Outline

Meijo University’s “Research Project for ‘21st Century-Type’ Natural Disaster Risk Reduction” was adopted as a Strategic Research Base Development Program for Private Universities by MEXT Japan (the Japanese Ministry of Education, Culture, Sports, Science and Technology) in 2012 (S1201023), and NDRR was launched. NDRR promotes advanced research in the prevention and reduction of disasters in order to reduce the risks of “21st century-type” natural disasters that faced by modern society, which include floods and landslide damage caused by torrential rain and earthquakes in urban areas. Five research topics are comprised in this project and the detail of each topics are as shown below.

1. Upgrading of Structural Safety and Post-Earthquake Serviceability of Infrastructures Against Repeated Huge Earthquakes
   - Development of damage evaluation methods for structural members
   - Development of seismic design methods of structures considering the post-earthquake serviceability
   - Development of damage control design methods based on the cumulative damage responses of reverse yielding system taking account of the scale factor

2. Reduction of the earthquake disaster risk by the earthquake-resistant evaluation of the buildings
   - Development of precise evaluation method for steel members
   - Earthquake-resistance evaluation for the RC space structures
   - Evaluation of wooden houses and inspection for the damps

3. Mechanisms of Hydro-disaster by Heavy Rainfall and Risk Reduction Procedures
   - Spatiotemporal variation of heavy rainfall
   - Runoff and flood control of urban streams
   - Numerical analysis of stochastic wave from heavy rainfall

4. Reduction of the risk of natural disaster in coastal low-lying area by cooperation of hydraulics and geotechnique
   - Research for levee breaching process on the geographical condition of a river
   - Clarification of the seismic behavior of the foundation ground of levee that constructed on alluvial low-lying area
   - Simulation on the subsidence of the levee during earthquake

5. The Roles and Possibility of “Core Victims” who Support Reconstruction of Community and Life after the Great East Japan Earthquake
   - Facilities and challenges related to decontamination function of local government
   - The roles of “Core Victims” (Resilience) for independence reconstruction by their own
   - Teaching material and implementation of disaster reduction training based on the reconstruction process by victims’ willpower
Research Achievements and Challenges

Study on Response Characteristics and Performance Evaluation Method of Long Span Steel Bridges Subjected to Compound Damage of Earthquake and Tsunami

During the 2011 Great East Japan earthquake, serious secondary disasters caused by collision of drifting containers or ships occurred in various structures. In this study, it is assumed that a large drifting ship collides with a large-span bridge in the gulf line during a tsunami. Bridge adopted in the analyses is a 1,000m long (250+500+250) large-span cable-stayed bridge. First of all, damage to the bridge under the earthquake excitation resulted from four simultaneous earthquakes is investigated. Next, the collision analysis of the damaged bridge is performed. The collision speed and direction of large ships are determined by a tsunami simulation. The impact load on the main tower of the damaged bridge induced by the large ship collision is adopted as wave-form force. Moreover, the ultimate capacity of structural member subjected to collision of drifting object is calculated by conducting a static elasto–plastic finite element analysis. Based on the collision force calculations, an approximate analytical method is proposed, and the maximum size of drifting object which can result in the collapse of the whole bridge structure is calculated.

As a result, the impact behaviors including local buckling and global buckling are evaluated. Ship impact effect is considered by using the maximum colliding force to the whole bridge. Consequently, it can be simply applied to large scale bridges. Some practical analytical examples illustrate the feasibility of this proposed method.


Research on Control Roll Waves of Flow with Sediment

Intermittent debris flows are known as viscous debris flow in China. However, lots of intermittent surges with sediment have been observed not only in China but also in the European Alps and elsewhere. It is often considered that these flows develop from hydraulic flow instabilities and evolve into distinct roll waves. The characteristic of such roll waves are not well understood. In this research we derive a wave equation for flows with sediment in an inclined channel and successfully compare results with laboratory experiments and wave motion observed in the field.

