Rocking Shear Wall Foundations in Regions of Moderate Seismicity

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Summary

This paper presents an investigation to reduce the size of shear wall foundations for earthquake forces in region of moderate seismicity. The approach taken is to allow rocking of the shear wall foundation and to include the frame action of the structure to assist as lateral force resisting system. An initial feasibility study is presented where the shear wall foundation and the structural frame are theoretically modelled as a single degree of freedom system, subjected to base accelerations from recorded ground motions. An example building is studied with the shear wall foundation designed for 40%, 60%, 80% and 100% of the design overturning moment from the seismic event. Time history analyses are performed with input from five earthquakes. It is shown that the concept is feasible and the next phase will consist of improved modelling to allow for distribution of mass over the height of the structure as well as shear wall stiffness.

Keywords: Seismic design, time history, shear wall, foundations, structural frame, moderate seismicity

1. Introduction

Reinforced concrete structures consisting of flat slabs and gravity loaded columns are often designed with reinforced concrete shear walls to resist the lateral loads which can be either wind or seismic loads.

In regions of moderate seismic intensity it has been shown that by designing the shear walls with a plastic hinge zone at the lower part of the wall a suitable structural system is created where slabs and columns are designed for gravity loads and shear walls for lateral loads. The behaviour of slabs and columns are then also verified against lateral drift criteria and possible punching shear at slab-column connections.

The assumption of a plastic hinge zone in the lower shear wall region implies that the wall is provided with a suitably stiff foundation with limited rotation and which remains linear elastic under extreme lateral loads on the upper structure. This often results in very large shear wall foundations.

This paper investigates a concept which can potentially result in reduced foundation sizes for shear wall foundations in regions of moderate seismicity. The concept consists of a rocking shear wall foundation that works together with the flat slab and column frame action to resist the seismic loads on the structure. As a first step in the evaluation the structure is modelled as a single degree of freedom system to determine the feasibility of the concept. This first step is described in this paper.

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2. Literature review

The concept of rocking foundations has been investigated before. Anderson [7] confirmed that the concept of rocking foundations can reduce the size of foundations considerably. In the current study the contribution of the structural frame is also considered, an effect not included in the study by Anderson.

3. Investigation

A typical eight storey office building with 250mm flat slab, 600x600 columns on a column grid of 6m x 6m was chosen for the investigation. Soil was assumed to be stiff with an allowable safe bearing pressure of 750 kPa. The shear wall foundation size was obtained after designing a typical shear wall using the lateral static force procedure for an earthquake with a nominal peak ground acceleration of 0.12g. A behaviour factor (ductility factor) of 5 was used for the shear wall according to the SANS 10160 [8]. The foundation size was based on over strength forces resulting from the shear wall design.

As a first step in the study, the shear wall is considered to be rigid. A single degree of freedom system where the stiffness of the foundation and the stiffness of the frame are combined (refer to Figure 1). The participating mass is chosen to be 60 to 70% of the structural mass, representing the mass of the structure associated with the fundament eigen frequency.

The foundation stiffness is obtained using the static moment-rotation response of the uplift-yield condition of rigid bases as described by Allotey and Naggar [2]. Foundation sizes were determined by assuming respectively 40%, 60%, 80% and 100% of the static design seismic moment. For the structural frame the elastic plastic force displacement curve was obtained from a push-over curve of the frame.

Material non-linear time history analyses were performed to obtain the response of the single degree of freedom system with 5% structural damping. Five ground motion time histories scaled to a peak ground acceleration of 0.125g were used in the analyses

3. Results and conclusions

As can be expected the results show a general increase of foundation rotations with reduced foundation size. The rotations are however in general less than rotation limits and the concept of rocking foundations is shown to be feasible for flat slab structures.

A further step in the investigation will be to improve the simple single degree of freedom system to also incorporate the stiffness of the shear wall and to provide a better distribution of mass over the height of the structure. The effect of increased shear force at slab column connections will have to be studied. Further investigations then need to include buildings of different heights and sizes.

The studied concept can potentially reduce shear wall foundation sizes and will contribute to a more efficient use of materials with less impact on the environment.

4. References

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[2] ALLOTEY N. AND NAGGAR M.H.E., “Analytical moment–rotation curves for rigid foundations based on a Winkler model”, *Soil Dynamics and Earthquake Engineering,* Vol. 23 (2003), pp 367–381