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2009年9月30日パリアマン地震を受けたインドネシア・パダン市の基幹建物の耐震性に関する詳細調査

Detailed Survey on the Earthquake Resistance of Backbone Buildings in Padang after the September 30 Pariaman Earthquake

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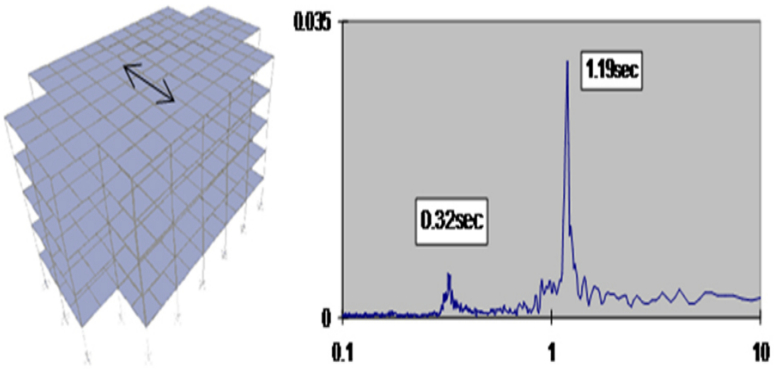

3-D frame model and microtremor measurement of the surveyed building

On Wednesday September 30, 2009, at 5:16 p.m., an Mw 7.6 Pariaman Earthquake struck the west coast of Sumatra, affecting Padang, Pariaman, and hilly areas east of Pariaman. Padang is the capital of West Sumatra. The earthquake caused significant damage to about 140,000 houses and 4,000 other buildings. In order to achieve better engineering of structures, the authors conducted detailed surveys on large scale RC buildings in Padang, from December 4th to 21st, 2009 and from January 20th to 24th:

1. Feature of the ground shaking:
Since there is no direct availability of seismic record on site, a questionnaire survey on the intensity and the duration were carried out. The results are for predicting the peak ground acceleration on site. Micro-tremor observations were carried out to find the predominant period of the ground in Padang, Pariaman, and the hilly areas. The predominant period of the hilly areas is useful for explaining why low rise building on such areas were extensively damaged whereas the same low building in other areas were slightly damaged.

2. Site survey of typically damaged three buildings:
The actual dimension of columns, beams, plates, walls, and re-bars, and the actual strength of the

concrete and the re-bar as well as the plan and elevation of the buildings were measured in the sites. The damage extent of each column was evaluated by a careful close watching survey. The damage was from slight to severe structural damage (collapse). Because of the damage, the structural components of the buildings were clearly revealed. The flaws of the design or construction were clearly seen: the use of plain re-bar, small stirrups, overlapping of re-bar at high moment region, and so on.

3. Response analysis using 3-D model of the buildings:
3-D frame models of the three buildings were defined and the models were checked through the comparisons of the natural frequency with the measured natural frequency by the micro-tremor observation on the buildings. The response stresses due to the estimated earthquake intensity were computed and compared with the column strength, and the consequent damages were discussed. The failure mechanism was postulated so that future failure should be avoided by proper retrofit or reconstruction.

4. Conclusions:
(1) The predominant period of micro-tremor in the downtown region of Padang was around 1.5 seconds, which imply the strong shaking by the September earthquake was severer for the large scale buildings.
(2) The design document of one of the buildings showed that the building had been designed by an old seismic design concept and had been applied with excessively small earthquake load. The other two were also supposed to be in the same situation through the detailed site investigation.
(3) Concerning the two buildings, the seismic resistance analytically estimated through the detailed field survey was clearly lower than the computed response stress to the estimated earthquake intensity. The other building had a particularly poor style of re-bar arrangement.
(4) Followings are recommended:
a) Very many reinforced concrete frame buildings in Indonesia are supposed to be in the same level. Systematic retrofit to such buildings is urgent to avoid next catastrophe.
b) The field engineer as well as the structure designer must be trained to understand the vital importance of the proper arrangement of re-bars.
c) Deformed re-bar should be used for both of the main reinforcement and the lateral confinements, and the detail of re-bar joints and the anchorage must exactly follow the requirements.

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キーワード:震度,常時微動観測,建物構造3次元モデル,構造解析,破壊機構,鉄筋配置

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