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SECTION DE GÉNIE CIVIL

Seismic assessment of an existing masonry building: Collège de Cojonnex

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Introduction and work description

Context of the project:

- Switzerland is an earthquake-prone location;
- Masonry is know to have unfavourable behaviour under seismic actions;
- Many buildings in Switzerland are constructed in masonry.

Chosen building for this project: Collège de Cojonnex (Blonay).

Goals:

- Model the chosen building using the Equivalent Frame Model (EFM);
- Perform a sensitivity analysis of the different parameters of the masonry to find the most influential parameters on the behaviour of the building;
- Assess the behaviour of the school building of Cojonnex under a level design earthquake using the EFM and hand calculations of the SIA D 0237.

Building description and seismic hazard

The Cojonnex school building (Figure 1) was constructed in 1924. It consists of stone masonry walls with reinforced concrete TT-slabs. These slabs were destroyed and rebuilt during the 1991 renovation. Many shear cracks were observed at the supports of these slabs and the safety of the building was compromised.

Regarding the values of the parameters of the masonry, they are not known, only the mean resistance of the stones composing the walls is known at $160\,MPa$. All the values of the parameters such as the Young's modulus and shear modulus of masonry are estimated for this project based on the Swiss codes or the literature.

Regarding the seismic hazard at the location of the building, the elastic design spectrum for the expected earthquake with a return period of 475 years of the Swiss code 261 is shown in Figure 2.

Figure 1: Exterior view of the building.

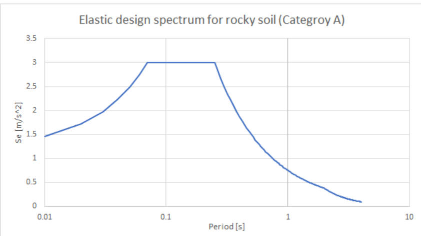

Figure 2: Elastic design spectrum according to the SIA 261.

Equivalent Frame Method (EFM)

The Equivalent Frame Method is a type of modelling that uses macro-elements to represent the elements of the structure. This is at the opposite of the Finite Element Methods.

For the EFM, the walls needs to be discretised in two different zones:

- Deformable zones: where the deformations can occur. These zones are further divided in two different elements:
  - Piers: vertical elements between openings (in red in Figure 4)
  - Spandrels: horizontal elements between openings (in green in Figure 4)
- Rigid zones: where no deformations occur (in light blue in Figure 4)

An example of on wall of the building and its associated discretisation is shown in Figures 3 and 4.

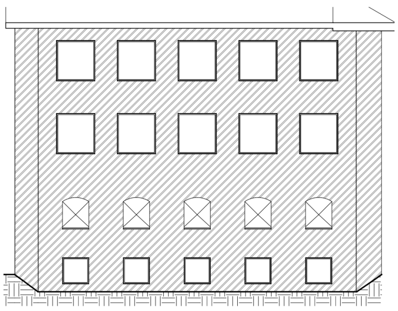

Figure 3: One wall of the Cojonnex school building.

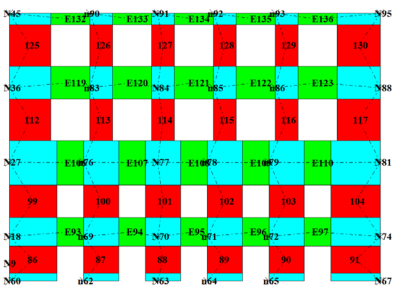

Figure 4: Associated discretisation of the wall of Figure 3.

Sensitivity analysis

For the sensitivity analysis, three results are analysed when changing one parameter:

- The eigenperiods of the building;
- The maximum out-of-plane displacement;
- The drifts of the elements in the building.

The results regarding the importance of each parameter are as shown in Table 1. Red means strong influence, orange is moderate, yellow is low and green in negligible to no influence.

		Influence on:			
		Periods	OOP displ.	Shear drifts	Flexural drifts
Parameters	E				
	G				
	fc				
	Gc				
	mu				
	muR				
	c				
	Damping	NA			
	E slab				
	Bending-r. slabs				
	Direction EQ	NA			
	Vertical solicitations	NA			

Table 1: Results for the importance of each parameter.

So, overall the most influential parameters on the results are the Young's modulus of masonry, the shear modulus of masonry, the damping and the type of slabs. These four parameters are thus the most important one to know when conducting a seismic assessment of a building as they have the affect significantly the global behaviour of the building.

Seismic assessment of the Cojonnex school building

The seismic assessment is done with the model under a chosen earthquake that matches the elastic design spectrum and the results obtained are compared with the hand calculations of the SIA D 0237.

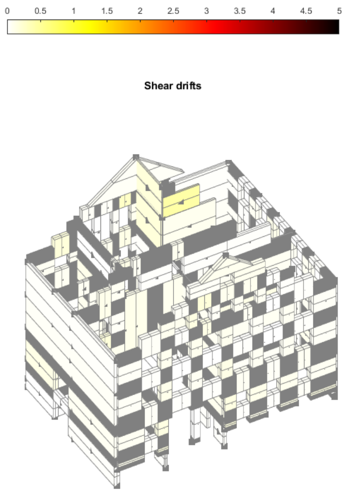

Figure 5: Results of the model for the maximum drifts in the building.

Shear in the concrete slab	α=	1.21
Out-of-plane failure	α=	2.5
In-plane displacements in X-direction	α=	27.1
In-plane displacements in Y-direction	α=	20.6
In-plane displacements in X-direction with torsion	α=	23.6
In-plane displacements in Y-direction with torsion	α=	19.9

Table 2: Results of the verifications of the hand calculations

Both the EFM and the hand calculations are in agreement in regards of the behaviour of the building as they both support the fact that the building is able to withstand the level design earthquake without failing. Figure 5 shows the maximum drifts of elements after the dynamic analysis and the Table 2 shows the verifications performed for the hand calculations.

Conclusions

Sensitivity analysis of the parameters:

- The most influential parameters were:
  - The Young's modulus of masonry.
  - The Shear modulus of masonry.
  - The damping.
  - The type of slabs (bending-resistant or not).

Seismic assessment of the building:

- The building is able to withstand the level design earthquake.
- The hand calculations give a relatively good approximation of the results.