Analysis Contest on a 7-story Reinforced Concrete Building under Near-fault Earthquakes

1. Purpose

On February 6, 2016, an M_L-6.6 earthquake on the Richter magnitude scale occurred in the Meinong District of Kaohsiung City, Taiwan. The earthquake caused catastrophic damage to Tainan city, including a significant number of collapsed and severely damaged buildings and 117 deaths. The collapsed buildings showed the structural disadvantages of irregularities and soft stories. In Taiwan, near-fault effects on building structures are a critically important issue. The high performance of the shaking table in NCREE Tainan Laboratory is capable of reproducing the characteristics of near-fault ground motions. A blind prediction contest is held in order to contribute to the development of computational prediction of seismic responses and efficient modeling techniques for reinforced concrete buildings involving near-fault effects and "soft/weak" 1st story condition. The goal is to promote efficient seismic performance assessment methods for reinforced concrete buildings. Accordingly, shaking-table tests of a 1/2-scale multi-story reinforced concrete building model will be carried out. Each of the participating teams shall predict the structural responses before and after the tests, and the closest prediction to the test results will be awarded.

Because the actually achieved table motion histories will be obtained later during the course of the testing and so are the observed structural responses on the shaking table, the contest is then separated into two stages:

Stage 1: Submit the analytical model, supplemental data, description of analysis model and computational environment described in Section 8(a)-**Stage 1** before the actually achieved table motion histories are obtained.

Stage 2: Post-test predictions using the actual table loadings. The same analytical model as that used for Stage 1 is to be used again for Stage 2 predictions.

2. Judge and Acting Committee

The contest is a part of the NCREE reinforce concrete research team project, and will be carried out by two working groups (WGs) of the team: The Analysis Method and Verification Working Group (WG) will do all the tasks including announcement, distribution of data, answering questions, and judgment. The Building Seismic Behavior Simulation WG will reduce the experimentally recorded data into the seismic responses of the seven-story building model induced by near-fault ground motions.

3. Qualification of the Participants

The participants can be either an individual or a team, but one individual can be involved in only one team or as an individual. Each team consists of four members at most. A member of the aforementioned WGs or a person who has an access to test specifications prior to the official announcement can still submit his/her prediction results, but is not eligible to compete for awards.

4. Category

The contest is categorized by the types of analysis methods and participants. Winners will be selected for each of the following categories:

(a) 3D-analysis:

Three-dimensional (3D-) analysis may be carried out by (but not limited to) finite element analysis with shell and/or solid elements, or frame analysis using fiber elements and/or beam-column line elements with plastic hinges.

(b) 2D-analysis:

Two-dimensional (2D-) analysis may be (but not limited to) plane frame analysis, including fiber elements and/or line elements.

Each category will have two winners according to type of participant as follows.

The contest is categorized by the types of participants. Winners will be selected for each of the following categories:

1. Researchers (including students)

2. Practicing Engineers.

A team is permitted to enroll in both the 3D and 2D categories. Any people is not permitted to attend two different teams in one category. Analysis may be carried out by (but not limited to) finite element analysis with shell and/or solid elements, or 3D/2D-frame analysis using fiber elements and/or beam-column line elements with plastic hinges.

Each category will have at least two winners according to the type of participants. A total of four winners will receive awards according to Section 10.

5. Schedule (by 12 midnight, GMT)

2018/8/13: Announcement of outline and schedule of the contest, and distribution of specification of structural components and basic material properties.

2018/11/1-20: Shaking-table test at NCREE Tainan Lab.

2018/12/14: Deadline of entry application.

2018/11/19~2019/1/15: Submission of all the data and documents described in Section 8-**Stage 1** by participants.

2019/1/18: Distribution of actual base acceleration record.

6. Plan of Tests and Analysis.

- The shaking table tests will be conducted consecutively with increasing levels of seismic motions. The seismic levels are not fixed a priori; the seismic level of the subsequent test will be determined according to the actual structural deformation and damage observed in the existing test.

- For post-test analysis, actually achieved table motion at each seismic level will be provided for use in the analysis. Analysis results should be submitted for the *Inelastic Level*, the seismic level immediately prior to the *Collapse Level* at which collapse of the building may occurred. The analysis should be performed continuously from the seismic level at which the first plastification occurs up to the *Collapse Level*, by serially combining the corresponding table motion histories.

7. Specimen Data to Be Provided.

The following data will be distributed via website:

https://www.ncree.org/2018AnalysisContest/

(1) Structural geometry: plan, elevation, cross-sectional properties of structural members, and detailed description of the specimen including connections to non-structural components.

(2) Details of loading conditions: weights of parts and non-structural components.

(3) Preliminary analysis results: pushover analysis, free vibration analysis (modal analysis), and preliminary time-history analysis carried out by the organizing committee.

(4) Component test results: beam, column, composite beam, and anchor bolt.

(5) Material test results: properties of steel and concrete, which are obtained by the test based on the Taiwan specifications.

(6) Methods of measurement and data processing.

