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Earthquake induced response and soil-structure interaction effects

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Objective

Earthquake induced acceleration data has been systematically collected in the Town Hall of Selfoss, Island, over a ten year period. The objective is to analyze and compare the seismic behavior of the Town Hall during two large earthquake events that occurred in the vicinity of the building on June 21, 2000 and May 29, 2008, with magnitude of 6.5 and 6.3 respectively. Preliminary analysis's of the recorded seismic response indicated a considerable difference in the behavior between the two events, in particular the dynamic response of the structure was observed to occur at different frequencies.

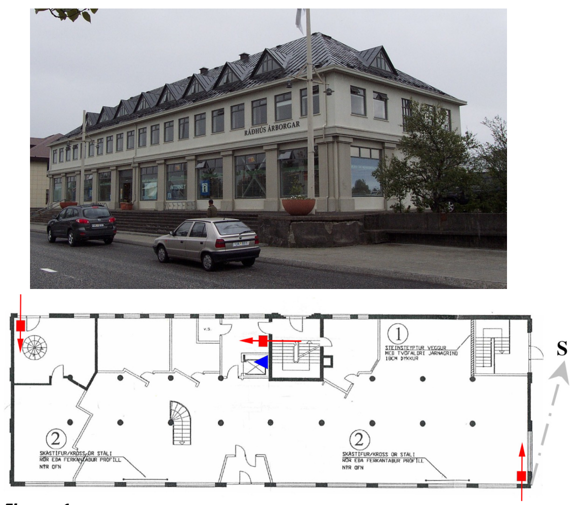

Figure 1

A photo showing the north side of the building. and a drawing showing the location and orientation of accelerometers.

Modelling of the Structural System

In an effort to explain the observed variation in the structural behavior, a finite element model [1] was created of the structure and the ground beneath. The ground in the vicinity of the building is expected to consist of three different soil and rock layers. The top layer (~7m) consists of extrusive rock, the second layer (~7m) is made of scoria. The bottom layer (~2m), on top of the bedrock, consists of sedimentary materials. The behavior of the different ground layers needs to be included and understood in order to be able to explain the response from the two recorded earthquakes in 2000 and 2008. Especially, it is important to include the effects of the bottom soft sedimentary layer. When subjected to an earthquake, the material properties will change in terms of shear strength and damping as a function of the intensity of the excitation. Thus, it is difficult to model the soil/rock layers with a linear model. However, this has been done for demonstration purposes by directly incorporating the varying strain effects as evaluated by the EERA program [2]. This procedure does not give a perfect match to the recorded response, but it provides a good indication how the soil-structure interaction affects the earthquake response characteristic and the structural behavior.

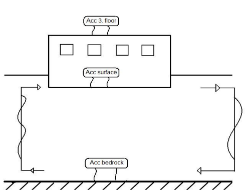

Figure 2

A schematic drawing of the system. The recorded basement accelerations are converted to bedrock accelerations. These are then used as input acceleration on the bedrock to recreate the response at the basement and at the third floor of the building..

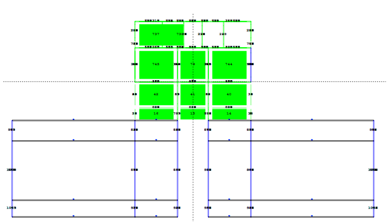

Figure 3

A side view of the finite element model with the blue spring elements representing the ground.

Soil Structure Interaction

The applied models have recreated a response similar to the response recorded in the Town Hall of Selfoss. It shows that the amount of strains in the sedimentary layer to a large degree controls the frequencies of response. The response spectra obtained, indicates that the large damping and excitation frequency shift created by the sedimentary layer reduces the amplitudes of the ground acceleration at higher frequencies. This has most likely been beneficial for the earthquake response of the building during the large 2008 event.

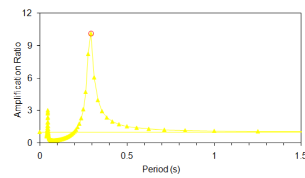

Figure 4

A typical amplification due to soil interaction. The amplification frequencies are reflected in the response spectra below.

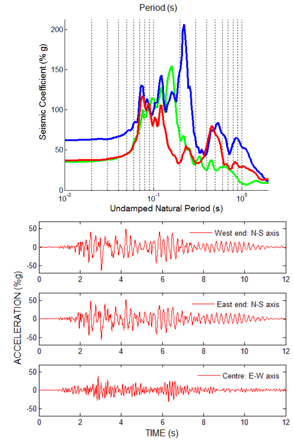

Figure 5

Calculated acceleration using the model.
Above: Ground floor response spectra
Below: Third floor relative response

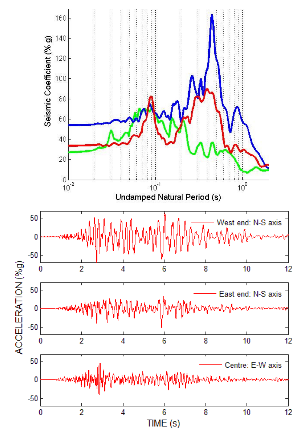

Figure 6

Recorded acceleration data.
Above: Ground floor response spectra
Below: Third floor relative response

Inelastic analysis

Inelastic analysis indicate that 39 members experienced post-yield behavior during the earthquake in 2008. The highest ductility demand occurs in the first floor columns, with a ductility ratio above 6. A structure of this type and age would be likely to suffer considerable damage at ductility levels above 3 to 4. Thus, the inelastic model seems to overestimate the inelastic behavior. Nevertheless, the model gives an indication of where to expect yielding. It is likely that a considerable part of the plastic capacity was utilized during the earthquake in 2008.

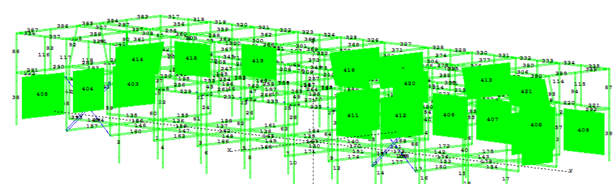

Figure 7

The element mesh of the model and used for the inelastic analysis.

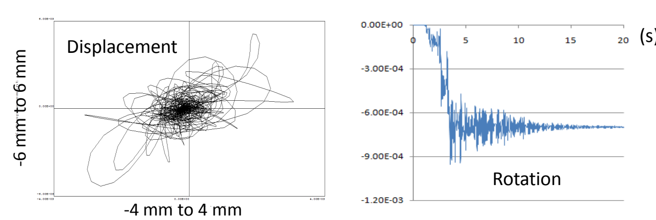

Figure 8

Calculated relative displacement and the rotation at the top of a first floor north side column, during the earthquake in 2008.

References

Carr, 2009, Ruaumoko3D - Inelastic Dynamic Analysis, Univ. of Canterbury, (2009)
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