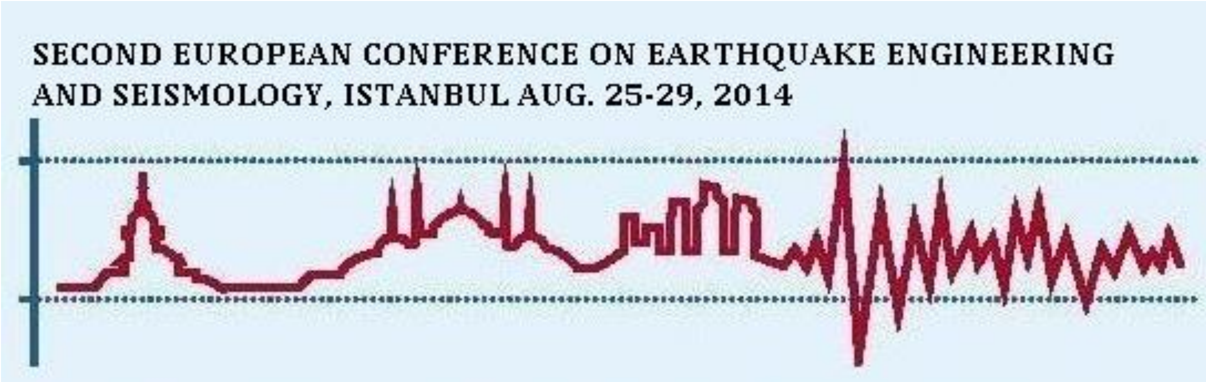

DESIGN PROCEDURE FOR CLADDINGS WITH DISSIPATIVE CONNECTIONS IN SEISMIC ZONES

Eleni SMYROU[1], İhsan Engin BAL[2], Ercan YÜKSEL[3], and Faruk KARADOĞAN[4]

Claddings serve architectural purposes and at the same time act as protective or insulating layer in prefabricated RC structures. Postulating that claddings are non-structural elements, their complexity due to the variability in material, shape, configuration, connection etc. is often overlooked. However, numerous failures of claddings after earthquake events (Mexico City, 1985; Northridge, 1994; Spitak 1988, L'Aquila, 2009 etc.) raised major concern about issues of safety because of serious injuries, cost due to expensive repair or replacement, and interruption of industrial activities.

The lack of adequate information on the response of claddings and their connections in seismic regions has hindered the development of a rational design procedure. The design approach widely used today and adopted by the current code provisions aims to the nearly complete isolation of the cladding from the building in an attempt to protect the cladding from damage. Since interaction with the building is expelled, any contribution of the cladding to the seismic response of the building is in principle eliminated.

Nevertheless, the exclusion of the contribution of the cladding ignores what several analytical and experimental studies consistently indicate: interaction between the cladding and the structure does occur even otherwise deliberately designed. Moreover, cladding alters the lateral stiffness of the structure with an immediate effect on the modes of vibration, while it can potentially play a role in the ductility and energy dissipation capacity of the structure.

Therefore, the research work presented here suggests that a structural role for the cladding system may be reasonable as long as it is taken into account during the design process. Such a consideration presupposes that the response of the cladding system is known and successfully controlled during an earthquake by means of using appropriate advanced connectors, capable of dissipating energy, the structural features of which are well established. A dissipative connector is the type of device that exhibits enhanced properties in terms of ductility and damping and constitutes a key element in the new concept of designing the cladding system participating in the response. An advanced connector is expected to accommodate deformations compatible to the predefined performance level and increase the energy dissipation that is beneficial for the building under seismic excitation. The type and physical shape of the connector is not of concern of this paper, thus a simple fictitious connector that has a hysteretic behaviour that follows the Elastic-Perfectly-Plastic rule is assumed in the design procedure.

Accurately expressed by Goodno et al. (1998), 'the cladding system would perform in a role not unlike that of other passive response modification systems. Then the design objective can be to provide either additional seismic protection for a building structure that is otherwise adequately designed or an acceptable baseline level of performance with a commensurate reduction in the cost of the conventional building structural system'. In line with this concept, an initial attempt to develop a design methodology is outlined. The proposed methodology includes the introduction of a new design

