



SL-C

Session Report
SESSION REPORT OF SPECIAL THEME SESSION
"IMPROVEMENT ON SEISMIC PERFORMANCE OF MASONRY BUILDINGS"

Yuji ISHIYAMA¹, Toshiyuki KUBOTA² and Yutaka YAMAZAKI¹

¹ Building Research Institute, Ministry of Construction,
Tsukuba, Japan

² Kinki University, Higashiosaka, Japan

SUMMARY

The special theme session "Improvement on Seismic Performance of Masonry Buildings" was held from 9:40 to 12:40 August 8, 1988 at Kyoto International Conference Hall during 9WCEE. The main purpose of the session was to promote the development of techniques to minimize earthquake damage of masonry structures, to mitigate structural seismic hazards to human lives and to utilize the resources efficiently through presentations of technical papers and discussion about the seismic performance of masonry buildings. During the session eleven papers were presented in total including a state-of-the-art report. Approximately seventy people attended the session.

INTRODUCTION

Masonry is one of the most widely used structural materials around the world and it is often the masonry structure which suffers the severest damage when earthquakes occur. Therefore, it is considered that the masonry structure is not only an important but a mandatory topic to be discussed during the World Conference on Earthquake Engineering.

This special theme session was designed to provide opportunity to deal with the seismic performance of structures and components, as well as analytical models on earthquake damage of masonry buildings, to exchange information on how to improve seismic performance of masonry structures with minimum reinforcement for developing countries where most masonry structures have not been reinforced and how to effectively and economically reinforce the structures for developed countries where most structures have been well reinforced already.

PRESENTATIONS OF PAPERS AND DISCUSSION

The session was co-chaired by Ir. T. Boen, National Delegate to IAEE from Indonesia and Prof. T. Nakamura from Kyoto Institute of Technology, Japan.

Eleven papers were presented in total including a state-of-the-art report. The coordinating committee of the special theme session selected 14 papers, but unfortunately three papers were not presented because of authors' absence. Through the presentation and discussion about 70 people attended the session.

In the state-of-the-art report (SL-R1 : DESIGN, CONSTRUCTION AND RESEARCH

IN MASONRY : CURRENT STATUS IN SELECTED REGIONS OF THE WORLD) was presented by Dr. J. L. Noland from U.S.A., about materials, current research, design methods and earthquake damage of several countries based on a questionnaire sent to people in several countries, the literature, papers presented at the technical session on masonry of this conference, and author's experience. It was observed that masonry design technology ranges from empirical to working stress based on linear-elastic behavior to ultimate strength and other limit states. A variety of masonry units are used from simple to complex. Research and development efforts address design and construction for seismic loads as well as others, unit shapes, evaluation and strengthening and codes.

Question by A. S. Arya from Univ. of Roorkee, India : May please inform on the methods of splicing of vertical bars in hollow masonry blocks ?

Answer : Lap-splicing is effective. Study on structural properties of lap-splicing bars has been carried out in New Zealand, Japan and also in U.S.

The first paper (SL-01 : STRENGTH OF WALL SUBASSEMBLIES : AN EXPERIMENTAL AND ANALYTICAL STUDY) was presented by Dr. P. Gülkan from Turkey about the experimental study of the strength of square adobe walls subjected to constant in-plane compression normal to the horizontal mortar joints and an incrementally applied diagonal loads. Within the range of the loads considered in the experimental phase an increase in the diagonal load carrying capacity was observed in the specimens. The biaxial strength of the assemblies could be satisfactorily computed in a qualitative way by an incremental non-linear finite element analysis when the soil was represented as an elastic-plastic material obeying the Mohr-Coulomb failure criterion.

Q. by S. C. Anand from Clemson Univ., Clemson, SC., U.S.A. : Has any other tests been conducted anywhere which describe similar behavior as presented in this paper ?

A. : Yes, of course. Similar tests on unreinforced concrete or clay masonry were carried out Europe standard in mid-70s.

The second paper (SL-02 : EXPERIMENTAL INVESTIGATION ON THE BEHAVIOUR OF UNREINFORCED MASONRY WALLS UNDER SEISMICALLY INDUCED LOADS AND LESSONS DERIVED) was presented by Prof. G. König from Germany about the shaking table and quasistatic tests performed to identify the fundamental response mechanisms of unreinforced masonry walls subjected to cyclic in-plane shear forces. Changing the axial load level, the brick type and the material strength for different types of cracking and post-cracking response were identified. Both the post-cracking strength and the plastic deformation capacity depended on the crack pattern. Walls with solid and strong units under low axial load performed deformations in a ductile manner, whereas brittle failure with almost no plastic deformation capacity was observed on walls under high axial load and on walls composed of highly perforated bricks with discontinuous inner webs.

Q. by S. J. K. Rao from Cal. State Univ., Long Beach, U.S.A. : How would you design of tests and test results relate to the seismic behavior of masonry walls by Priestly of New Zealand (now at U.S. San Diego) and Kariotis (of ABK methodology, LA Building code - RGA : Rule of General Application) ?

