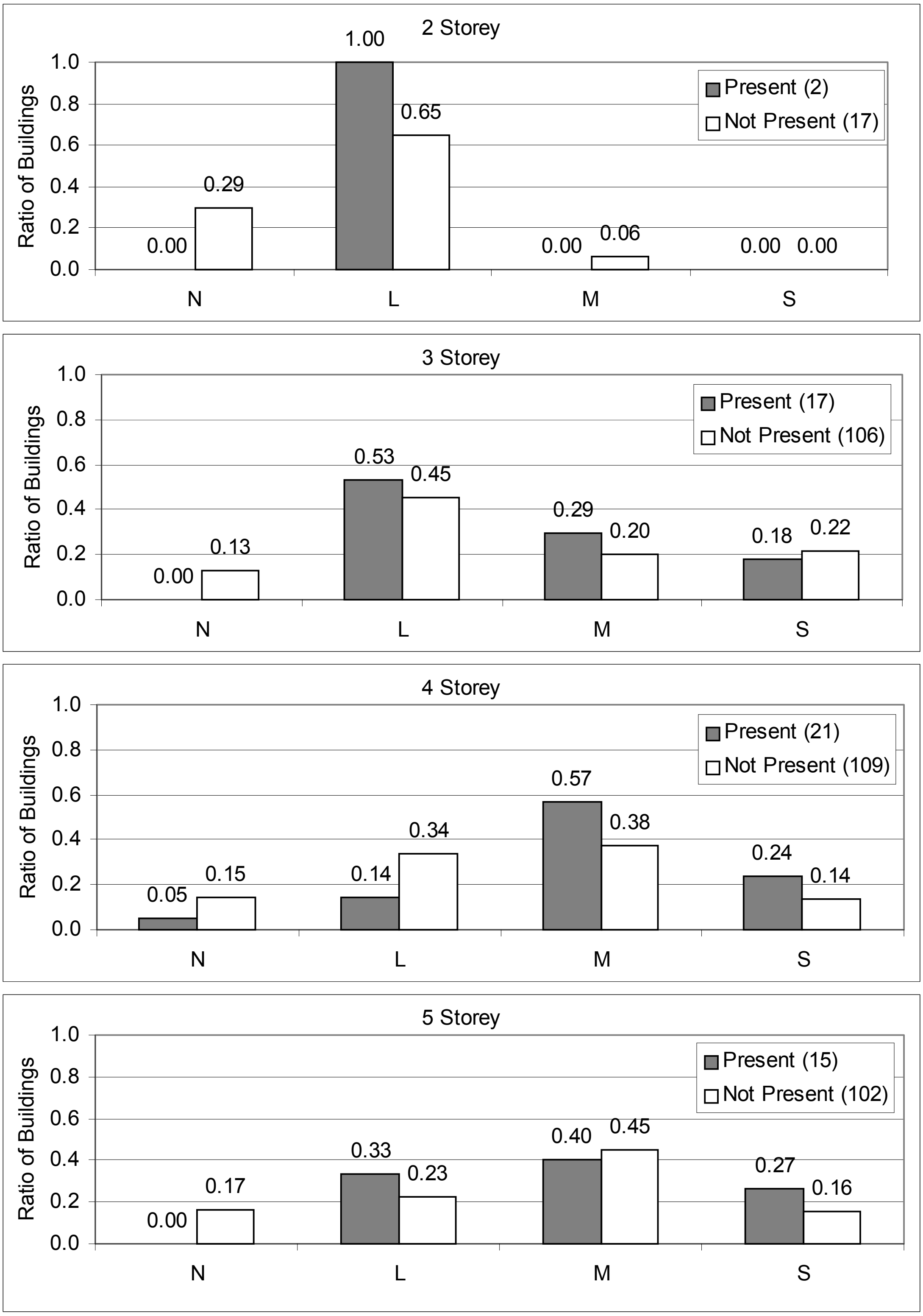


Figure 8. The effect of heavy overhangs in buildings on the distribution of damage

APPENDIX C1.3: Global Information System Framework

Introduction

The aim of these studies was defined as to assess the structural damage observed in the city of Düzce after November 12, 1999 Düzce earthquake of Mw=7.2. For this purpose two sets of databases were compiled. These are namely i) structural and performance characteristics, ii) site characterization and geotechnical engineering databases. To be able to assess the share of soil structure interaction on the overall observed damage, the findings of these two databases were decided to be presented and assessed within global information system framework

Structural Data Compilation

As a result of extensive data gathering and compilation efforts, so far the compilation of select structural engineering parameters for over 431 buildings ranging from single story to 5-story reinforced concrete structures was completed. During data compilation efforts, in addition to the number of stories of the structures and the structural performance classifications as no damage, light, medium and severe damage, other select characteristics are listed as follows:

- i) the minimum number of bays in two dimensions,
- ii) existence of a soft story,
- iii) existence of an added story,
- iv) presence of geometric irregularity in building plan,
- v) existence of heavy overhangs such as balconies with parapets,
- vi) apparent building quality, etc

A complete list of gathered data items can be seen on the attached data summary form in Appendix C1.1.

Geotechnical Data Compilation

In addition to the above summarized structural data compilation efforts, for the purpose of a) identifying geotechnical factors which have possibly contributed to the overall damage levels and b) eliminating them from the overall damage to clearly attribute the remaining damage to mainly variations in structural characteristics of buildings, geotechnical data compilation efforts were carried out parallel to structural characterization.

So far a database composed of i) over 240 borelogs usually extending to 20 m depth with ii) standard penetration test results obtained at applicable depths in addition to iii) "disturbed" and "undisturbed" sampling at various layers as well as iv) seismic p-wave and s-wave velocity measurements obtained at 115 locations, has been compiled. The compilation of subsurface characterization studies at approximately 15 sites is still continuing and expected to be finished before Mid July.

Parallel to data compilation efforts, the processing of geotechnical data has been started. Important soil parameters were selected as:

i) depth to water table
ii) depth to liquefiable (critical) layer
iii) thickness of liquefiable layer(s)
iv) average standard penetration blow counts in the critical layer
v) standard deviation of average standard penetration blow counts in the critical layer
vi) fines content of the soil in the critical layer
vii) vertical effective stress at the mid-height of the critical layer
viii) thickness of the layer with SPT blow counts less than 10 in the upper 10m.
ix) peak ground acceleration after soil site response
x) settlement estimations
xi) lateral displacement estimations, etc.

The aim of these efforts is to develop generalized soil profiles for the city of Düzce. So far 4 distinct different soil profiles were identified. Once the processing all subsurface characterization studies is over, based on developed generalized soil profiles, the amplification/de-amplification characteristics of Düzce soils which can be further used in the estimation of variation of strong ground motion levels throughout Düzce city, will be identified. In addition to the contribution of subsurface soils to the observed damage through site amplification, the ground deformations component will also be questioned. For this purpose, it is planned to estimate settlements and lateral movements at select sites for the purpose of better understanding soil-structure interaction and its effects on observed performance.

Geographic Information Systems Framework

As summarized in previous paragraphs, as a result of these research efforts, a significant size-database composed of various information pieces streaming from different but interrelated and interdependent research teams has been compiled. To be able to sort, correlate and access the needed information in a timely and orderly manner, it was decided to adopt geographic information systems framework for data retrieval. The tool for this was selected as Map-info software package.

As shown in Figure 1, the locations of each surveyed structure (blue dots) can be seen on the developed base map. However, each blue dot shown bears more information than just the location of the surveyed buildings.

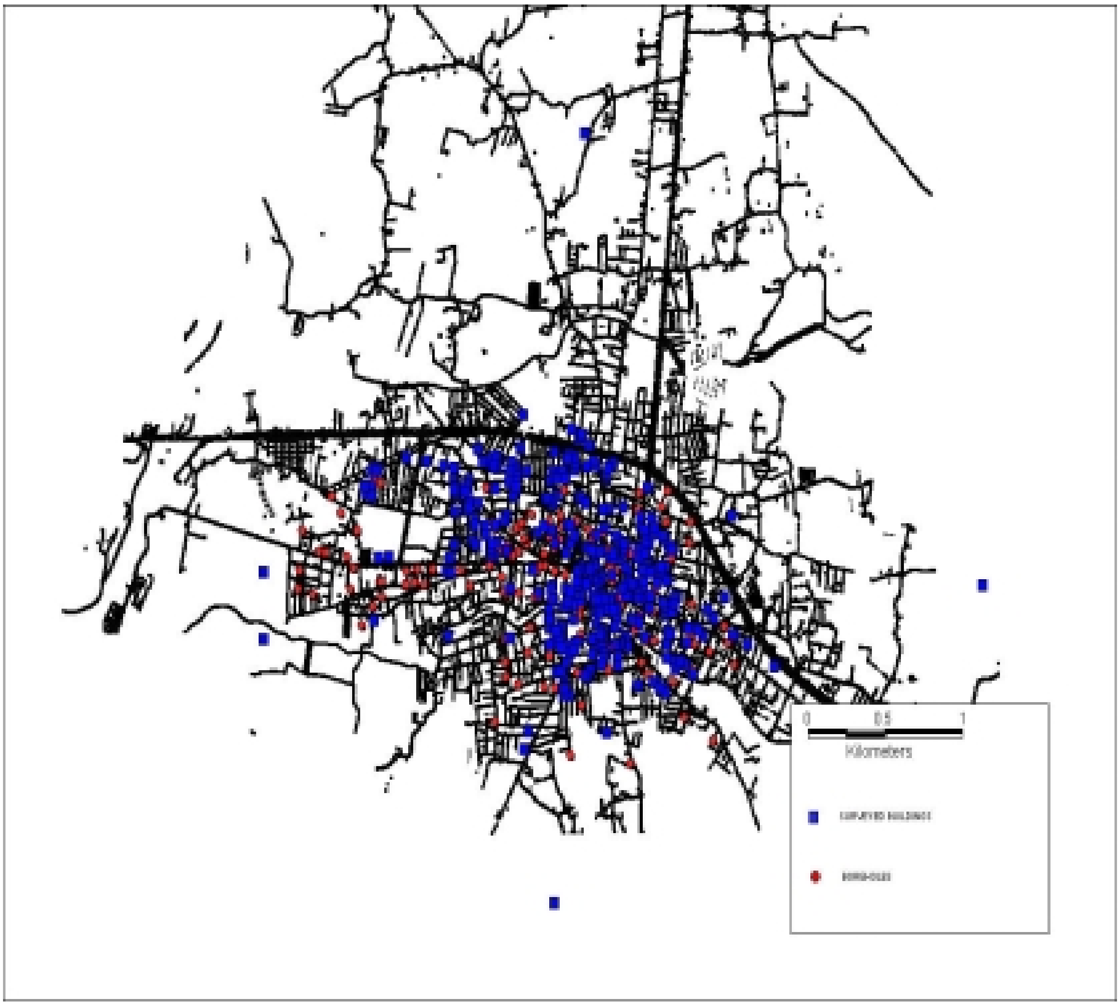


Figure 1. Base map of Düzce

As discussed previously, by clicking on the blue points, one can access to more than 20 different structural data including the number of stories, the height of each story, presence of a soft story, the level of damage, etc., as shown in Figure 2.

