ΕΠΕΣ
TEE | TKM
Ελληνική Επιστημονική Εταιρία Ερευνών Σκυροδέματος (ΕΠΕΣ) – ΤΕΕ / Τμήμα Κεντρικής Μακεδονίας
Πανελλήνιο Συνέδριο Σκυροδέματος **«Κατασκευές από Σκυρόδεμα»**
Θεσσαλονίκη, 10-12 Νοεμβρίου 2016

Recent developments in seismic design of reinforced concrete dual systems

Andreas J. Kappos
Professor, Director of Research Centre for Civil Engineering Structures, City University London, UK, Andreas.Kappos.1@city.ac.uk

Leena Tahir
Graduate student, Department of Civil Engineering, City University London, UK, Leena.Tahir-Kibriya@city.ac.uk

Extended abstract

The design of frame-wall systems has emerged as the favoured method of providing effective earthquake resistance in multi-storey buildings. The shear force and bending moment design envelopes for dual systems, obtained according to the current European Seismic code (CEN 2004), are not satisfactory since they overestimate the design forces in the upper half of the walls, while not properly considering potential overstrength of plastic zones at the wall base. A modified procedure for developing the design envelopes, taking into account the above mentioned factors, has been proposed by Kappos and Antoniadis (2006, 2011). This study presents an extension of the proposed design procedures, formulated using 2D dual systems, to the design of walls in 3D dual buildings. A parametric study is presented, concerning a total of four dual systems, designed for medium and high ductility classes and peak ground acceleration levels of 0.16g and 0.24g. Results from 3D inelastic response-history analyses are compared with those from the application of the design procedures of Eurocode 8 (CEN, 2004) as well as the Kappos and Antoniadis (2011) methodology adapted here to 3D buildings.

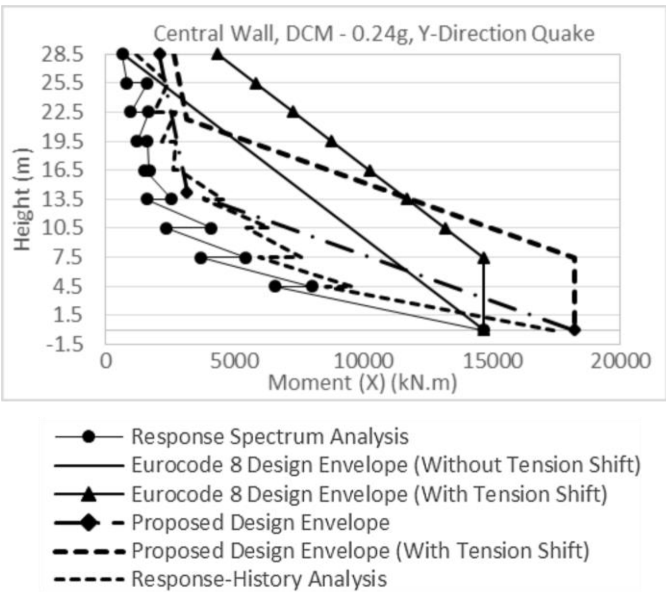
The basic structure considered for this study is a 9-storey reinforced concrete building comprising of a central core and L-shaped shear walls located in each corner of the building. The design of the dual structures was carried out according to the provisions of the pertinent Eurocodes (2 and 8), including all capacity design requirements of Eurocode 8 (EC8) for the flexural and shear design of walls. The Kappos and Antoniadis (2011) method for constructing flexural and shear design envelopes was also applied to the same buildings.

The finite element software packages ETABS and RUAUMOKO 3D were used for the linear and nonlinear analyses of the three-dimensional (spatial) structural models. The response spectrum method of analysis was used for the linear analysis. The Kappos and Antoniadis as well as the EC8 design procedures were evaluated against the results of inelastic time history analyses from which the maximum moments and shear forces developed in the walls of the structure during seismic actions of different intensities were found. Response-history analysis was carried out for a set of both natural records, representative of catastrophic earthquakes and synthetic records, all scaled to the design intensities for each structure (0.16g or 0.24g) associated with the ‘damage limitation’ performance level (limit state).

