U.S.-Japan Cooperative Earthquake Research Program on Composite and Hybrid Structures - U.S.-side Progress

by

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ABSTRACT

A five-year research program on Composite and Hybrid Structures as Phase 5 of the U.S.-Japan Cooperative Earthquake Research Program was recommended to be initiated in 1993 in both countries. The research work in Japan started in fiscal year 1993. However, fuller participation of researchers on both sides started in early summer 1995. The sponsorship of the program is by the National Science Foundation in the U.S. and by the Ministry of Construction along with a number of industry groups in Japan. This paper presents a brief status report of the program and research progress made to date on the U.S. side. Because of diverse and broad scope of the subject area, the research program is organized into the following four groups: Concrete Filled Tube Column Systems (CFT); Reinforced Concrete (RC) and Steel Reinforced Concrete (SRC) Column Systems (RCS); and RC/SRC Wall Systems (HWS); New Materials, Elements and Systems (RFI). A theme structure with well selected layout, geometry and design loads for the research is also presented, which provides a common focus for various systems to be studied, and also a common prototype structure from which the components and sub-assemblages are drawn.

Key Words:
Concrete Filled Steel Tube;
RC Column with Steel Girder;
RCS Core Wall with Exterior Steel Frame;
New Materials Elements and Systems.

1. INTRODUCTION

The U.S.-Japan Cooperative Earthquake Research Program began in 1979 under the auspices of the UJNR Panel on Wind and Seismic Effects. The overall objective of the total program is to improve seismic safety practices in both countries through cooperative studies to determine the relationship among full-scale tests, small-scale tests, component tests, and related analytical and design implication studies. First four phases of the program have been Reinforced Concrete (RC) Structures, Steel Structures, Masonry Structures, and Precast Concrete Structures. Research on Mixed Steel/RC Structures was identified as an important phase of the program as recommended in the planning group report.

It is widely recognized that innovative uses of two or more different materials in a structure leads to more efficient system for resisting seismic forces. During the past ten years the use of composite and hybrid structures has increased in the U.S. and Japan. In spite of some research and development work by Japanese construction companies, not enough is known at present regarding their seismic behavior or performance. Design procedures and codes for use in typical design offices are not well developed at present.

Considering the importance of developing design guidelines (a unified code development) for typical composite and hybrid structures that are used in current practice, and of developing new and innovative composite structural elements and hybrid systems using advanced new materials and/or devices, a five-year research program on Composite and Hybrid Structures was recommended as the fifth phase of the ongoing U.S.-Japan Cooperative Earthquake Research Program. The recommendations were based on a number of technical meetings of the U.S. and Japan Planning Groups and finally a Joint Planning Group Workshop held in Berkeley on September 10-12, 1992 (Ref. 1).

Because of diverse and broad scope of the subject area, the research program is organized into the following four groups: Concrete Filled Tube Column Systems (CFT); RC/Steel Reinforced Concrete Column Systems (RCS);

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and RC/SRC Wall Systems (HWS); New Materials, Elements and Systems (RFI). A theme structure provides a common focus of the program to facilitate cross comparison between various system types identified and to derive structural elements and sub-assemblages for detailed studies.

2. PROGRAM MANAGEMENT, COORDINATION AND CURRENT STATUS

The research program is planned for a period of five years in both countries, and funding has been provided accordingly. Research work on the Japanese side started in the spring of 1993. However, fuller participation and coordination of research work on both sides started in early summer 1995 when the first group of U.S. research projects were awarded. Cooperation and coordination of work by all participants are most essential to successful completion of this program. Various committees have been formed for this purpose. A Joint Technical Sub-Committee (JTSC) in each of the four components of the research program provides technical advice and coordination. Each JTSC has a co-chairman from each side with membership including all researchers in that area. These groups meet as often as needed. All participants and institutions are also part of the bigger Joint Technical Coordinating Committee (JTCC) to review progress and discuss scientific and technical issues on a common basis. This committee meets once a year. The last (fourth) JTCC meeting was held in Monterey, California, in October 1997. The fifth JTCC meeting is scheduled to be held in fall 1998 soon after the award of fourth year U.S. research projects which is expected in April-May 1998. A smaller group called Joint Steering Committee (JSC), which consists of key representatives from the JTCC, oversees the entire program and provides guidance on issues that are common to the four components of the program. The overall program has a technical coordinator and a co-chairman from each side.

In addition to sharing of technical information and ideas among researchers, exchange of personnel involved is strongly encouraged. This is happening more now as the research program has gotten into its advance stage. Active participation of practitioners and various industry representatives in planning, coordination and execution of the research work is also a strong feature of this program.

3. PROGRAM OBJECTIVES

Since the subject area of the Composite and Hybrid Structures is diverse and broad, the research program was organized into the following four groups: CFT Column Systems; RC/SRC Column Systems; and RC/SRC Wall Systems; New Materials, Elements and Systems. The first three groups aim at developing practical design guidelines (a unified code development) for typical composite and hybrid structures currently used. The last group aims at developing new and innovative composite structural elements and hybrid systems using advanced new materials and/or devices.

4. THEME STRUCTURE

The theme structure provides a common focus and a strong link between various components of the research program, facilitate cross comparisons between various systems to be studied, and also provides a common prototype structure from which the structural elements and sub-assemblages for detailed studies are drawn. The following criteria were used for selection of the theme structure:

- The building plan was selected so as to reflect the benefits that the hybrid structures provide over non-hybrid structures.
- The basic plan is common to various types of hybrid structures. The number of stories and the make-up and combination of structural components and details can be varied.
- Rules to determine dead load, live load and seismic forces to be used in design simulation are common in the U.S. and Japan Groups.