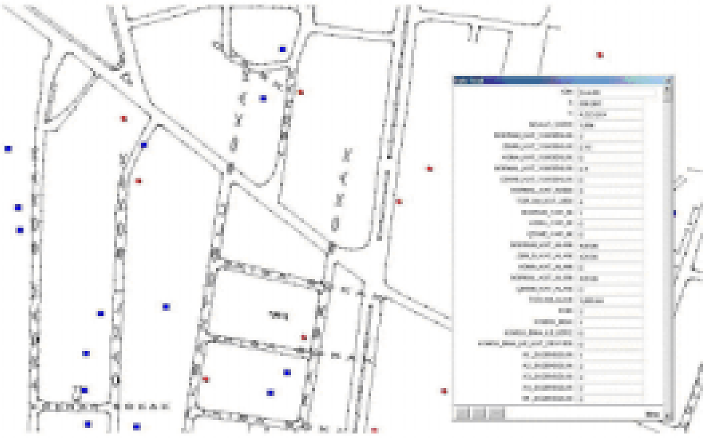


Figure 2. Structural and performance characteristics of a select building

Similarly, by using these detailed descriptions available for each building, it is also possible to visually subgroup the overall database into smaller bins such as the locations of buildings higher than three story with soft story (Fig. 3).

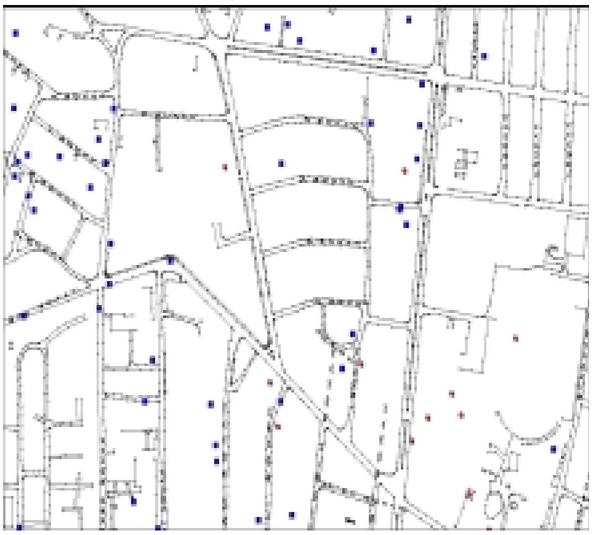


Figure 3. Locations of buildings higher than three story with soft story

Same can be achieved for the presentation of geotechnical data compiled. Similarly the brown dots in Figure 1 show the locations of borehole and sounding data. At each brown dot, to access geotechnical data listed previously is as easy as clicking on it. The compilation and assessment of geotechnical data is still continuing and planned to be finished before mid-July. It is also planned to perform an effective stress-based nonlinear seismic analyses of the city of Düzce, as a result of which some site-specific strong ground motion data such as peak ground acceleration, response spectrum, etc. will be available.

APPENDIX C2: SUB-PROJECT 2 - REHABILITATION METHODOLOGY DEVELOPMENT – 2nd PROGRESS REPORT

C2.1. INTRODUCTION

The seismic repair and/or strengthening philosophy generally consist of system behavior improvement and member repair/strengthening. In the system behavior improvement technique, a new lateral load carrying system is introduced to increase the lateral strength and the lateral stiffness of the existing system. Besides overall system improvement, if the capacities of reinforced concrete elements are not sufficient against lateral loads, their repair and/or strengthening is required. The scope of this sub-project is to develop new strengthening techniques.

From the starting of the project, the experimental investigations have been planned, some of the major experiments have been performed, and some analytical works have been done and have been correlated with experimental results.

C2.1.1. Strengthening Principles

The two basic approaches have been chosen in the planning workshop for the seismic retrofitting of the existing undamaged reinforced concrete building structures were:

- Strengthening of the existing hollow brick masonry infills by CFRP and
- Use of post-tensioned diagonals in the chosen frame bays

to increase the lateral stiffness and thus to improve the seismic response of the existing structural system, since insufficient lateral stiffness is the most common seismic deficiency in this kind of structures in Turkey and in the other countries of the region. A critical evaluation of the latter approach indicated some serious drawbacks of this technique, which caused concern about the potential problems expected in practical applications. It was therefore decided not to give priority to this approach and consider it as a secondary alternative, which may be studied, if time allows. However, another technique was adopted as the second basic approach:

- Strengthening of the existing hollow brick masonry infills by introducing one or two layer precast concrete panels (small enough to be carried by two workers) in-situ connected to each other and to the existing reinforced concrete frame elements to act as a reinforced concrete infill.

C2.1.2. Testing Principles

Considering the laboratory facilities available, majority of the tests are planned to be performed on two-dimensional, one-bay, two-storey, one-third scale reinforced concrete frame models under reversed cyclic quasi-static loading. These two-storey frames are considered as the lower floors of multi-storey building structures. However, the effects of various modeling parameters will be investigated by different types of verification tests. Some selected tests will also be performed on three-bay frames to justify the generalization of the results obtained from one-bay frames to multi-bay frames. Similarly, a few full scale models will also be tested to investigate the scale effects on the results. One three-dimensional shake table test has also been planned to be performed under an actual earthquake excitation in Skopje, Macedonia. The test set-ups to be used are briefly introduced in the following paragraphs.

- Horizontal One-bay Twin Frames (METU) – This rather simple test set-up had been developed more than a decade ago using rather limited testing facilities and employed in three PhD and half-a-dozen MSc theses. The model consists of two identical one-bay two-storey frames monolithically connected to the two sides of a heavy foundation beam, Figure 1. The model is supported at the ends of the top floor beams as a simple beam and loaded at the other end of the foundation beam in a horizontal closed loading frame. The equal reactions of the simple beam carrying a central concentrated load represent the horizontal seismic load applied at the second floor level. Vertical load is applied to the columns by means of two rigid steel box beams pulled towards each other by post-tensioning cables as schematically shown in Figure 1. Totally six specimens have been prepared and all of them have been tested. The test results, and analytical works based on the test results have been given in Section C2.2.1.
- Vertical One-bay Frames (METU-BU) – One-bay two-storey frames identical to one half of the twin frames are erected in front of the strong wall and their foundation beams are rigidly attached to the strong floor. A double acting hydraulic ram, pin connected to the top floor beam and the strong wall, applies the reversed cyclic quasi-static load representing the seismic effect as schematically shown in Figure 2. In both METU and BU test setups have been prepared, the formworks have been manufactured. In METU this type of specimens will be tested with two strengthening techniques, namely CFRP strengthened and precast panel strengthened. For this purpose six specimens have been cast. In BU only CFRP strengthened specimens will be tested. For details of BU side, please see Section C2.5.
- One-bay Half-scale Frames (ITU) – The supporting and loading systems are very similar to the preceding test set-up. The major differences are the (i) higher capacities of the testing equipment enabling testing of a full-scale model and (ii) single storey test frame. The work in ITU is in proper planning. For the details, please see Section C2.6.

- Three-bay Frames (METU) – Three-bay two-storey frames having similar properties as the vertical one-bay METU frames are tested in vertical configuration under reversed cyclic load applied by double acting hydraulic jacks bearing against the strong wall, as schematically shown in Figure 3. Since the degree of indeterminacy of the structural system is much higher than that of the one-bay frame, column reactions need to be measured. A special reaction transducer has already been developed and tested, so that it will be used at bases of the two exterior columns. Such transducers are not needed for interior columns, since the infill is placed in the central span. In METU, one specimen has already been cast with the shear wall in the middle bay. That specimen will be tested in the second half of the May, and it will be used as a reference specimen.

C2.2. CFRP STRENGTHENED MASONRY INFILLS (METU & BU)

C2.2.1. Completed Tests (METU)

Six one-bay two-storey twin frames belonging to the CFRP blanket and diagonal strip strengthening category have been produced in the laboratory, and all of them have already been tested under reversed cyclic load applied in the horizontal closed loading frame.

The first one was the reference specimen (Figure 4-T1), which was intentionally designed as a weak frame reflecting the deficiencies of common poor practice observed especially in low rise residential buildings in small towns. Hollow brick wall was again typical of the common practice. A layer of typical plaster covered both the wall and the frame. Since it was the reference specimen, no measure of strengthening was applied to this frame. The observed behavior and strength conformed to the expectations, and they will be used as references in comparison with those of the retrofitted specimens to be tested later.

The second one had identical properties as the reference specimen (Figure 4-T2), however, its infill walls were covered (no extension to the frame members) with CFRP blanket on both sides.

The third one had identical properties as the reference specimen (Figure 4-T3), however, its one face (namely the exterior face) was covered with extension to the frame members with CFRP blanket. The extended part of the CFRP was anchored to the frame.

The forth one had identical properties as the reference specimen (Figure 4-T4), however, its infill walls were covered on both sides with extension to the exterior face frame members with CFRP blanket. This time the developed anchorage is applied both interior and exterior faces of the frame.

The CFRP which covers both sides of the infill walls were also anchored.

The first four tests prove that tension diagonal behavior of the CFRP bonded to the reinforced concrete members is very effective. Therefore using diagonal strips instead of full blankets is investigated due to reasons of economy. The fifth one had identical properties as the specimen four (Figure 4-T5), however, instead of using CFRP blanket CFRP diagonal strips were used. In that case, the amount of CFRP used is reduced to 1/5 of the previous test specimen. In this test the bricks did not failed, but the failure was occurred at the column ends.

The final specimen is very similar to the fifth one with first story column ends were wrapped. In this final test brick did not failed. Shear failure occurred at the first story joints, which was the next weak spot.

In Table 1, the initial test results were given. This table shows that the stiffness of the CFRP strengthened members increases only %20 which suppose to be considered as not very significant. Therefore one can conclude that the strength demand is not increased. On the other hand the base shear capacity increases up to %200-250, which shows the success of the strengthening technique. It is also seen that the forth and fifth tests were the best strengthened specimens. The fifth one should be preferred since the economy is also a very important parameter.

Table 1 – CFRP strengthened test results

	Concrete Strength (MPa)	Maximum load applied (kN)	Ratio of maximum load (with respect to T1)	Initial stiffness (kN/m)	Ratio of initial stiffness (with respect to T1)
T1	19.48	56.76	1.00	33750	1.00
T2	15.28	62.18	1.16	29860	0.89
T3	12.88	64.93	1.11	32840	0.97
T4	17.35	131.46	2.35	40400	1.20
T5	12.00	115.25	2.13	38010	1.13
T6	14.70	100.4	1.77	33877	1.00

The envelope curves of the all six specimens are given in Figure 5. Also typical load-displacement curves for specimen 4 and specimen 5 are given in Figure 6 and Figure 7, respectively.

C2.2.2. Parameters Studied

Six specimens have been prepared and have been tested in METU. One of them was a bare frame with masonry infills without strengthened with CFRP. Then for the rest the same specimen with CFRP strengthened have been tested and compared with the bare frame. From these tests it has been seen that the existing hollow brick walls strengthened by CFRP (carbon fiber reinforced plastics) prevents the brittle failure of the brick masonry, and increases the ductility. The parameters which have been studied in this group of tests are listed below:

- Extent of CFRP Application – From the tests it has been seen that a CFRP blanket applied to the brick wall alone is delayed cracking in the wall and thus leads to a marginal improvement in the ductility and the strength. A CFRP blanket, extended to the reinforced concrete elements and bonded to the beams and columns, is on the other hand, is far more effective, since it serve as a tension diagonal in either direction.

- Number of CFRP Layers – Two CFRP blankets applied to either side of the wall naturally confines the masonry and consequently lead to a higher level of improvement. On the other hand the performed tests prove that one diagonally placed single layer is as effective as the two orthogonally placed layers. Therefore due to the high cost of this material single layer application has been preferred.

- CFRP Covered Area – The tests show that using diagonal strips is as effective as using full blankets.