(7) Time histories and response spectra of seismic motions: measured acceleration histories for post-test analysis. Photographs showing specimen preparation will be available from website.

8. Analysis results to be submitted.

nodal coordinates and node-element relations are not needed.

(2) Supplemental data:

Figures describing the global deformation and plastification of the frame, and the time histories of floor displacements relative to the shaking table should be submitted as supplemental data.

(3) Description of analysis model:

Finite elements, constitutive model, time integration method, method for geometrically nonlinear analysis, and so on, should be explained.

(4) Computational environment:

Brand and model of computer, analysis program availability (free, commercial, or for in-house research), CPU time, and wall clock time, etc. should be described.

Stage 2: Post-test analysis.

(a) Data for judgment:

[A] For *Elastic Level*: Maximum values of floor displacement relative to the shaking table, absolute acceleration and overturning moment on each floor; maximum values of story shear, story drift angle; maximum engineering strain at a specified point (e.g., center of the column on the 1st story) in an elastic region; and residual story drift on each story (the story drift at the end of the duration of the specified seismic motion).

[B] For *Inelastic Level*: Maximum values of relative displacement from base, absolute acceleration and overturning moment at each floor; maximum values of story shear, story drift angle; maximum engineering strain at a specified point (center of the column in 1st story) in an elastic region; and residual story drift at each story (the story drift at the end of the specified duration of the seismic motion).

[C] For *Collapse Level*: Time, measured from the beginning of the collapse-level motion, at which the drift angle of any story in *X*- or *Y*-direction reaches 0.05 or -0.05 rad. for the seismic motion.

(b) Supplemental data:

Along with the predictions, contestants should submit a technical report of 5-10 pages electronically as a pdf document in accordance with the template for the International Conference on Earthquake Engineering in Commemoration of the 1999 Chi-Chi Earthquake. Contents of the report may include text, figures and tables that describe the model, utilized software platform, materials, elements, solution algorithms, assumptions, discussion of the analysis results, and summary of key results beyond those in the spreadsheet. Figures describing the global deformation and plastification of the frame, and the time histories of relative displacements should be submitted as supplemental data. Note that the analysis

results obtained from the time history that differs widely from that of test results will be rejected to prevent accidental agreement of the numerical and test results. The paper format of the International Conference on Earthquake Engineering for 20th Anniversary of the 1999 Chi-Chi Earthquake can be downloaded from the Submission Format tab.

(c) Input files to the analysis program:

Exactly the same input data, except for the table acceleration histories and material properties of concrete, should be used for post-test analysis. The geometry data such as nodal coordinates and node-element relations are not needed.

General remarks.

I. The forms for submittal will be distributed by the committee.

II. The responses in the X-, Y- and Z- direction should be presented for 3D analysis, while only the X- and Z- directional responses are to be presented for 2D analysis.

III. Evaluate maximum (absolute value) relative displacement and total acceleration envelopes on the upper surface at the center of each floor.

IV. Formulas for computing story drift, overturning moment and story shear will be supplied by the committee.

V. The axial strain of a column to be reported is resulted only from the dynamic excitation; i.e., it does not contain the initial strain due to dead load at the beginning of the test.

VI. 'Maximum' is defined as the absolute value of peak response (independent of sign convention).

VII. Predictions shall be in SI units (mm, kN, sec, rad); do not use 'g' or '%'; and each number should have four significant figures. For example, a story drift angle can be reported as 0.01234 rad., and an overturning moment can be reported as 0.1234E+10 kN-mm. Unit Conversion: 1 inch = 25.4 mm, 1kip = 4.448 kN.

9. Method of judgment.

(1) Compare the RMS errors for each response quantity, which is computed from

$$E_i = \sqrt{\sum_j \left(F_{i,j} - F_{i,j}^*\right)^2}$$

$F_{i,j}$: analysis result of the ith response quantity at the jth floor/story.

$F_{i,j}^*$: test result of the ith response quantity at the jth floor/story.

E_i: RMS error of the ith response quantity

(2) The basic point b_i for the ith response quantity is 8 for the minimum error, 5 for the

second, 3 for the third, and 1 for the fourth. The total point P is computed from

$$P = \sum_{i=1}^{n} w_i b_i$$

w_i : weight for the ith response quantity

n: number of response quantities

The team/individual with the maximum total point will be the winner for each category. The weight w_i will be announced by the committee before the shaking table test just for reference. Nevertheless, each team has to calculate the structural weight carefully as possible.

(3)   The judgment will be carried out completely anonymously. Judges will only know the participant submission name only via an alias.

(4)   In each category, up to and including the third place winners will be announced and the names of all the participants will be asked to disclose their names and affiliations.

10. Awards.

If there are sufficient (based on the judgement of the evaluation committee) participants in each category, there will be two winners for each of the two categories. Otherwise, no distinction will be made between the two categories in announcing the winners. Awards will be given in a special ceremony at the **International Conference on Earthquake Engineering in Commemoration of the 20th Anniversary of the 1999 Chi-Chi Earthquake.** NCREE will cover the travel and accommodation expenses for the winners' participation in the conference.