3D NONLINEAR SEISMIC PERFORMANCE OF TUNNEL FORM BUILDINGS

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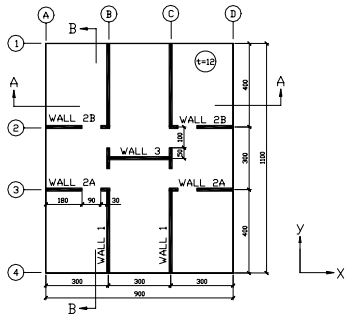
Objective

Non-damaged and high performance conditions of multi-storey tunnel form buildings during 1999, (M_w=7.4) Kocaeli and (M_w=7.1) Duzce earthquakes in Turkey motivated the investigation of their characteristic dynamic behavior and properties, and evaluation of their seismic performances.

Tunnel Form Buildings

Tunnel-tunnel form system is a construction technique that the walls and the slab are cast in a single operation.

❑ Utilize all wall elements as primary load carrying members.
❑ Monolithic structures due to simultaneous casting of walls, slabs and cross-walls.
❑ Walls and slabs have almost the same thickness less than the other conventional RC shear-walls and slabs.



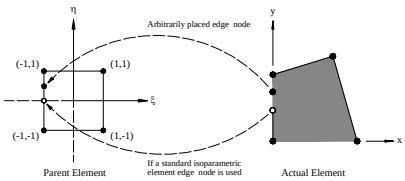
Typical floor plan

Methodology

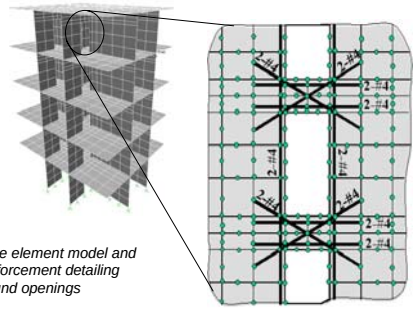
❑ Isoparametric shell element having closing-opening and rotating crack capabilities was developed to generate more realistic 2D and 3D finite element simulations.
❑ 2D and 3D Nonlinear pushover analyses were conducted on two case studies for their capacity evaluations.
❑ Performance of the structures were determined via capacity spectrum method and performance based design procedures.

Analytical Model Development

A nonlinear isoparametric shell element providing the capability of a variable edge order and arbitrarily placed movable edge nodes (to consider the location, and amount of main reinforcement near the edges and around the openings as discrete reinforcement) was developed.

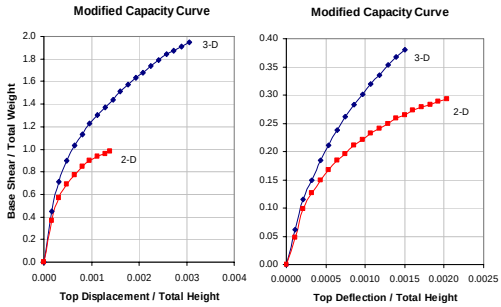


The capability of moving any of the element's edge nodes to any location along an edge allows these edge nodes to be placed in a proper position such that, they can serve as end nodes for the cover of the main discrete reinforcement. This provides a robust stiffness contribution coming from the main reinforcement.

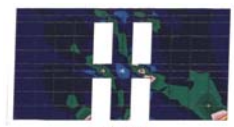


Finite element model and reinforcement detailing around openings

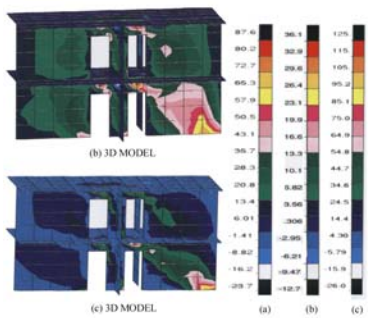
Capacity Spectrum Analysis



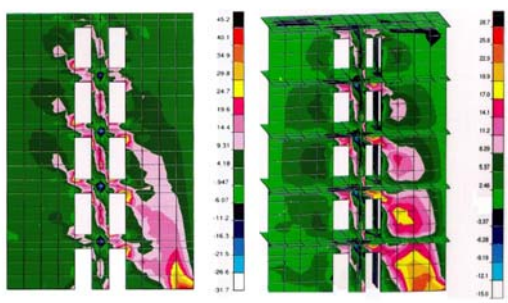
(a) 2-Storey Building *(b) 5-Storey Building*



Shear stress distributions for 2-story building (units are in ton and m): (a) 2D model (at failure); (b) 3D model; (c) 3D model (at failure)



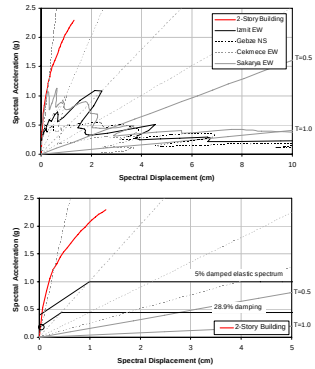
A combination of a distributed shear-wall mechanism and a story mechanism lead to the collapse stage accompanying the inelastic deformation. The overall system behavior was completely controlled by the symmetrically distributed shear walls. The 5-story case provided enhanced deformation capacity

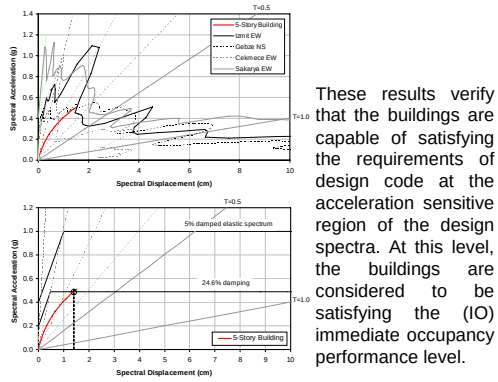


Shear stress distribution around the openings of 5-Story building

Performance Evaluation

Capacity spectrum method was applied based on the Turkish Seismic Code (1998) design spectrum (soft soil condition) and by using the 1999 Kocaeli earthquake main shock records (5% damped)

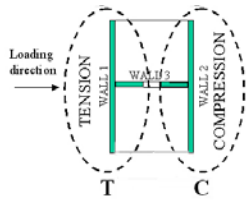


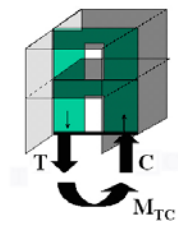


These results verify that the buildings are capable of satisfying the requirements of design code at the acceleration sensitive region of the design spectra. At this level, the buildings are considered to be satisfying the (IO) immediate occupancy performance level.

Tension/Comp. Coupling Effects

Tension-compression (T/C) coupling, executed by in-plane or membrane forces within the shear walls, is a 3D originated force mechanism build-up in tunnel form buildings due to the combined effects of wall-to-wall and wall-to-slab interactions.





Conclusion

❑This study shows that the applied methodology has a considerable significance for predicting the actual capacity, failure mechanism, and evaluation of the seismic response of tunnel form buildings.
❑Total resistance capacities of the three-dimensionally analyzed structures were observed to be more than that of two dimensionally modeled cases.
❑Strong disruption of the shear flow was observed around the openings.

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