- CFRP Anchorage Techniques – CFRP itself and the bonding agent (glue) have very high strengths and are capable of carrying very high stresses. It has been seen that the anchorage has to be strong enough to transfer these rather high forces to the supporting elements. These forces cause very high shear stresses in the concrete or the plaster. Therefore an effective technique is developed to ensure proper anchorage of the CFRP band. Since for the time being the developed anchorage technique is studied in the 1/3 scaled elements, full scale tests are planned to be performed in the University of Texas by the PI of this sub-project.

- CFRP Orientation – It has been seen that one layer specially oriented (in the directions of the diagonals) carbon fiber reinforcement is as effective as the two layers with fibers in orthogonal directions.

C2.2.3. Half-Scale Verification Tests (ITU)

From the completed tests at METU a reasonably clear idea is obtained about the efficiency and effectiveness of the CFRP strengthening technique. Some tests have been selected and are going to be repeated on half-scale models, to investigate the effects of scale on the results, before drawing any generalized conclusions. It is necessary to point out that the initial intention was to make full scale verification tests of the CFRP strengthening technique at the ITU laboratories.

However, after visiting the ITU Structural Engineering Laboratory , it was understood that the facilities that they have would not be sufficient for full scale tests. It is then decided to test near full-scale specimens within the framework of the experimental work at ITU.

C2.2.4. Three-Bay Frame Tests (METU)

With the intention of understanding the actual multi-bay frame behavior after introduction of the CFRP strengthening, some of the tests, which have already been performed on one-bay twin frames will be repeated on three-bay frames vertically tested under reversed cyclic load applied by a double acting hydraulic ram bearing against the strong wall. For this reason a reference frame with shear wall at the mid-bay has already been cast, and is going to be tested at the mid of May 2002.

C2.3. PRECAST PANEL STRENGTHENED MASONRY INFILLS (METU)

This seismic strengthening approach using conventional materials is expected to provide a more economical solution to the problem of retrofitting of the building structures still in use, without causing much disturbance to the occupant. Instead of replacing the brick wall by a cast-in-situ concrete infill panel, a concrete infill is formed, on either one or both sides of the existing masonry wall, by in-situ connecting precast concrete slabs of manageable size to each other and to the surrounding reinforced concrete beams and columns. The parameters to be considered in this group of tests are listed below:

- Number of PC Panel Layers – Depending on the properties of the specific structure being strengthened, (i) a single and relatively thick (80~100 mm) infill layer may be formed on one side of the existing brick wall or (ii) two relatively thin (40~50 mm) PC layers may be used on either side of the wall.
- Panel Size and Geometry – Precast concrete slabs should be small enough to be carried by two workers. The slabs forming the infill panel when connected together should have a suitable geometry and size. Various alternatives may be developed for the specimens of this test series.
- Connection Details – The most important and complicated problem of this technique is obviously the connection details. Connections need to be sufficiently strong to provide solid and rigid infill behavior; they must be simple enough not to require expert workmanship; last but not least, they also need to be economical. Various possibilities are being considered towards developing various connection detail alternatives, which will be experimentally investigated.

This group of tests is planned to be performed mainly on vertical one-bay two-storey frames subjected to reversed cyclic load applied by a hydraulic jack supported by the strong wall. The formworks of these specimens have been manufactured. For the time being, six specimens have been prepared. In addition, one or two verification tests may also be realized on three-bay frames.

C2.4. PROGRESS EVALUATION

C2.4.1. Accomplishments

Considering the timetable given in the project plan, this sub-project appears to be ahead of schedule. Besides experimental work planning completed to a great extent, actual testing have also started, and six 1/3 scale tests have already been performed.

C2.4.2. Future Plans

The sub-project appears to be progressing well in conformity with the work schedule. No change of plans is therefore proposed at this stage.

C2.4.3. Young Scientists

The PI of the present sub-project is a young scientist (an assistant professor) himself. Two other young assistant professors are leading the research teams in ITU (Istanbul Technical University) and BU (Bosphorous University).

Two PhD (Mr. Mehmet Baran and Mr. Emre Akin) and five MS students (Mr . Cenan Mertol, Mr. Secer Keskin, Mr. Emrah Erduran, Mr. Murat Duvarci, Mr. Ibrahim Erden) have already been engaged in METU; three of them are actively working on various aspects of the project. One MSc students is going to be graduated in June 2002. One MSc student in ITU and one in BU have also received their thesis assignments concerning the planned tests.

C2.4.4. Travel

In line with the resolutions of the organizational meeting held in May, the principal investigator of the present sub-project participated in an international conference on FRP composites used in civil engineering hold in Hong Kong in December 2001.

The NPD of the project participated in ACI 2002 conference hold in Detroit, USA, in April 2002. In addition he visited University of Ottawa, Canada.

C2.4.5. Proposed Changes

No change of plans is proposed at this stage.

C2.5 Boğaziçi University Joint Contribution

Seismic upgrading of existing reinforced concrete (R/C) brick infilled frames is currently investigated experimentally as a part of a joint project. Two storey, one-bay frames with brick infill will be constructed and strengthened with Carbon Fiber Reinforced Polymers (CFRP). Insufficient lap-splice length in the columns is planned as the main variable of this part of the research. The specimens designed such that the columns are weaker than beams, as observed in most of the R/C frames that need upgrading, on the other hand violating the rules of the earthquake code. Five specimens are planned in this study, one being a pilot test without a brick infill. The remaining specimens will have brick infill with a cement base plaster, three of which with CFRP overlay. Beam and column longitudinal reinforcement consists of 8 mm diameter plain bars with a nominal yield strength of fy=220 MPa, while the hoops in either of the members is D=4 mm. Lap splice length in columns is 16 times the longitudinal bar diameter. No special hoop detailing or closer spacing is applied either for column or beam ends. Hoop ends are 90 degrees, contradicting with the existing earthquake codes. Concrete strength for the R/C frame is around 15-18 MPa. The test specimens are scaled down to approximately 1/3 of the prototype structure in geometry and in reinforcement detail. The reinforcement detailing of the frames are not in accordance with the present earthquake code. Specimens and the test variables are given in Table 1

Table 1 – Specimens and Test Variables

Spc.	Column Long.	Beam Long.	f'c (MPa)	Beam & Column Tie	Column Splice Length	Frame type	FRP on Wall (orientation)	FRP confinement over Column Splice Length
KB-S0	4Φ8, S220	6Φ8,S220	10 ~15	Φ4 / 10 cmS220	16 Db	Pilot / External	No	No
KB-S1	4Φ8, S220	6Φ8, S220	10 ~15	Φ4 / 10 cm S220	16 Db	Control /External	No	No
KB-S2	4Φ8, S220	6Φ8, S220	10 ~15	Φ4 / 10 cm S220	16 Db	w-FRP /External	Continuous (90˚)	No
KB-S3	4Φ8, S220	6Φ8, S220	10 ~15	Φ4 / 10 cm S220	16 Db	w-FRP /External	Continuous (90˚)	Yes
KB-S4	4Φ8, S220	6Φ8, S220	10 ~15	Φ4 / 10 cm S220	16 Db	w-FRP /External	Between Slabs	Yes

Specimens will be tested vertically on the strong floor of the Structures Laboratory. Since the hole configuration and spacing of the strong floor doesn't match with the planned connection detail of the frame foundation (see Figure 8) to the strong floor a "new foundation" (see Figure 9) is already produced. The 60 cm spacing of D=70mm holes of the "new foundation" will be used to fix this block to the strong floor, while 14 M36 threaded holes will be used to connect the test frame to the block (Figure 9).

Steel formwork will be used in order to have dimensional consistency between the specimens. The steel formwork is already delivered to the Laboratory, and currently assembled. The production of the reinforcing cages is currently in progress. The beam and column cages are already produced for the five planned specimens, while the frame foundation reinforcing cage for one specimen is finished.

Since the test specimens will simulate the prototype building, a concrete strength in the range of 15-18 MPa will be used. Mix design proportions for this concrete class are determined in the lab and the pilot specimen with this mix-proportion will be cast in the first week of June. The test frame and its foundation will be cast monolithically. Due to the heavy foundation block, the transportation of the specimen to the test rig may cause cracks in the frame. In order to eliminate this problem, a special steel frame for transportation only is currently designed and will be produced by June-2002.

C2.6 Istanbul Technical University Joint Contribution

The experimental research program launched in the Structural and Earthquake Engineering Laboratory of Istanbul Technical University is summarized below and testing program is reviewed.

Specimens and Their Fabrication:

One bay two story approximately ½ scale ten specimens have been scheduled for fabrication in the laboratory. The details of these specimens are given in Figure 10.

Infill walls of ordinary brittle bricks will be placed into the frames in the way used in practice and both surfaces will be plastered prior to the application of carbon fibers on one side only. The only difference between the two groups of five specimens is the development lengths of the reinforcements coming out foundation.

Concrete will be cast when the form works are in upright position.

The target compressive strength of the concrete is chosen to be 10 to 15 MPa, to simulate the concrete quality generally observed in the existing RC buildings in Turkey.

Two identical formworks have been prepared for quick fabrication of the specimens.

One specimen will be prepared from each group of tests in the first round of fabrication and will be tested primarily. After having had modification, if it becomes necessary, the rest of the four specimens will be cast two by two from each group.

The foundation of the first specimen and the reinforcements are ready for casting the concrete as of May 15, 2002. It is expected to cast the first specimens within the next two weeks, until May 31, 2002.

Testing Set up:

Two hydraulic actuators each 250 kN loading capacity will be used simultaneously during the tests.

An eight cm thick special base plate having dimensions 1m x 1m in plan is needed to mount the actuators on the reaction walls, Figure 11. Two special adopter plate sets are designed for the connection of actuator heads to the specimen, Figure 12. Four rods are used to transfer the tensile forces from the side where actuators are mounted, to the other side of the specimen.

A special apparatus has been designed for the vertical load application on the specimen, Figure 13.

One-bay-two-story specimens will have its own foundation which is going to be tied down to the adaptor foundation which will be cast and be fixed on the testing bed, Figure 14.

The adaptor plates and loading devices are ordered and they will be available as of June

2002. The special thick nuts, which will be utilized to anchor the specimen down to the adaptor foundation, will also be ready by that time. Nowadays attention is paid on assembling these 250 special nuts, which will be embedded into the concrete and keeping their orientation proper to the holes on the shear walls. This part of the testing set-up, which has relatively high importance in comparison to the fabrication of other units, will be ready during the first week of June.

The firs test is planned for end of June 2002.

There will be no difficulty to make ready the other specimens during the tests of first specimens.