A. : Test results obtained here is considered to be basically similar to the Priestly's test.

The third paper (SL-03 : SHAKING TABLE TESTS OF IMPROVED ADOBE MASONRY HOUSES) was presented by Prof. G. Ottazi from Peru about the main results of an experiment research project in adobe earthen buildings. The objective was to

determine the influence of improved construction techniques and reinforcement on the seismic behavior of adobe buildings. Eight full-scale adobe housing modules representing one story rural dwellings, were tested on shaking table, under simulated seismic base motions derived from the acceleration record registered in Lima-Peru during the May 1970 earthquake. The behavior of the houses constructed by traditional and improved (reinforced by canes or timber) technology were mainly discussed.

Q. by C. Gavarini from Univ. of Rome, Italy : What can you say about the decay of canes after some years ?

A. : This is the most typical question we have on the canes. We have not found any problems on historical monuments, such as the Chan-Chan ruins which is 700 years old.

Q. by P. Gülkan from Univ. of Hacettepe, Turkey : Was the axial load on the walls typical of full-size houses ?

A. : Yes. The axial load applied was determined based upon a typical roof system of single story adobe masonry houses. The axial load is very low.

Q. by A. S. Arya from Univ. of Roorkee, India : Test of specimen only with vertical canes showed typical wall separation at corners and lack of lateral bending strength of walls. Was any test carried out using only horizontal canes ? In the opinion of this discussion, horizontal reinforcing of walls in adobe and other masonry with mud-mortar, particularly in one-storeyed houses is more important than the vertical reinforcing.

A. : Decreased small scale model tests using only horizontal reinforcing was carried out. Test results indicated that both horizontal and vertical reinforcing are necessary to improve seismic behavior of adobe masonry houses.

The fourth paper (SL-04 : BEHAVIOR OF REINFORCED MASONRY CONSTRUCTION IN THE CHILEAN EARTHQUAKE OF MARCH 3, 1985) was presented by Prof. R. E. Klinger from U.S.A. about the analytical seismic behaviors of a 4-story apartment building of grouted concrete block masonry which experienced the Chilean Earthquake of March 3, 1985. The computed behaviors were compared against the observed behaviors and the recommendation of structural requirements was discussed. It was suggested that a wall area ratio (in plane) of at least 2.5 % in each principal plan direction, multiple walls in each direction, and the use of 0.07 % horizontal reinforcement, and of about 0.20 % vertical reinforcement at wall ends are required.

Q. by H. Nei from Taisei Corporation, Japan : What was the reason why the foundation of the building discussed is separated ? I think continuous foundation is better than separated one.

A. : Yes. I agree with you. I also don't know why the foundation is separated.

Q. by M. Como from Univ. of Rome, Italy : What is the percentage of steel vertical reinforcement in the masonry wall of the buildings ?

A. : The vertical and horizontal reinforcement of this building are 0.33 % and 0.13 %, respectively. This vertical reinforcement ratio is much more greater than the one required in the codes in many of countries.

The fifth paper (SL-05 : ESTIMATION OF BASE SHEAR COEFFICIENT FOR THE CHILEAN EARTHQUAKE OF MARCH 3, 1985, BASED ON THE RESPONSE OF REINFORCED MASONRY BUILDINGS) was presented by Prof. P. Hidargo from Chile about the estimation of the base shear coefficient for the Chilean Earthquake of March 3,

1985 through the observed damage of three reinforced masonry buildings and the data from cyclic in-plane shear tests.

Q. by G. König from Inst. für Massivebau, Techn. Hochschule Darmstadt, FRG : The criterion for shear cracking, shown in your slide, depends upon the horizontal reinforcement. Do you have any explanation for that fact ?

A. : As similar to a reinforced concrete system, the initial shear cracking value, not ultimate shear cracking, is independent of the horizontal reinforcement ratio.

Q. by R. G. Saragoni from Univ. of Chile, Chile : I only want to make a general comment in Santiago city where the studied building are located. One strong motion acceleration was obtained on one SMAC Japanese instrument. The maximum peak ground acceleration was 0.11 g. The same comment is valid for the previous paper.

A. : Yes. I know about the record you mentioned. We did not want to use this record because the record was obtained in a building, not in the free field ground, and also, it gave us just a peak acceleration value rather than a time history record.

The sixth paper (SL-06 : REPAIR AND STRENGTHENING OF DAMAGED STONE HOUSES AFTER DHAMAR EARTHQUAKE OF DEC. 1982) was presented by Prof. A. S. Arya from India about the repair and strengthening of damaged stone houses which were damaged during Dec. 1982 earthquake in Dhamar Province of Yemen Arab Republic. The main causes of damage were outlined and the essential elements necessary for earthquake resistance were explained with practical details. The cost of total repairs was estimated less than 20 % of reconstruction cost.