Typical results for bending moments and shear forces are shown in Figure 1; similar trends were found in the other cases studied, reported in the full paper. It is noted that the proposed design envelopes exceed the EC8 design envelopes at the base due to the inclusion of overstrength of the critical region of the wall in the proposed methodology, which is not considered in the EC8 design envelopes. Moreover, the modified flexural design envelopes are significantly lower than the EC8 design envelopes in the upper half of the wall. Minimum flexural reinforcement requirements prevail for the upper half of the wall height for the walls designed in accordance with the modified method, whereas this is not the case for the EC8 methodology.

The EC8 shear design envelopes (bottom of Figure 1) are generally observed to be greater than those from the proposed method; the latter leads to a decrease in shear reinforcement in the upper one-third of the walls. It can be noted that the proposed design method adequately envelopes the non-linear flexural response of the wall. Ignoring the tension shift, it is observed that EC8 underpredicts the actual flexural response of the shear walls in the lower part of the building due to ignoring the overstrength of the base section. In the upper one-third of the shear wall height the EC8 shear design envelope has much greater values than the actual (inelastic) response. On the contrary, the proposed shear design envelopes are in general fully consistent with the inelastic analysis predictions. This study explored the feasibility and suitability of the design procedure proposed by Kappos and Antoniadis (2011) for the design of walls in 3D buildings with dual structural systems. It was found that, with some straightforward adjustment, the proposed procedure can be applied to 3D structures. The resulting economies in reinforcement in the upper half of the structure are about 30%, compared to that resulting according to the EC8 design envelopes.

Inelastic response-history analysis validates the proposed methodology whereas the current EC8 procedure is found to not adequately capture the flexural response of the buildings. It is recommended that additional studies be carried out involving three-dimensional structures of different heights and verification against higher levels of seismic action, which would eventually permit a revision in current European seismic code procedures



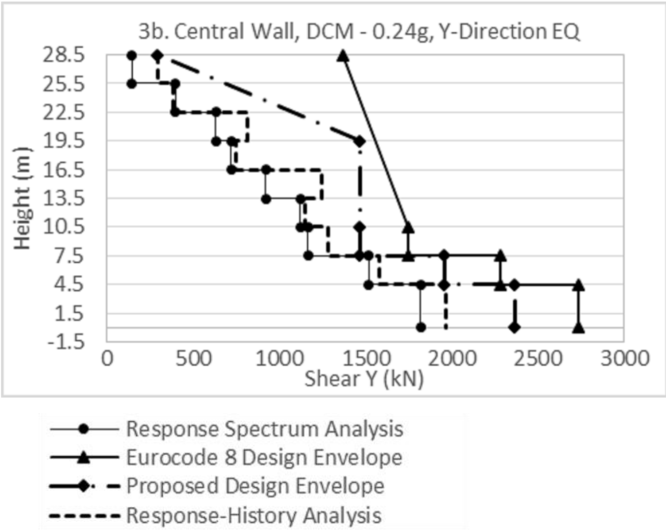


Fig. 1 Bending Moment (top) and Shear Force Envelopes in the central wall of the dual structure designed to DCM, for design earthquake intensity of 0.24g and cracked members.

References

CEN (Comité Européen de Normalisation) Techn. Comm. 250. 2004. *Eurocode 8: Design of Structures for Earthquake Resistance —Part 1: General Rules, Seismic Actions and Rules for Buildings. (EN1998-1-1:2004)*. Brussels: CEN.

Kappos A.J. and Antoniadis P.S. 2006. A contribution to seismic shear design of R/C walls in dual structures. Bulletin of Earthquake Engineering. 5(3):443–466.

Kappos, A.J. and Antoniadis, P.S. 2011. Evaluation and suggestions for improvement of seismic design procedures for R/C walls in dual systems. Earthquake Engineering and Structural Dynamics 40 (1) no. 0098-8847: 35-53.

.