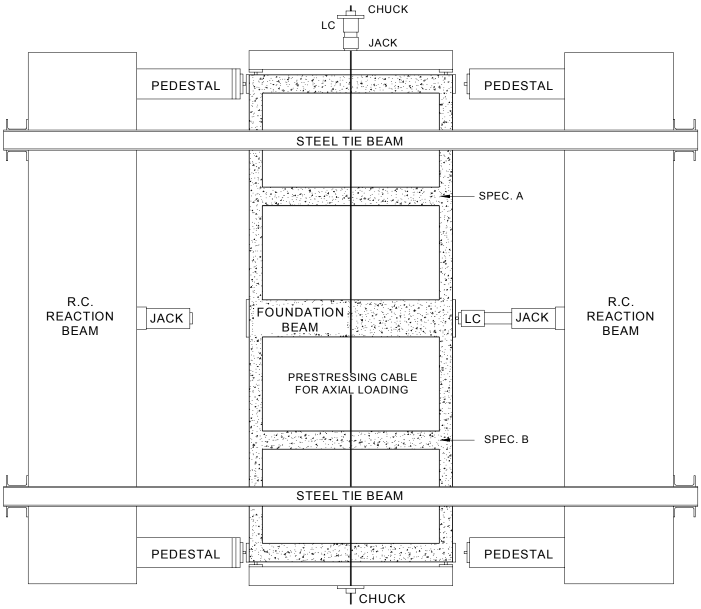


Figure 1. Horizontal one-bay twin frame

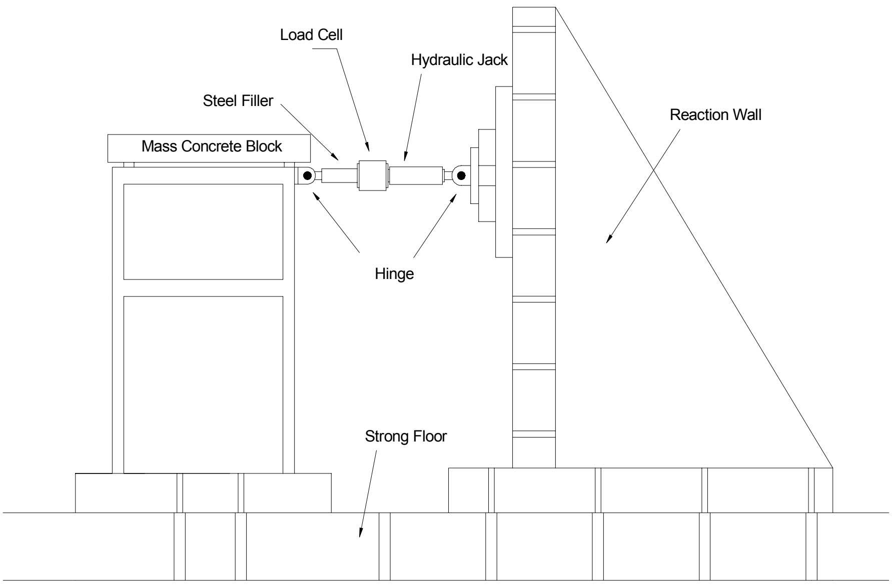


Figure 2. Vertical one-bay frame

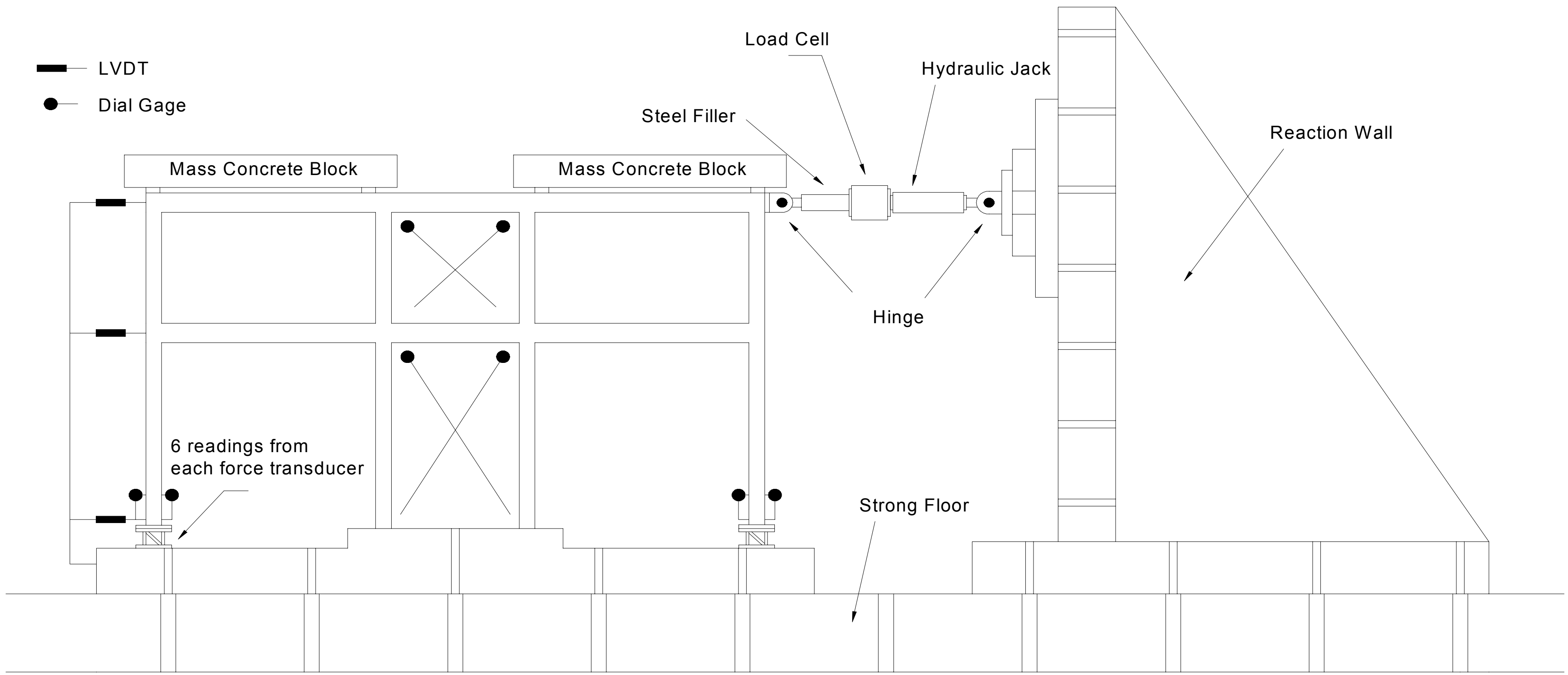
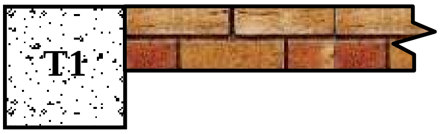
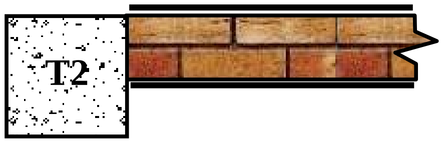


Figure 3. Vertical three-bay frame

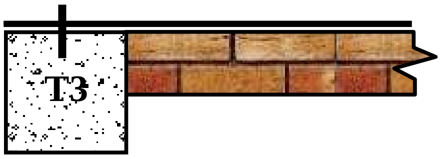


Reference: Masonry infill



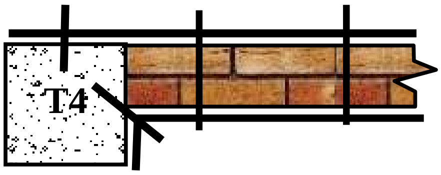
Infill walls CFRP strengthened

on both sides



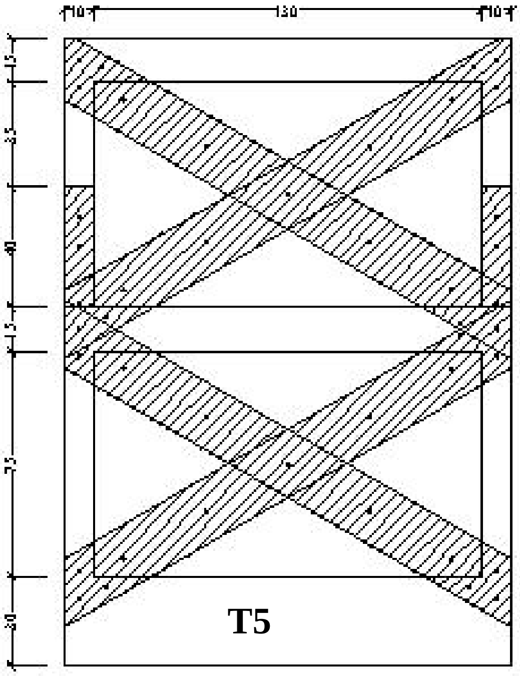
Outside face (including frame elements)