Comparing this theory with observations in an experimental flume of 56m length, 10cm width, 15cm depth and a smooth bed shows good results. Fig.1 depicts results of theoretical equation and an experiments where mean depth was $h_0=1.07$ cm, mean velocity $u_0=101.5$ cm/s and solid concentration $C=0.12$ (solid particle: median diameter $d_{50}=0.6$mm, density $\sigma=1.41$g/cm$^3$). Some intermittent debris flows have been observed at Lattenbach-creek in Austria. A typical example of a wave observed at Lattenbach and a result of theoretical equation are shown in Fig.2. These results indicate for wave equation to respond the phenomenon.

In this research, an analysis and earthquake resistant design procedure for a free-form reinforced concrete shell roof under severe earthquake motions is proposed\(^1\). The method of analysis adopted for design is as follow; firstly a linear free vibration analysis for global understanding, secondly a linear elastic time history analysis using both several recorded earthquake motions and artificial design earthquake motions from which a set of design earthquake forces, defined as statically equivalent forces, are evaluated considering ultimate limit state, thirdly a push-over analysis based on the evaluated seismic forces, and finally materially and geometrically nonlinear dynamic analysis for ultimate limit state. Through a set of these analysis, structural proportioning was determined. Comparison between the push-over analysis results based on the evaluated static seismic forces with those obtained by geometrically and materially nonlinear time history analysis was also performed to prove the validity of the push-over analysis, and its validity was confirmed clearly for use in structural design. Prior to this study, the results of a dynamic destructive experiment of a reinforced concrete (RC) arch and its numerical analysis for the purpose of evaluation of earthquake resistance of an RC arch/shell of a large span and verification of the numerical analysis technique are shown\(^2\). For a shallow shell, it is especially important to treat imperfection, shrinkage/creep and thermal effect of concrete over a long period of time. In this study, some results of trying the estimation of deformation characteristics by measurements and analyses for a newly constructed shallow reinforced concrete shell are also shown. Evaluation of thermal, shrinkage and creep effects on static and dynamic ultimate strength is tried as an example\(^3\).

1) Katsuo NAKATA, Takashi TAKAMIZAWA, Atsushi MUTOH, Shoji NAKAZAWA, Shiro KATO, Structural Design of a Church of Free Form - Example of Earthquake Resistant Design of Reinforced Concrete Shell in Japan -, IASS, 2014. (CD-ROM)
3) Atsushi MUTOH, Yuhki ITO, Hiroshi KOMATSU and Mutsuro SASAKI, Evaluation of thermal, shrinkage and creep effects in shallow RC shells by Measurements and Analyses, IASS, 2012, total 6 pages(CD-ROM)

**Study on the Appropriate Evaluation Method for the Strength Coefficients of River Levees**

The strength coefficients of soil, e.g., cohesion \(c\) and internal frictional angle \(\phi\), are very important factors for stability inspections of river levees against seepage failure. The total stress-based slip circle analysis method is thought to be a suitable method for discussing the stability of river levees, and 3 types of test conditions that consolidated-undrained (CU), consolidated- undrained triaxial tests with pore water pressure measurements (CU-bar) and consolidated-drained (CD) triaxial tests are recommended for the determination of strength coefficients in Japan. In this study, a series of CU-bar and CD tests for sandy and gravel soils, sampled from real river levees, is carried out in order to confirm the difference in the strength coefficients obtained from different test conditions.

Fig. 1 is an example of the Mohr's stress circle and the failure criterion obtained from the triaxial tests. Total stress parameters, such as \(c_{cu}\) and \(\phi_{cu}\), were calculated using the total stress from the CU-bar test results, which can be considered to be equivalent of the test results of conventional CU test. \(\phi\) and \(c\) were calculated using the effective stress from the CU-bar test results, and \(\phi_{cu}\) and \(c_{cu}\) were calculated using the total stress in the CD tests. As a result, strength parameters \(\phi_{cu}\) and \(c_{cu}\) based in the total stress were susceptible to the dispersion in specimens. Thus, it is difficult to obtain the appropriate strength coefficients through conventional CU triaxial tests. On the other hand, the test results observed by both CU-bar and CD tests are found to be not influenced by the dispersion in specimens due to the reflection of dilatancy properties during shearing. Thus, it is easy to determine the strength coefficient under these test conditions.

Moreover, a new determination method for \(c\) and \(\phi\) from Mohr's stress circle was proposed in this research, and above results will be included in the advanced guideline for the safety evaluation of river levees that will be published this year.