5. RESEARCH ON CFT SYSTEMS

A number of research projects were funded during the first two years. These projects focused on the behavior of CFT column-to-WF beam moment connections. The specimens are nearly full size and include circular and square tube sections for columns. The connection details include the use of diaphragms, shear studs, welds, and bolts. The main variables are the connection details to transfer beam forces into the column. The objectives are:

1) To determine the force transfer mechanism, examine the effects of various connection details on this mechanism, and on the connection strength, stiffness and ductility under cyclic loading.

2) Develop and evaluate practical and economical connection details for seismic resistance.

3) Formulate practical design guidelines.

Some testing work also includes study of beam-columns under combined axial force and bending. Analytical studies accompany the experimental work. The analytical models include complex finite element formulations in an effort to develop simpler empirical or mechanics based models for practical design work. Analytical work is also aiming at studying the bond and shrinkage effects, and confinement effects in CFT members subjected to different load conditions.

6. RESEARCH ON RCS SYSTEMS

RCS structures in the U.S. generally consist of columns made of light steel shapes encased in RC. The light steel shape provides ease of erection and connection to the steel beam. Currently, there are seven active projects in the U.S., that are related to RCS structures. The projects include preparation of database on connections, testing of exterior and interior beam-to-column connections with and without floor slab, composite frames with partially restrained connections, and use of high strength steel and concrete. The joint detail variables include: lateral ties, beam bearing plates, use of FRC in place of stirrups. Analytical studies focus on modeling the connection and frame behavior to address practical analysis and design issues.

7. RESEARCH ON HWS SYSTEMS

In one research project on seismic behavior of steel/composite coupling beams and their connections to the RC shear wall has been studied experimentally and analytically. Four one-third scale specimens were tested which represented a portion of the wall and one half length of the coupling beam from a 20 story theme structure. The effect of concrete encasement of the steel beam and details of the connection in the embedded portion have been studied. Two more research projects were started in the second year which deal with studies of composite SRC shear walls with steel boundary elements, and steel frames with RC cast-in-place in-fill walls.

8. RESEARCH ON NEW MATERIALS, ELEMENTS AND SYSTEMS (RFI)

The research work in this group aims at developing and application of new and advanced materials in innovative composite structural elements and systems (Research For Innovation - RFI). Thus, the studies in this group are more of feasibility type than those in the previous three groups where the objectives are to develop detailed guidelines for practical design work.

Significant amount of research work has been devoted to advanced cementitious and plastic composite materials. Albeit, the available information needs to be expanded to application in seismic load conditions. In two projects under this program, work is in progress on developing innovative composite systems consisting of steel and fiber reinforced concrete (FRC). The structural elements are made of selective combinations of FRC and steel members. The combinations under study include: FRC-encased open web steel joists, and high performance FRC core encased in slurry infiltrated mat concrete (SIMCON) shells for reinforcement as well as stay-in-place form work. In another project application of fiber reinforced concrete in the joint regions of RCS systems is being studied. Work is also in progress on further development of Engineered Cementitious Composite (ECC) materials and their selective use in structural elements, such as columns with large ductility demands.

9. CONCLUDING REMARKS

A brief overview of the progress of U.S.-Japan Cooperative Earthquake Research Program on Composite and Hybrid Structures has been presented in this paper. This five-year program started in 1993 in Japan and in 1995 in the U.S. The two year time lag is being taken as an opportunity to plan the future research work in a more careful and useful manner in order to derive the most benefit from the work that has already been completed on both sides. The overall coordination efforts, cooperation and exchange of information have been excellent. More active exchange of research personnel is currently occurring in this program. At least

four or five researchers from each side have participated for short and long term durations.

More details on the current status and technical progress made in this program can be found in the minutes of the last (fourth) JTCC meeting (Ref. 2). A listing of the general recommendations from that meeting is given in the Appendix of this paper. A www site has also been established which contains updated information on the overall status of this program as well as summary of results and findings from individual research projects (www.eerc.berkeley.edu/usjhcs).

10. REFERENCES

1. "Recommendation for U.S.-Japan Cooperative Research Program - Phase 5 Composite and Hybrid Structures," Report No. UMCEE 92-29, Department of Civil and Environmental Engineering, The University of Michigan, Ann Arbor, MI, 48109-2125, November 1992.

2. "Summary, Resolutions and Recommendations of the Fourth Joint Technical Coordinating Committee Meeting," Report No. UMCEE 98-03, Department of Civil and Environmental Engineering, The University of Michigan, Ann Arbor, MI, 48109-2125, January 1998.

11. APPENDIX

General Recommendations from the 4th JTCC meeting:

1. Exchange of researchers, and research data (e.g., via www) on both sides should be continued at an increased level.

2. Close cooperation and collaborative research effort on both sides should be continued till the end of the five year program of both countries.

3. Scope of this program may be expanded to include more thorough examination of promising innovative technologies and materials (such as those explored in the RFI Program) applied to repair and upgrading of existing structures, application to infrastructure systems, and so on.

4. Efforts to synthesize and interpret knowledge gained in the program, and to disseminate this knowledge and design/analysis methodologies to the design profession and industry should be accelerated.

5. Consideration should be given to perform testing work on carefully selected full frames in possible cooperation with other research programs.

6. Material manufacturers, construction and other industrial organizations should continue to actively support the research program.

7. Each JTSC should meet as needed to achieve good coherence in the cooperative research work.

8. Each JTSC should study development of performance criteria as related to design guidelines to be developed in each country.

9. Use of common set of ground motions is encouraged to permit more direct comparison of dynamic analysis results.

10. The funding agencies in both countries should maintain proper balance of research effort among the four areas of the program consistent with the research needs.

11. Funding should be provided for joint coordinated publication of research work with practical implications.

12. The 5th JTCC meeting should be held in early fall of 1998 at a place to be hosted by the Japan side.