strengthened with CFRP



Infill walls and outside face of

the frame elements CFRP strengthened



Diagonal strip CFRP strengthened frame

Figure 4. CFRP Strengthened one bay two storey frames tested horizontally

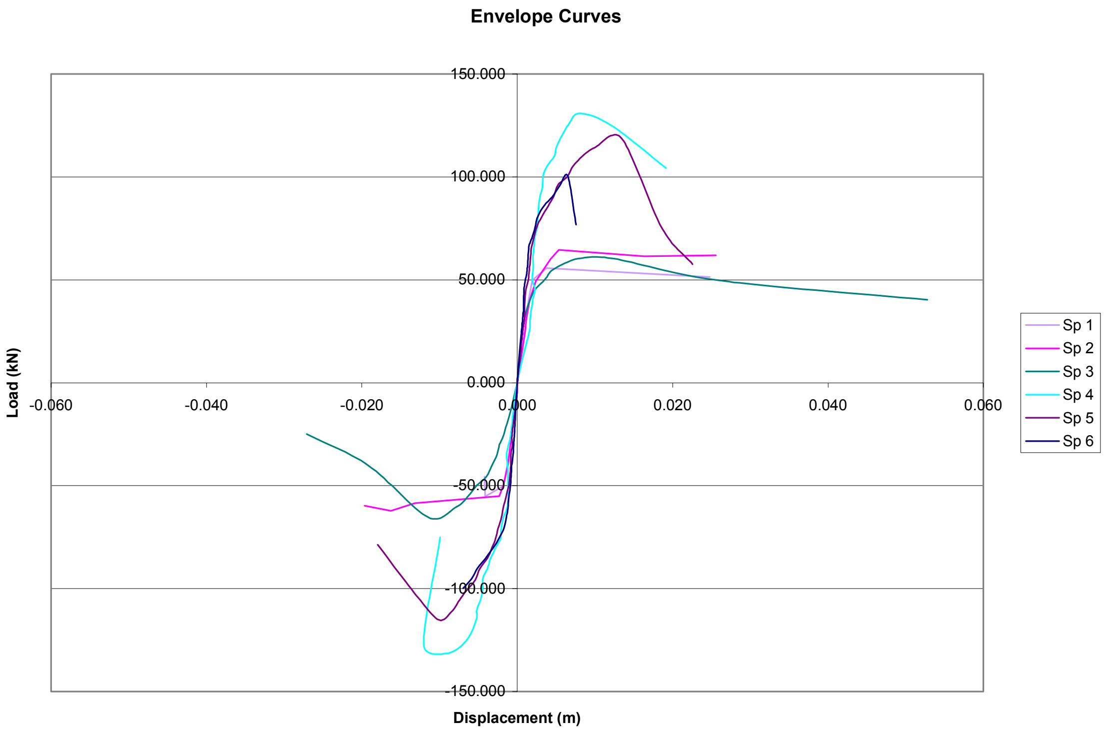


Figure 5. Envelope curves for all specimens

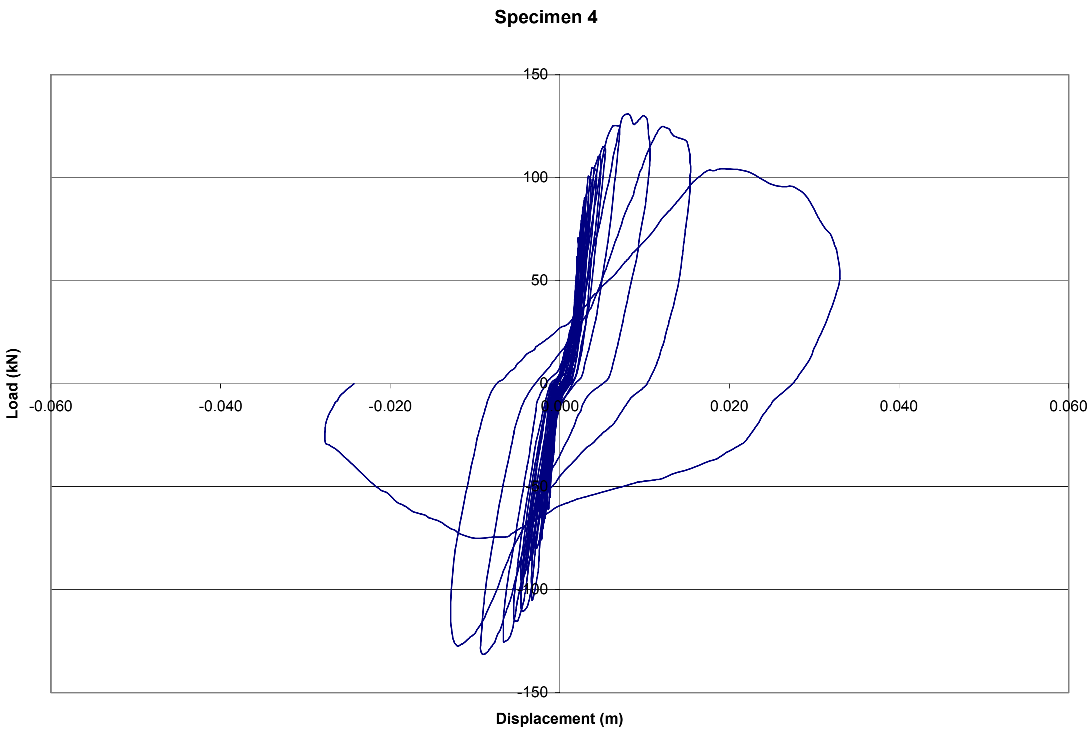


Figure 6. Hysteresis curve for specimen 4

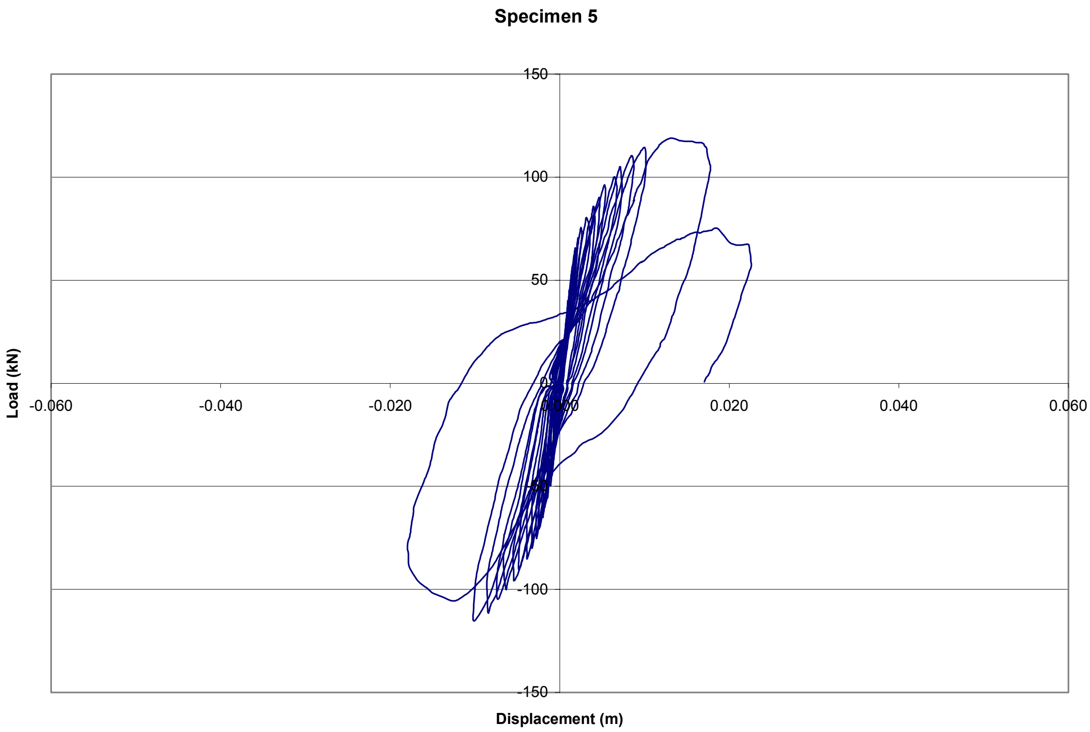
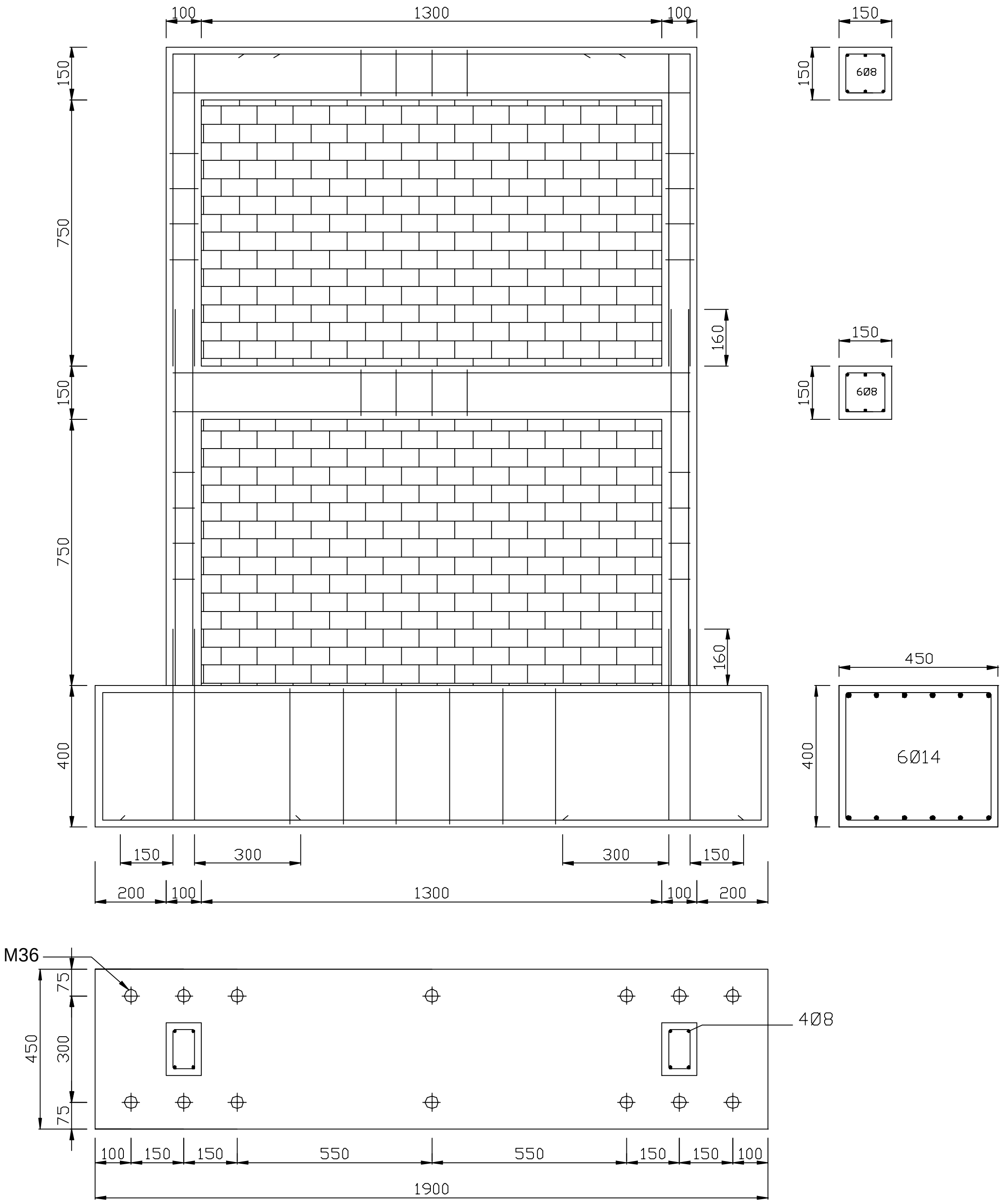


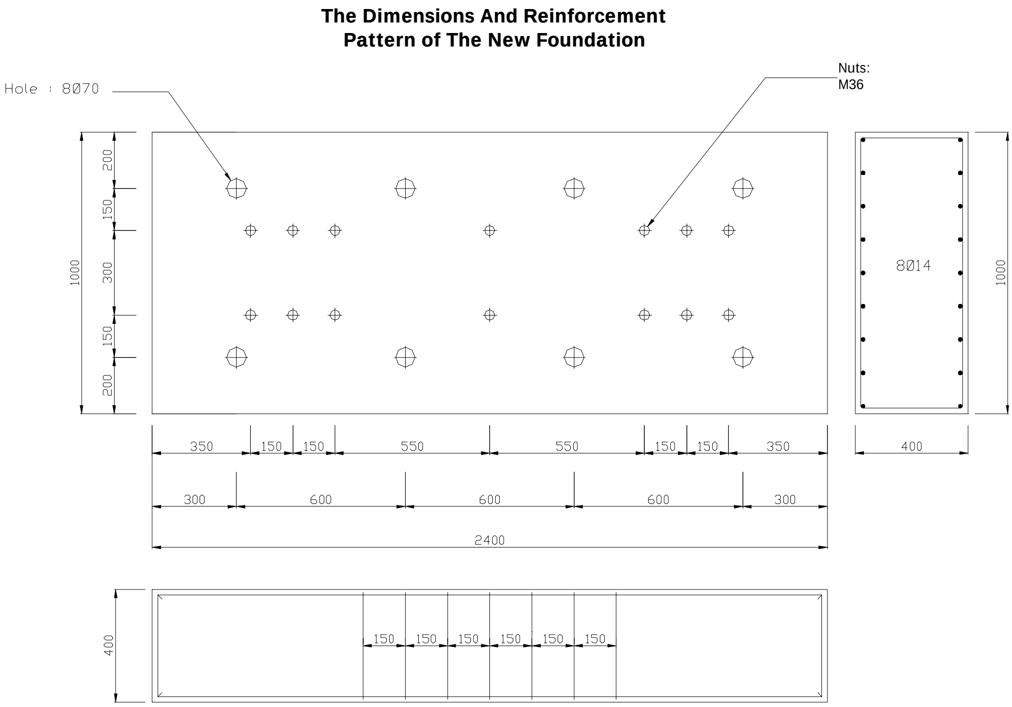
Figure 7. Hysteresis curve for specimen 5

The Dimensions And Reinforcement Pattern of The Specimens



Column and Beam Ties: Ø4/100
Column and Beam Longitudinal Bars: Ø8
Frame Foundation Ties: Ø10/150
All the dimensions are in mm

