PARAMETRIC EVALUATION FOR THE ADEQUATE SHEAR WALL INDEX IN REINFORCED CONCRETE BUILDINGS TO BE CONSTRUCTED IN HIGH SEISMICITY REGIONS

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1. SUMMARY

Post-earthquake field observations following recent devastating earthquakes have once again highlighted the critical role of shear walls in reinforced concrete structures. Buildings with sufficient shear walls demonstrated superior seismic performance and avoided collapse, even when the walls were irregularly placed within the plan. In this study, the influence of varying shear wall indices—defined as the ratio of total shear wall area to total floor area—on the seismic behavior of newly constructed reinforced concrete buildings in high seismicity regions was investigated through analytical analyses. A representative floor plan was developed, and forty-five three-dimensional structural models were generated with nine different story heights ranging from four to twelve stories and five different shear wall indices ranging from 0.8% to 2.4%. Residential building plans from high seismicity regions of Turkey, including Istanbul, Malatya, Gaziantep, Kahramanmaras, Hatay, and Adana, were examined, with preference given to projects dated 2020 or later to reflect current construction practices. These buildings commonly featured commercial ground floors, mezzanines, and core walls enclosing elevator and stair shafts. To systematically evaluate the effect of wall index on structural performance, five wall index levels (0.8%, 1.2%, 1.6%, 2.0%, and 2.4%) were created for each story configuration. The reference layout included all wall elements corresponding to the 2.4% wall index. Lower index levels were derived by converting selected wall elements into column elements while preserving plan symmetry and avoiding torsional irregularities. Walls removed in this process were typically located at the edges or non-central axes to ensure that the rigidity center and the integrity of the elevator and staircase core walls remained unchanged. In this way, all generated buildings had identical floor plans and structural systems, and the only variable was the wall index. This methodology enabled direct comparisons of seismic response under different index values without the influence of plan irregularities. A total of 135 structural analyses were performed using ETABS in accordance with the Turkish Building Earthquake Code (TBEC, 2018). Three local soil classes were considered separately: ZC, representing very dense soil and soft rock with shear wave velocities of 360–760 m/s; ZD, representing stiff soil with velocities of 180–360 m/s; and ZE, representing soft soil with velocities below 180 m/s. Seismic input was determined according to Turkish Seismic Hazard Map (TDTH-2018) using acceleration parameters for short period (Ss) and 1-second period (S1) and elastic design spectrum was generated in compliance with TBEC,2018. Elastic design spectrums were generated for each soil class using TDTH-2018 parameters corresponding to a DD-2 earthquake level with a 475-year return period. Due to variations in dynamic properties among the models, Response Spectrum Analysis (RSA) was applied in all cases as prescribed by the TBEC,2018. The results of 135 analyses were evaluated in terms of key seismic demand parameters, including base shear, story displacements, inter-story drift ratios, and demand-to-capacity (D/C) ratios of shear walls. Based on these comparisons, the effectiveness of optimal shear wall index values was thoroughly assessed with respect to both story height and soil class. The analyses indicated that seismic forces were lowest in ZC soil, followed by ZD and ZE soils. In low-rise buildings, increasing total shear wall area could lead to higher seismic forces, raising base shear values by up to 6% of building weight. This finding suggests that lower wall indices may be preferable for low-rise buildings across all soil classes. Period and base shear evaluations further showed that simply increasing total wall area is not optimal. Instead, approximately equal wall indices in both directions provided more effective results by reducing capacity deficiencies. Comparisons of base shear with story height revealed that in ZC soils, the same wall index values could be used elastically across different heights, while in ZE soils, the wall index should be increased with height to prevent capacity shortages, with values of about 2% recommended for buildings between 7 and 12 stories. Demand-to-capacity analyses demonstrated that approximately equal shear wall indices in both directions are critical for avoiding overstress in shear walls. For four-story buildings, indices of 0.8–1.0% in ZC, 1.2% in ZD, and 1.5% in ZE were sufficient. For five to seven stories, balanced indices of 1.0% (5–6 stories) and 1.2% (7 stories) in ZC, increasing from 1.2% to 1.5% in ZD, and about 2.0% in ZE for seven stories were effective. For mid- to high-rise buildings with seven to twelve stories, indices of up to 1.5% in ZC, 1.5–2.0% in ZD, and 2.0% or greater in ZE ensured adequate capacity. Overall, the results highlight the importance of designing shear walls not only based on total wall area but also by ensuring balanced distribution in both directions and tailoring index values to soil conditions and building height. These findings provide practical insights for optimizing wall indices in reinforced concrete buildings to enhance seismic safety in high seismicity regions.

Keywords: Buildings, Earthquake Resistant Structures, Reinforced Concrete, Shear Wall Index
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REFERENCES

ACI 318-19 (2019). Building Code Requirements for Structural Concrete and Commentary. American Concrete Institute.

Çömlekoğlu, H. G. (2009). Effect of shear walls on the behaviour of the reinforced concrete buildings under earthquake loading. Middle East University, Ankara.

Ersoy, U. (1999). Effect of Architectural and Structural System on Earthquake Resistant of Buildings. Mesa, Ankara.

Fintel, M. (1991). Shearwall- An Answer for Seismic Resistance?, Concrete International, Vol. 13, (pp 48-53).

Fintel, M. (1995). Performance of Buildings with Shearwalls in Earthquakes of The Last Thirty Years, PCI Journal, (pp 62-80).

Günel, M. & Ilgin, H. E. (2014). Tall Buildings Structural Systems and Aerodynamic Form. Routledge, New York.

Moehle, J. (2015). Seismic Desing of Reinforced Concrete Buildings. McGraw-Hill Education, USA.

Wallece, J. W. (1994). A New Methodology for Seismic Desing of Reinforced Concrete Shearwalls, Journal of Structural Engineering, ASCE, Vol. 120 (pp 863-884).