[1] Asst. Prof. , Dept. of Civil Eng, Istanbul Tech. Univ., Istanbul, esmyrou@itu.edu.tr
[2] Asst. Prof., Earthquake Eng. & Disaster Manag. Institute, Istanbul Tech. Univ., Istanbul, iebal@itu.edu.tr
[3] Assoc. Prof., Dept. of Civil Eng, Istanbul Tech. Univ., Istanbul, yukselerc@itu.edu.tr
[4] Emer. Prof., Dept. of Civil Eng, Istanbul Tech. Univ., Istanbul, karadogan@itu.edu.tr

philosophy where the contribution of the claddings and the connectors is one of the primary design parameters that affect directly the behaviour factor and thus the design loads. The proposed design methodology is quite similar to existing code-based design approaches so that practitioners can easily follow the proposed method. The design approached proposed here assumes a base-shear contribution of the claddings attached to the structure, and a behaviour factor R is then assigned to the structure based on the contribution of the claddings to the base shear. The proposed design approach is similar to that of frame-wall structures where the behaviour factor R of the overall system depends on the contribution of the RC walls to the base shear. Necessary design aspects, such as the need for a rigid diaphragm, limit state drifts for the columns, or deformation limits for the connectors have also been discussed in detail.

In order to build and verify the proposed design methodology, several benchmark structures have been modelled. An example benchmark structure can be seen in Figure 2. The design steps and the final design outcome are compared to the results of a series of nonlinear time history analyses. 20 selected records (Bal et al., 2013) complying the design spectrum of Eurocode 8 have been used for the analyses. Limit states of the columns as well as the connectors used have been compared with the limit values. The energy consumption on each component of the system have been evaluated in time domain. The claddings are found significantly effective in case of long shakings that impose several reversal deformations on the prefabricated RC structures.

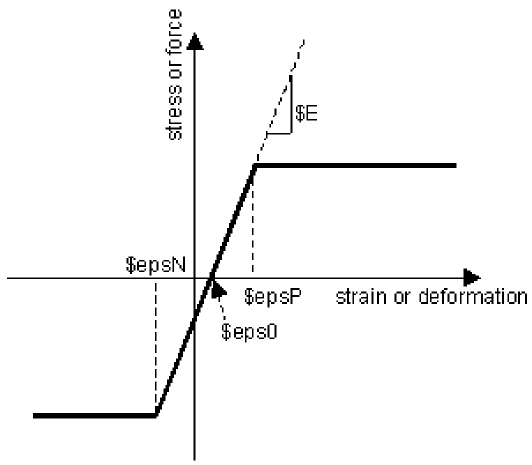

Figure 1. The elastic-perfectly-plastic behaviour of the energy dissipator used on cladding panels

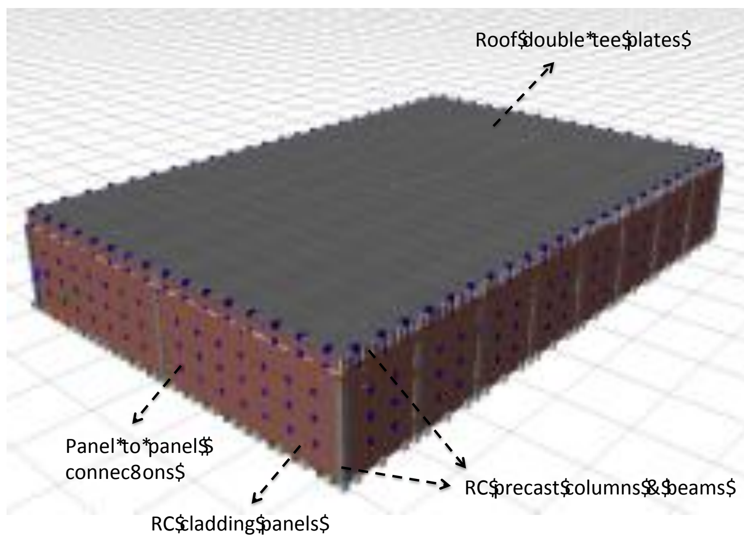

Figure 2. A 3D numerical model of a benchmark RC precast structure used in verification of the proposed design approach

REFERENCES

Bal İ E, Karadoğan F, and Yüksel E (2014) "An Engineering Approach for Structure-Oriented Record Selection", Proceedings of the 2nd ECEES, Istanbul, Turkey.

Goodno B J, Craig J I, (1998) "Ductile Cladding Connection Systems for Seismic Design", *NIST GCR 98-758, Technical Report, US.*

Yüksel E. et al. (2014a) "Energy dissipative steel cushions", Proceedings of the 2nd ECEES, Istanbul, Turkey.

Yüksel E. et al. (2014b) "Cyclic tests on the precast panels equipped with steel cushions", Proceedings of the 2nd ECEES, Istanbul, Turkey.