Figure 8. Specimen Reinforcement Detailing



New Foundation Ties: Ø14/150

All the dimensions are in mm

Figure 9. Details of New Foundation

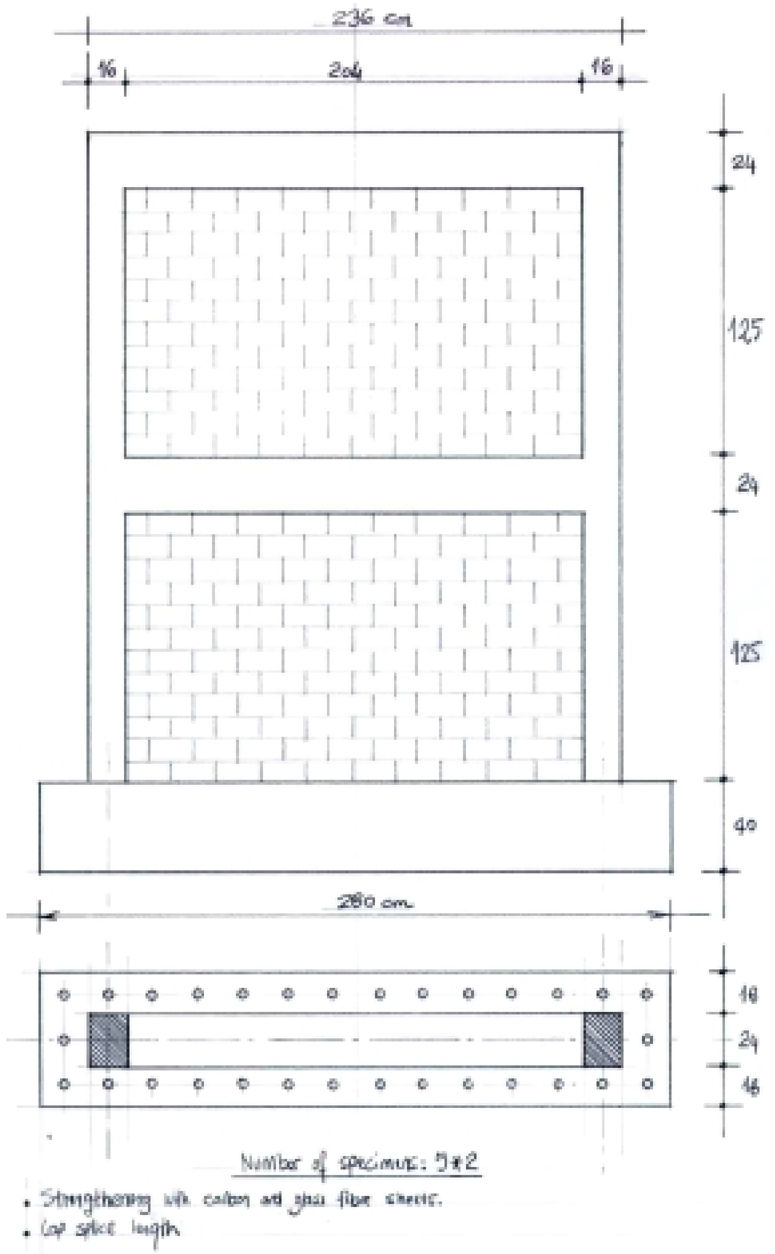


Figure 10. Geometry of the test specimens

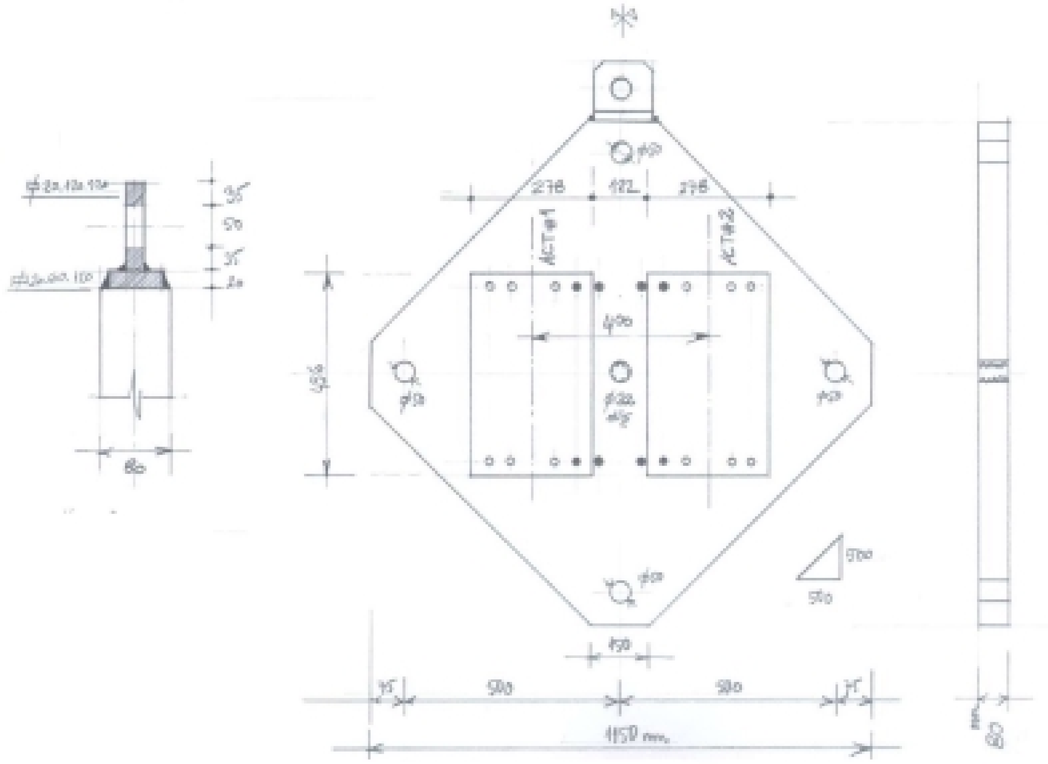


Figure 11. Base Plates for Actuators

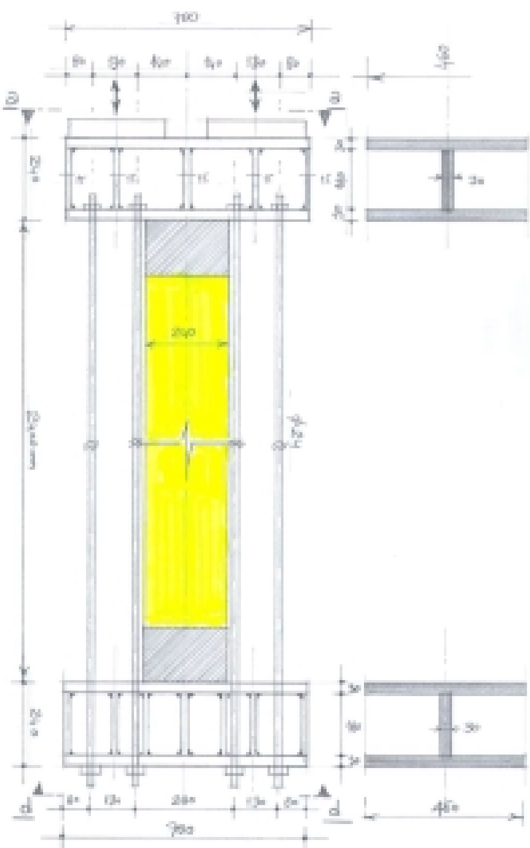


Figure 12. Details of the Horizontal Loading Apparatus

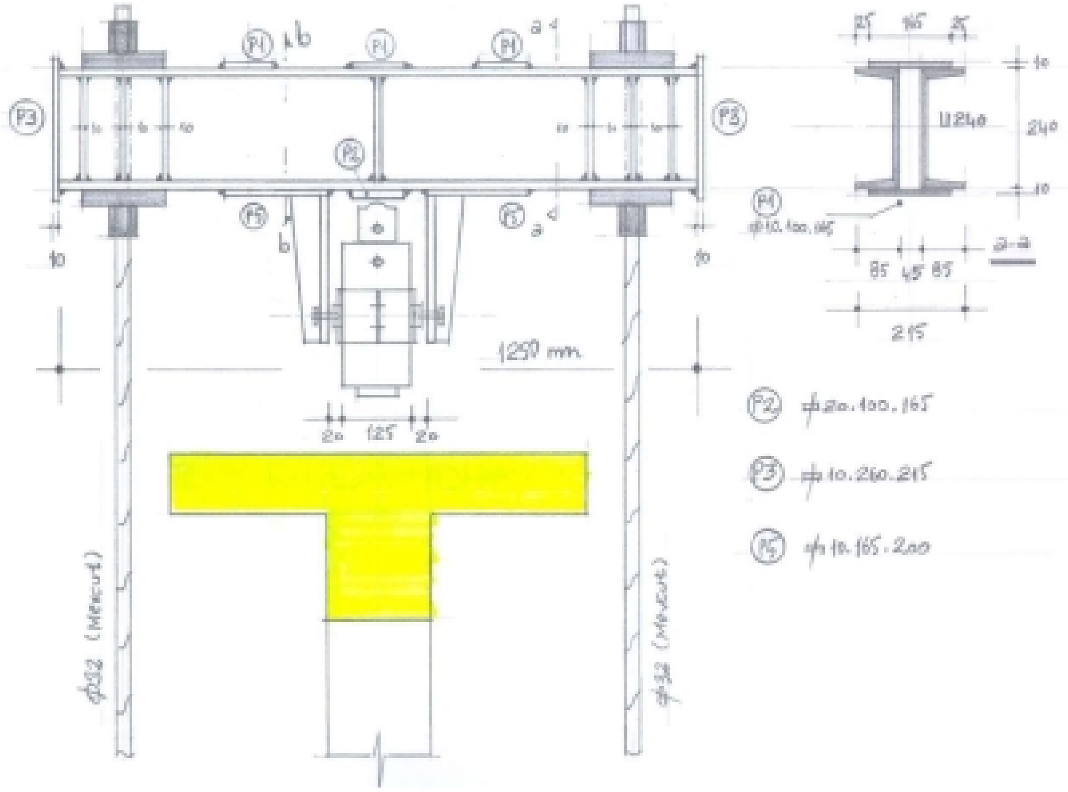


Figure 13. Details of the Vertical Loading Apparatus

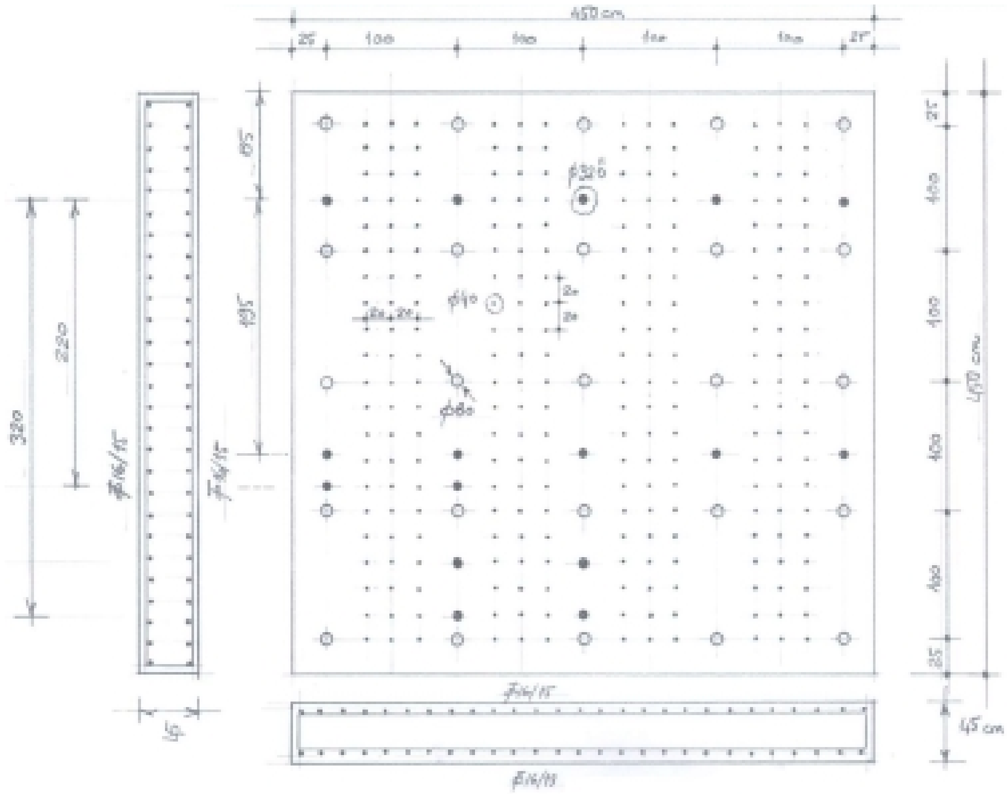


Figure 14. Geometry of the Mat Foundation

APPENDIX C3: SUB-PROJECT 3 – DISSEMINATION OF THE KNOWLEDGE GAINED

Subproject 3 was planned to include a program of extensive publication of research and professional results suitable for engineering application, two national/international workshops and engineer training sessions including distance learning techniques. Preparatory work dealing with the subproject is proceeding satisfactorily in accordance with the decisions taken at the Coordination Workshop in Antalya for the NATO Project [May 25-28, 2001]. In conjunction and coordination with the other subprojects, it is expected to organize the workshops in 2003. A summary of recent activity may be given as follows:

