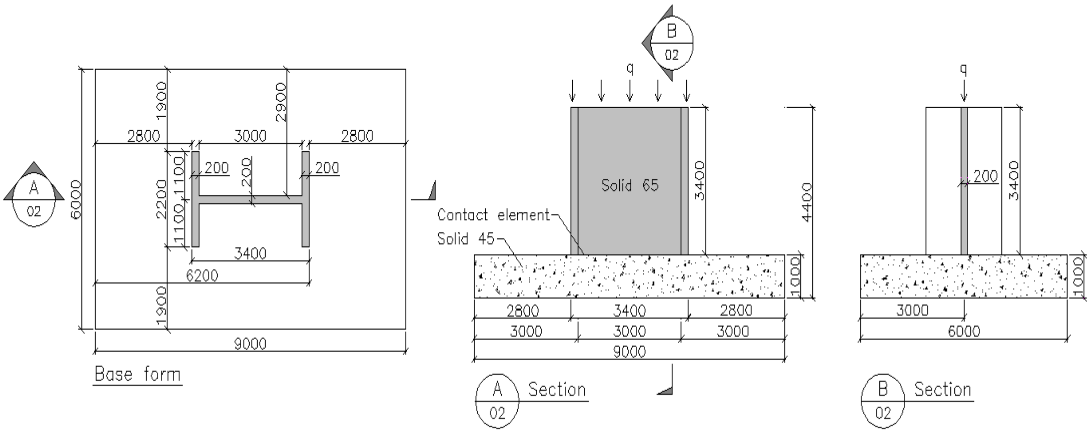
Seismic action on low-rise concrete shear wall buildings on flexible foundation

The objective of this project is to develop a robust efficient and reliable simplified method for the structural design of low- to medium-rise concrete shear wall buildings in earthquake prone areas and thereby to improve the current state-of-the-art in structural design for earthquake action. The main focus is on strong-motion prediction models, emphasising response of concrete structures on soil foundation, including “the Icelandic gravel cushion foundation”.

The current engineering design practice in Europe, as well as seismic hazard analysis procedure, is either based on, or is aiming towards, application of Eurocode 8 (EC8). The most widely applied analysis technique for low- to medium-rise buildings within the framework of EC8 is based on the so-called earthquake response spectrum method applying invariant spectral shape (for a prescribed site condition) that is scaled using site-specific peak ground acceleration (PGA) and structural behaviour factor (or force reduction factor) reflecting the target damage level assumed by the designer. The response spectra obtained in this way according to the EC8 provisions are supposed to conform to uniform hazard spectra commonly representing a 475 year mean return period for residential buildings.

Application of the PGA’s scaled response spectrum method assumes that the structure is fixed to the ground. Hence, the engineering modelling based on this method does not account for rocking and sliding degrees-of-freedom for prediction of the structural behaviour. In other words, the structural model can not rock or slide on the contact surface between the ground and the basement and hence the computational model can not predict the observed structural behaviour with reasonable engineering accuracy. Currently there exists no robust reliable simple method to account for this type of soil-structure interaction (SSI) of low- to medium-rise reinforced concrete shear wall buildings. The practical implications are that SSI is most commonly simply neglected. The SSI has, however, some notable impact on the behaviour of buildings with reinforces concrete structural walls as the load carrying elements. Experience reveals that displacements at the ground level are increased and relative displacements at the top reduced, resulting in reduction of tensional forces in the longitude reinforcement as well as decrease in shear force at the bottom of the structural walls. Furthermore, the inertia effects governing the forces acting on building content is reduced, which leads to damage reduction and increases the safety of people in the buildings during the passage of earthquake events. Therefore, it is essential to be able to account rationally and reliably for SSI in the structural design and analysis of buildings where the load carrying elements consists of reinforced structural walls.



A generic test model represented by a concrete shear wall embedded on gravel cushion foundation. Dimensions are only indicative.

In earthquake engineering design the SSI-effects are generally ignored to simplify analysis and speed up calculations to deliver quickly solutions for static load cases and design combinations. For such analysis, fixed basement approach is usually judge to be acceptable. However, the fixed-ground analysis does not depict the actual earthquake behaviour of the structure. The seismic response of soils is highly complex and depends on a wide range of factors, many of which are not properly represented by current engineering practice.

The typical Icelandic dwelling is a low-rise reinforced concrete shear wall building, cast-in-situ and founded on a gravel cushion or directly on a stiff, rock-type, layer that may rest on other soft or stiff layers of different soil or rock material characteristics. This structural tradition is also applied to industrial buildings and structures that are a part of the infrastructure life-line system. Experience has revealed that buildings of this type resisted the severe South Iceland earthquakes in 2000 and 2008 surprisingly well and often without visible damage. This is notable due to the fact that these buildings, as a rule, do not conform to current Icelandic building code provisions regarding reinforcement detailing.

Another issue to be addressed is effect of the lava-sediment layered structure, commonly found Iceland, on the building response. Layered geological structures will be dealt with, where the Holocene top lava typically rests on alluvial sediments covering the post-glacial bed rock. The soil-structure interaction will be treated in generic physical and numeric building models by applying earthquake simulator (shaking table) and finite element techniques.

The uncertainty in the prediction process will be treated in detail by establishing strong-motion prediction models including all basic variables needed to realistically describe the selected predictor variables, e.g. base shear, overturning moment, tension in characteristic re-bar etc, in a particular generic building model. By this approach we intend to avoid accumulation of uncertainty commonly observed in multi-step modelling.