Q. by A. W. Coburn from the Martin Centre for Architectural and Urban Studies, Univ. of Cambridge, U.K. : My question is more in the nature of a comment. I would like to pay tribute to the very practical nature of Prof. Arya's contribution. After the 1982 earthquake, OXFAM and a number of other charities set up the Dhamar Building Education Project, to train village builders in earthquake-resistant construction techniques in the knowledge that a large amount of reconstruction and repair would be mainly self-help. Prof. Arya's visit and his help with the very practical nature of repair how to drill through 60 cm walls, how to cut a ring beam into the top of existing walls and so on, all within the capabilities of the Yemen builders, were extremely useful in developing the techniques used. These techniques have been successfully applied to large of buildings in the area damaged by the 1982 Dhamar earthquake. The recovery of the town and surrounding area owes a considerable amount to the technical contribution presented in this paper.

Q. by C. Gavarini from Univ. of Rome, Italy : Did you evaluate the horizontal strength of the buildings after the repair and strengthening works ?

A. : No, it was not carried out. Because material strength was unknown and also no laboratory test was available.

Q. by R. E. Torres from National Univ. of Engineering, Peru : In this case, cement mortar is used for repair and strengthening. How do you think if the cement mortar cannot be used for the works, such as in case of some monuments, etc. ?

A. : There was a 600 years age adobe Buddhist temple. To strengthen the temple, we suggested to provide only additional buttresses of same material which is still available in the area.

The seventh paper (SL-08 : AN ATTEMPT FOR A NEW DEFINITION OF SEISMIC VULNERABILITY OF MASONRY BUILDINGS) was presented by Prof. C. Gavarini from Italy about a proposal of a new seismic vulnerability scale of masonry buildings such that the correlation with the damage produced by earthquakes could be as good as possible. The new index was based on the same parameters presently contained in the so called second level form currently used in Italy.

The eighth paper (SL-10 : EARTHQUAKE-RESISTANT PROVISIONS FOR ADOBE CONSTRUCTION IN PERU) was presented by Prof. J. Bariola from Peru about the research that served as basis for the earthquake-resistant provisions for adobe construction in Peru and the general characteristics of the code. Main points studied in pertinent investigations were the critical importance of drying shrinkage of adobe mortar on masonry strength and the use of cane reinforcement to assure safety against collapse. The code incorporated this results specifying the minimum of straw addition for drying shrinkage control and the obligatory use of cane reinforcement.

The ninth paper (SL-12 : SEISMIC DESIGN OF REINFORCED MASONRY) was presented by Prof. G. C. Hart from U.S.A. about the seismic design of reinforced masonry. It was proposed that in order to rationally develop a reinforced masonry design criteria it is desirable to use a limit state design approach with design values selected through the use of structural reliability theory.

The tenth paper (SL-13 : DEVELOPMENT OF MEDIUM-RISE REINFORCED MASONRY SYSTEMS) was presented by Dr. S. Okamoto from Japan about the newly developed medium-rise reinforced masonry system and related research such as component tests and a full scale test of a five story reinforced masonry building. At present in Japan, only up to three story masonry buildings are permitted to be constructed. The new design guidelines for medium-rise reinforced masonry buildings will be used up to five stories.

Q. by P. Hidalgo from Univ. of Catholic, Santiago, Chile : Concerning the test of the five story building, how did you select the relative values of the lateral forces applied to the specimen ?

A. : The lateral force distribution on each story of the specimen was determined based upon so-called Ai-distribution which is specified in the Building Standard Law of Japan.

CLOSURE

Masonry structures may be classified into two kinds, i. e. unreinforced and reinforced ones. Since the unreinforced masonry structures usually have poor seismic resistance, it is expected to be proposed appropriate low cost reinforcing materials and strengthening methods through various kinds of research in order to mitigate the structural hazard to human lives. On the other hand, for the reinforced masonry structures, the limit state design is desirable considering the ductility based on various kinds of test data in order to effectively and economically reinforce them.

At the end of the session, on behalf of the coordinators of the session, Dr. Y. Ishiyama expressed sincere appreciation to all participants to the session. He also informed the IAEE non-engineered construction committee meeting which would be held in the evening of the same day at Room 560 and invited everyone to be welcomed. The summary of the meeting is included in the Appendix.

APPENDIX : SUMMARY OF THE IAEE NON-ENGINEERED COMMITTEE MEETING

The meeting of IAEE Non-Engineered Committee was held at 17:30 on Aug. 8, 1988 in IAEE office on 5th floor at Kyoto International Conference Hall. The authors of the special theme session SL - IMPROVEMENT ON SEISMIC PERFORMANCE OF MASONRY BUILDINGS - and also some other participants (total number about 30) attended the meeting. After deliberations of the IAEE Guidelines on Earthquake Resistant Non-Engineered Construction, there was consensus among the house on the following points:

1) For implementation of seismic safe measures on non-engineered buildings, which cause the greatest loss of life and misery to the people during a damaging earthquake, the severe seismic zones of the world where local governments' interest is also available may be taken for Pilot Projects during IDNDR.

2) It was noted that although Non-Engineered building (badly designed buildings, etc.) constitute the majority of buildings not only in the developing countries but also developed countries (constructed more than 50 years ago). The concern in the IAEE World Conference is not commensurate. IAEE may give thought to have greater consideration of relevant matters in future conferences (by way of invited talks, theme sessions, etc.).

3) It was recommended that for life saving during earthquakes, greater emphasis may be laid on research and education on various types of masonry constructions (brick, stone, block, adobe and the like).