- An important aspect of knowledge dissemination deals with the provision of updated and readily accessible information about the NATO Project itself. A comprehensive web-site in both English and Turkish is under construction, which is planned to have the address http://www.seru.metu.edu.tr/
- The dissemination of knowledge and technical information from research publications requires the organization and management of vast amounts of data. A large database of information on seismic analysis and design, structural assessment and rehabilitation has been compiled as part of the subproject. An EXCEL program is currently in an advanced stage of development, which will enable author and keyword search of relevant documents, as well as the sorting of similar new input.
- Work is also underway on the technical translation into English of the recently published edition of the Turkish Standard TS500 dealing with reinforced concrete. The publication of the English version of this Standard will enable it to be used for specific educational purposes, but it is also intended to collect feedback regarding the clauses of this Standard that deal directly with seismic analysis, design and detailing.
- Publications as well as seminars on the national level dealing with various aspects of the NATO Project are continuing as part of the educational fall-out of the subproject.
- Assistant Professor Dr Uğurhan Akyüz, a Junior Researcher in two of the sub-projects [Development of Seismic Vulnerability Techniques and Training / Dissemination of Results] participated in the "CICE 2001- International Conference on FRP Composites in Civil Engineering" in Hong Kong during 12-15 December 2001. The scope of this Conference was directly relevant to the work of Dr Akyüz for the NATO SfP project.
- As components of the academic training aspects of the project, it should be mentioned that

Research Assistant Onur Sonuvar has been pursuing studies at the University of Texas at Austin since August 2001 and Research Assistant Erdem Canbay is being supported on the National Budget at Purdue University since February 2002. Future plans for similar training and academic experience include sending Assistant Professor Dr Uğurhan Akyüz in the summer of 2002 (using NATO funds) for a period of three months to the University of Texas, to be followed by a similar period for Dr Şevket Özden of Kocaeli University.

All research projects possess, produce or provide an educational content. The upward distillation of knowledge leads to wisdom; the filtering down of knowledge leads to know-how. The vital function of a University is indeed the development and discovery of knowledge through research, but it can be stated without much argument that the most important duty of a University is to make the spin-off from this knowledge immediately and freely available to the community. The imparting or transfer of technical knowledge, initially as research-oriented information or, after proper processing, as know-how, calls for expertise at different levels. The Middle East Technical University Project Team is specially equipped for this task of continuing education in both English and Turkish. The members of the Project Team have impeccable research credentials and extensive experience over the years in teaching students, practicing engineers, technical managers and building contractors possessing differing backgrounds of competence and technical responsibility.

It is suggested that the dissemination of research results from the present project be conducted in the following formats:

- Individual lectures, seminars, short refresher courses and training workshops on the latest methodologies and techniques for the seismic assessment and rehabilitation of buildings
- The preparation of desktop-published course material explaining and illustrating salient items of the Turkish and other contemporary earthquake codes; structural behavior during earthquakes; damage assessment for urban and rural structures; rehabilitation techniques as developed from experimentation and research, etc.
- Broadcasting of systematized knowledge relating to the seismic amelioration of structures and buildings of different types by means of compact discs, video films, the Internet and television channels [if possible]

It is expected that after some trial runs, the continuing education activities could develop into formal programs leading to evaluation of student performance and possible award of certificates of proficiency.

APPENDIX D: SUMMARY REPORT PRESENTED BY MACEDONIA

In accordance with the project plan on project SfP-977231 entitled “Seismic Assessment and Rehabilitation of Existing Buildings”, there have been performed all the preparation activities for commencement of the design of the model to be constructed and tested on the seismic shaking table in IZIIS.

A set of real records from occurred strong earthquakes has been selected (Selected as possible records in this set have been also the records from the Kocaeli (Turkey) 1999 earthquake to be included as seismic input in testing the 3D models)

The seismic shaking table has been tested without the model in order to calibrate the seismic input.

All the RC frames that have so far been constructed and tested on the seismic shaking tables in the laboratories world-wide, have been investigated.

Three junior collaborators have been included in the process of design of the model, its instrumentation and testing.

Although the necessary measuring equipment has still not been procured, it is not a hindrance for the construction of the model at the time being.

Despite some difficulties, the procurement of the following equipment is underway:

- Measuring and calibration equipment composed of 3 digital voltmeters and 1 calibrator
- 20 LVDT-s and 45 core connection rods
- Signal conditioning system.

The difficulties refer to exemption from payment of customs duties and VAT. However, since we have already acquired an experience with importation of equipment through another project, we think that we shall overcome the problem. The customs clearance and VAT letter sent by the Director of the SfP Programme will greatly contribute to that effect.

At the moment, the only equipment that has been procured is a PC computer Latitutde 4000

(DELL).

We have finally succeeded in opening an Operational Account in the name of Mihail Garevski. The first payment (one-of-advance) has already been made on this account by NATO.

This account shall make more efficient the payments to be made for the construction of the models.

Since the last six month progress report until now, there has been only one travel of Prof. Mihail Garevski. Namely he participated in the Eight East Asian Conference on Structural Engineering and Construction (EASEC-8), which was held in Singapore. The Congress lasted three days, i.e., from 5 till 7th December 2001. 670 papers were presented at this Congress of which 70% are in the field of Earthquake Engineering and Rehabilitation of Structures. Particularly important are the papers on the earthquake that has recently stricken Taiwan. During the Congress, there have been contacts with some professors from Taiwan with whom experience was exchanged regarding the behavior of the buildings during the Turkish earthquakes of 1999 and the Taiwan catastrophic earthquake that happened in the same year. From the lectures, the direct talks with the participants in the Congress who presented papers on damages to structures under the catastrophic earthquakes, it can be concluded that the major damage occurred as a result of inadequate design and construction.

Other travels were not anticipated since the investigations were not much intensive.

In the next six months, several travels are anticipated. Planned is a travel of a young investigator to the University of Berkeley, California, where there is a seismic shaking table of the same proportions as that in IZIIS, but is more sophisticated. The stay of this young investigator is planned to last about one month. Due to the length of the stay, the accommodation is planned to be in the University campus in order to avoid hotel expenses.

It is also planned that the PPD (Prof. M. Garevski) attend the NATO Science for Peace Workshop on Commercialization which will take place in Istanbul on 9, 10 and 11 June 2002. The stay in Istanbul shall be used also for a visit to the Istanbul Technical University where there are ongoing analytical and experimental investigations related to this project.

In September 2002, in London, there shall be held the 12th European Congress in Earthquake Engineering. This event which is held at each 4 years, represents the most important conference in Earthquake Engineering after the World Congress. Since many useful papers on seismic rehabilitation of existing structures are expected to be presented at this Conference, it is planned that two young investigators and two senior investigators – participants in SfP take part in it by financial support from the project. If necessary, there shall be also one visit to the University in Austin.

There were certain administrative difficulties referring to the opening of an operational account. Namely it couldn't be opened in the name of IZIIS. However this problem was overcome by opening of such an account to the name of the PPD (Mihail Garevski). There are also some difficulties with the importation of the equipment, i.e., exemption from payment of customs duty and VAT. However, I think that this problem will be overcome since we have already acquired a certain experience with importation of equipment intended for another project.

During the next six months, no visits by NATO experts are anticipated.

Publication of papers is also not anticipated for the next six months since the results from the seismic shaking table tests shall be obtained at the end of the next six month period and there shall be no enough time for their publishing. However, it is envisaged to publish several papers on the shaking table tests until the completion of the entire project. One paper is planned to be published in the Proceedings of the World Congress on Earthquake Engineering to be held in Vancouver in 2004.

No changes in the teams of investigators are planned.

APPENDIX E: SUMMARY PROGRESS REPORT PRESENTED BY FORTH/ICE-HT PATRAS

E.1. Development of a practical seismic vulnerability methodology for Greece.

E.1.1 Initial Screening methodology

A methodology was developed along the lines of FEMA 154 (ATC-21): "Rapid visual screening of buildings for potential seismic hazards: A Manual" (1988). The methodology was limited to the scope of the project (low- to medium-rise RC frame or dual buildings of ordinary importance) and tailored to the existing building stock and the seismicity and associated zonation in Greece. Development of the methodology is practically complete. It is presented here briefly, without background or justification.

Following ATC-21, a Structural Score S is calculated as the sum of the Basic Structural Score (BSH) and of a series of Performance Modification Factors (PMF). The lower the value of S, the larger is the seismic vulnerability of a specific building, with S values less than 0 meaning that under the design earthquake at the site according to the current seismic code in Greece heavy damage is almost certain.

Two milestone years are identified for Greece: 1985 and 1995, coinciding with major revisions of the Greek seismic code. Structural Types are identified relative to these years and assigned the following BSH values for the major zones of the current (2000) Greek seismic zone: Zone I (low seismicity, EPA=0.12g), Zone II (medium seismicity, EPA=0.16g), Zone III (high seismicity, EPA=0.24g), Zone IV (very high seismicity, EPA=0.36g). An important feature in the characterization is the presence of an (almost) open ground story in a building with masonry infills (Pilotis).

Structural type, with milestone year	zone I	zone II	zones III & IV
Post-1995 buildings, w/o Pilotis or short columns	6.0	4.5	3.5
Post-1995 buildings, with Pilotis or short columns	5.0	4.0	3.0
1985-1995 buildings, w/o infills or short columns	4.0	3.0	2.5
1985-1995 buildings, with plan- & heightwise regularly arranged infills and w/o short columns	4.5	3.5	3.0
1985-1995 framed systems with Pilotis or short columns	2.5	2.0	1.5
Pre-1985 buildings, w/o infills or short columns	3.0	2.5	1.5
Pre-1985 buildings w/o short columns, dual (wall-frames), or framed but with infills regular in plan and elevation	3.5	2.5	2.0
Pre-1995 framed systems with Pilotis or short columns	1.5	1.0	0.5
Pre-1985 wall systems	4.0	3.0	2.5
Precast frame buildings	1.5	1.0	0.5
Precast wall panel buildings	4.0	3.5	3.0

The proposed PMFs are:

	Pre-1985	1985-1995	Post-1995
Poor construction quality or rebar corrosion	-0.5	-0.5	-0.5
Strong structural irregularity in plan	-1.5	-1.0	-0.5
Strong structural irregularity in elevation	-1.0	-0.5	0
Over 6 stories	-0.5	-0.5	0
Ground conditions: stiff or soft soil	-0.5	-0.5	-0.5
At top of long, steep (>45^{o}) ridge >30m high	-0.5	-0.5	-0.5
Corner building, in contact with adjacent	-0.5	-0.5	0
Mid-floor pounding with adjacent building	-0.5	-0.5	-0.5

E.1.2 Preliminary Evaluation methodology

A methodology is under development - and close to completion - for the preliminary evaluation of low- to medium rise frame or dual RC buildings. It is based on a linear-elastic static analysis of the building in the two orthogonal horizontal directions, for lateral forces consistent with the code-specified 5%-damped spectra and the fundamental period estimated through the Rayleigh quotient, using secant-to-yield member stiffness. The model includes all concrete members as prismatic elements but neglects masonry infills. RC members are evaluated by comparing chord rotation demands from the analysis to estimates of the corresponding (ultimate) deformation capacities, calculated on the basis of default values or estimates of material properties and amount of reinforcement. The possibility of member shear failure is assessed on the basis of capacity-design upper limits of shear force demands.

E.1.3 Final (detailed) Evaluation methodology

A methodology is under development (close to 50% completion) for the final and detailed of low- to medium rise frame or dual RC buildings. It is based on a nonlinear-static (pushover) analysis of the building in the two orthogonal horizontal directions, up to a target displacement from the code-specified 5%-damped spectra and the fundamental period estimated through the Rayleigh quotient, using secant-to-yield member stiffness. The model includes all concrete members as prismatic elements with point-hinges at the two ends, as well as masonry infills as equivalent elasto-plastic diagonal struts. RC members are evaluated by comparing chord rotation demands from the analysis to estimates of the corresponding (ultimate) deformation capacities, calculated on the basis of material properties and amount of reinforcement estimated from the construction documents and in-situ measurements. The possibility of member shear failure is assessed on the basis of shear force demands from the analysis, taking into account the effect of cyclic flexural deformations on shear strength. The possibility of joint shear failure is also checked.

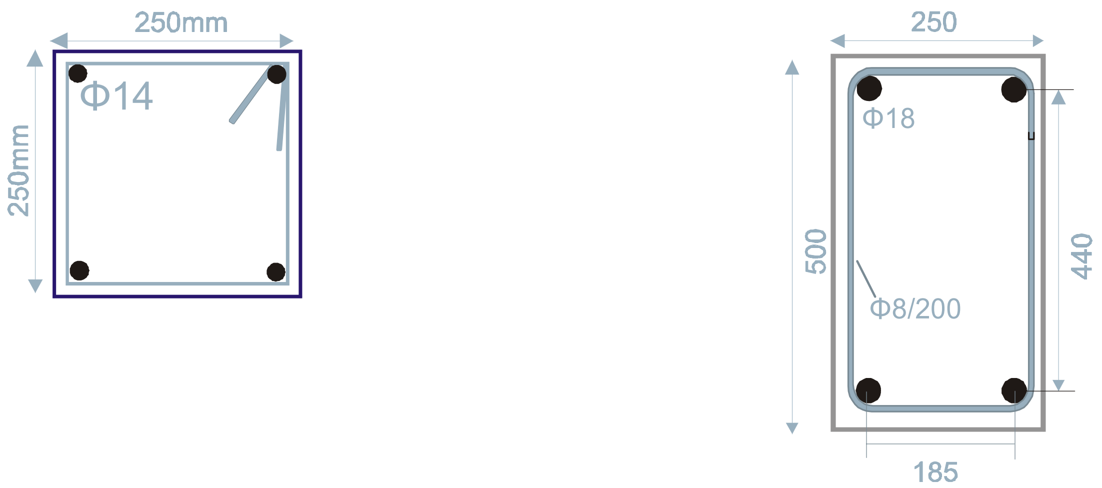
E2. Experimental Research of Vulnerability of Old-type RC Components under Cyclic Loading and of

Effectiveness of Retrofitting

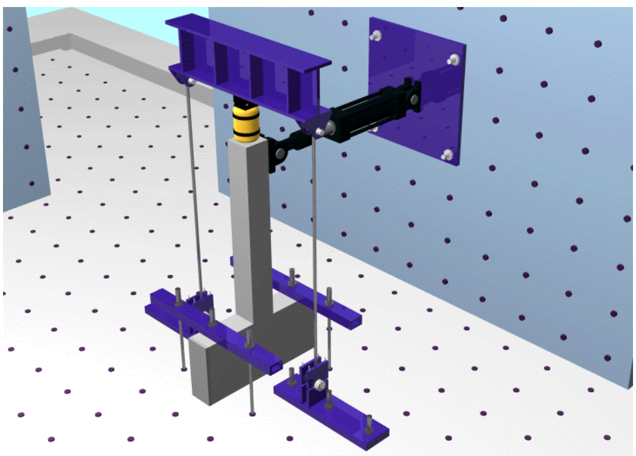
The tests performed and foreseen regard columns with dimensions, reinforcement detailing and material properties typical of existing RC building structures. This includes two column geometries: (i.e. cross-section dimensions). The total column height is 1.6m, i.e. equal to half a typical story height (the same for the two cases):

Type A: a 250mm-square cross-section, reinforced with four-14mm smooth bars (S220) in the longitudinal direction and with 8-mm smooth (S220) stirrups at 200mm spacing in the transverse direction.

Type B: a 250×500mm cross-section, reinforced with four-18mm ribbed bars (S500) in the longitudinal direction and with 8-mm smooth (S220) stirrups at 200mm spacing in the transverse direction.



Specimen configuration (a) Type A, (b) Type B



Loading set-up

The strength and deformation capacity of so designed column elements is studied under cycling of horizontal displacements at the presence of a constant axial force. They are tested either before or after retrofitting with either conventional (reinforced concrete jacketing) or innovative (employing composite materials) techniques. More specifically, the testing program is the following :

Type A specimens: the following tests aim at investigating the effect of the retrofitting technique on the strength and deformation capacity of non-seismically designed column elements:

Control specimen without lap-splicing and in its initial configuration (not retrofitted)

Specimen without lap-splicing, retrofitted with 2 layers of carbon fiber-reinforced polymer wraps.

Specimen without lap-splicing, retrofitted with 4 layers of carbon fiber-reinforced polymer wraps.

Specimen without lap-splicing, retrofitted with reinforced concrete jacket, to be applied with concurrent presence of the axial load (to represent real conditions of application).

Specimen without lap-splicing, retrofitted with reinforced concrete jacket to be applied after the initial specimen has sustained some degree of damage.

Further specimens to investigate other parameters of the retrofitting with reinforced concrete jackets, depending on the outcomes of the above tests.

Type B specimens: the following tests will focus on the implications lap-splicing has on the performance of columns in non-earthquake-resistant buildings and on how can their behavior be improved by retrofitting. The longitudinal reinforcement will be either continuous at the connection of the column with the foundation, or, as usually is the case and particularly in existing (old) buildings, the reinforcement will be lap-spliced near the bottom

An unretrofitted specimen without lap-splices, as control

Three unretrofitted specimens, each with different lap-splice lengths (e.g. 15-, 30-, and 45-bar diameters).

Three specimens with different lap-splice lengths (e.g. 15-, 30-, and 45-bar diameters) but retrofitted with carbon fiber-reinforced wraps.

Two specimens without lap-.splices but retrofitted with carbon fiber-reinforced wraps in two or five layers, as controls to specimens under c) above.

The design of all aforementioned test specimens has been completed. The three specimens under a) and c) of case 2 above (cross-section 250×500mm) have already been tested.

E3. Summary report for FORTH/ICE-HT / PATRAS

SfP Short Title: Seismic Assessment

SfP 977231 – FORTH/ICE-HT

SfP Title: SEISMIC ASSESSMENT AND REHABILITATION OF EXISTING BUILDINGS

Project Co-Directors:

Prof. Michael N. Fardis

Approval Date: *1 December 2000* Effective Date: *1 June, 2002*

Duration: *3 years; expected completion by May 31, 2004*

Information about the SfP Project through Internet: *No site is available*

Major Objectives

- *To develop practical seismic vulnerability assessment methodologies for existing buildings in Greece.*
- *To develop practical rehabilitation methodologies for existing buildings*

Overview of Achievements since the Start of the Project until (*30 April or 31 October of current year)*

- *R&D activities in Sub-Project 1: Development of Seismic Vulnerability Assessment Methodologies and Sub-Project 2: Development of Retrofitting Techniques for Existing Structures were started. These activities include*
  - *Literature survey studies*
  - *Proposal for initial screening methodology for existing RC building in Greece; the methodology is of the sidewalk survey type and has been tailored to the inventory and technical characteristics of buildings in Greece, as well as to the seismicity of the country.*

- *Development of methodologies for preliminary and for final (detailed) seismic evaluation of existing buildings; the two types of methodology are parallel, but the first is characterized by a much lower level of sophistication, requirements for input data and expertise by the engineer.*
- *The testing program of concrete columns representative of old construction has been defined, metal forms for the specimens have been constructed, three specimens (one unretrofitted and two retrofitted with advanced composites - FRPs) have been already prepared and tested.*

Milestones for the Next Six Months

- *Completion of the preliminary and the final seismic evaluation methodologies is expected.*
- *Construction of additional test specimens, retrofitted or not.*
- *Definition and design of subassemblies to be tested, before and after retrofitting.*

Implementation of Results

NATO Consultant

Other Collaborating Institutions

SfP - 977231

SfP Title: *SEISMIC ASSESSMENT AND REHABILITATION OF EXISTING BUILDINGS*

Project Co-Directors:

(NPD) *Prof. Güney Özcebe*

(PPD) *Prof. Mihail Garevski*

Prof. Michael N. Fardis

Approval Date: *1 December 2000* Effective Starting date: *1 June 2001*

Duration: *3* years; expected completion by *31 May 2004*

Information about the SfP Project through Internet: *No information is made available yet.*

Major Objectives

- *To develop seismic vulnerability assessment methodologies for existing buildings.*
- *To develop seismic rehabilitation methodologies for existing (undamaged) buildings.*
- *To make sample applications of the developed methodologies.*
- *Dissemination of results, engineer training (classroom/internet), researcher training (on the job).*

Overview of Achievements since the Start of the Project until 31 October 2001

- *On May 25, 2001 a press conference was held in TUBITAK Headquarters in Ankara with the participation of Prof. N. K. Pak, Prof. G. Ozcebe (NPD), Prof. M. Garevski (PPD), Prof. M. N. Fardis and Prof. J. Jirsa (project co-directors).*
- *A coordination workshop was held in Antalya-Kemer on 26-28 May 2001. All project partners except Prof. K. Pitilakis of CERTH-Thessaloniki participated in this workshop.*

- *R&D activities in Sub-project 1: Development of Seismic Vulnerability Assessment Methodologies and Sub-projet 2: Development of Retrofitting Techniques for Existing Structures were started. These activities include:*
    - *Literature survey studies.*
    - *Studies on initial screening and preliminary evaluation and*
    - *Strengthening of the existing hollow brick masonry infills by CFRP (system strengthening tests on weak one-bay-two-story RC frames with brick masonry infills)*

Milestones for the Next Six Months

Information about the SfP Project through Internet will be made available.

- *Development of Preliminary evaluation methodology is expected (METU).*
- *Strengthening of the existing hollow brick masonry infills by CFRP will be continued (METU, ITU, KU, BU).*
- *Strengthening of the existing hollow brick masonry infills by using precast panels (METU).*
- *Training of young scientists will be focused.*

Implementation of Results

During the period 1 March 2001 to 27 August 2001 one MSc thesis was completed (in METU)

Overview of Patents or Patent Applications

N/A

NATO Consultant

There is no NATO consultant assigned to this project.

Additional Collaborating Institutions

- ISTANBUL TECHNICAL UNIVERSITY
- KOCAELI UNIVERSITY
- BOGAZICI (BOSPHORUS) UNIVERSITY

Abbreviations:

TUBITAK - The Scientific and Technical Council of Turkey

METU - The Middle East Technical University

ITU – Istanbul Technical University

KU: Kocaeli University

BU: Bogazici (Bosphorus) University