COMPUTER MODELING OF THE JOINTS FOR WGP CONSTRUCTION SYSTEM

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1 INTRODUCTION

Most of prefabricated concrete buildings made for example under "Wroclaw Great Plate" construction system (for short WGP), however very popular in Lower Silesia, were built in the '60-ties and '70-ties of XX century. Until now a lot of them have not been renovated, therefore their technical state, in many situations, is very poor or almost pre-failure.

Poland is not situated in any seismic region of the earth, however there are still areas were underground mining is being conducted. In these areas, phenomena so-called 'paraseismic tremors', are very frequent. In the situation when a building examination is realized in order to define its safety, it is necessary to make a complete analysis, in which an influence of tremors should be included.

To decide if a building is able to carry out any dynamic loads or not, it is necessary to compute its dynamic characteristics, i.e. natural frequencies. It is not possible using any standard techniques. After diagnosis a building *in situ* by an expert, computer techniques together with specialized software for dynamic, static, and strength analyses become a suitable tool.

In this paper a special attention was paid to a typical twelve-store, WGP prefabricated building, concerning horizontal joints. During dynamic actions these joints have a decisive influence on building's behavior. Paraseismic tremors are especially dangerous for this type of buildings and can be the reason of pre-failure states. It can be difficult and very expensive to prepare laboratory investigations of the part of the building or of a separate joint; therefore a computer modeling to investigate behavior of such elements and whole buildings under different kinds of loads was used.

2 DESCRIPTION OF FEM JOINT MODEL

2.1 Primary model

Primary joint model was geometrically identical with typical horizontal joint used in prefabricated building system. In this joint, shown in Figure 1, there are four different elements: 1 – slab (ceiling) plate, 2 – wall (upper and bottom) plates, 3 – joint fulfillment concrete, 4 – cement mortar.

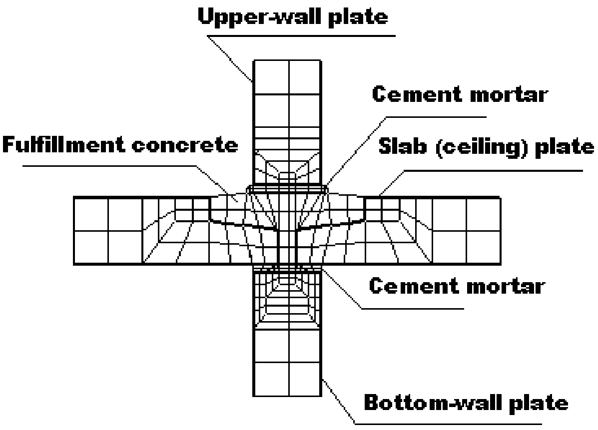


Fig. 1. Primary FEM model of the connection

All elements were divided with finite elements net and received nonlinear material characteristics according to [1], [2] and [3]. QPM8 3D elements with 8 nodes were applied as finite elements. Nonlinear analysis was carried out using built-in *LUSAS FEM System* multi-crack concrete Jefferson model [4]. Figures 2 and 3 shows results of the nonlinear analysis. It appears that failure mechanism starts in the middle of the joint.

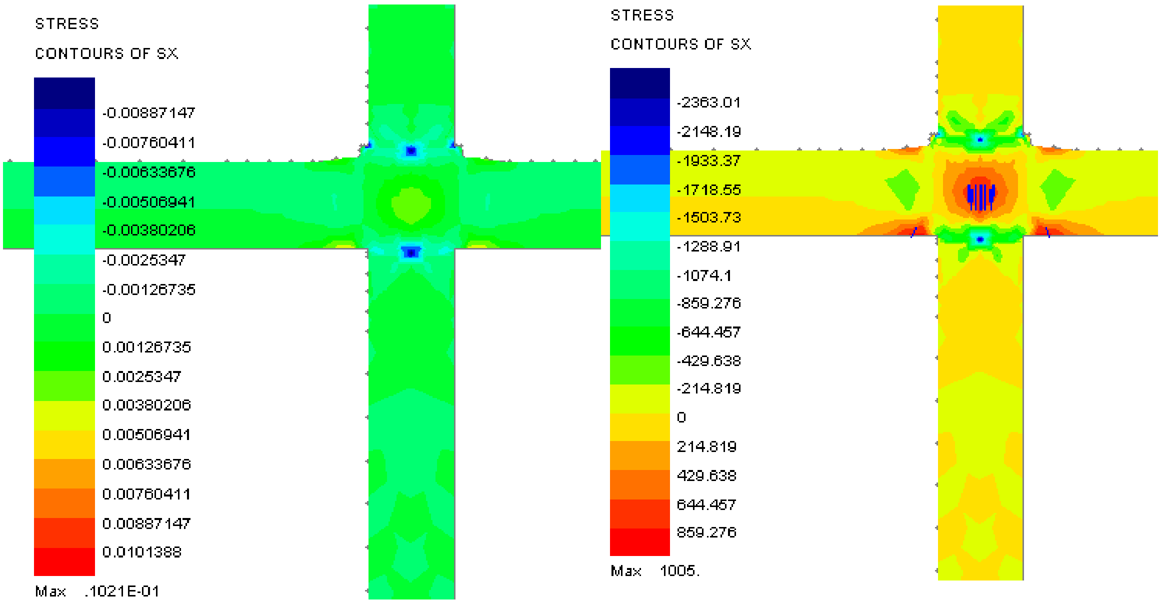


Fig. 2. Primary model – results of σ_x stresses – beginning phase

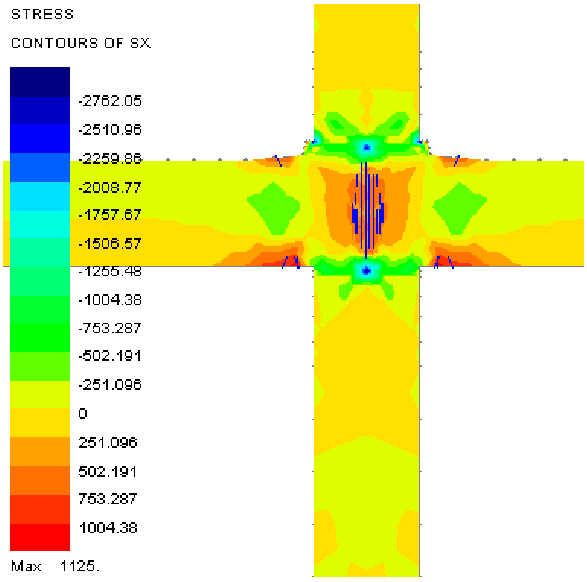


Fig. 3. Primary model – results of σ_x stresses – failure phase

2.2 Substitute model

Because of its complicated form, such a primary model is useless during large-models analysis. Therefore, a substitute (supplementary and more simplified) model, shown in Figure 4, was allowed. This new model was built with finite element called *JOINT*, which contains transitional and rotational springs. All *JOINT* characteristics – springs' stiffness, were calculated according to the primary model. Such element is suitable for static and dynamic when substitutes part of horizontal joint. An example of using substitute model is shown in Figure 5.

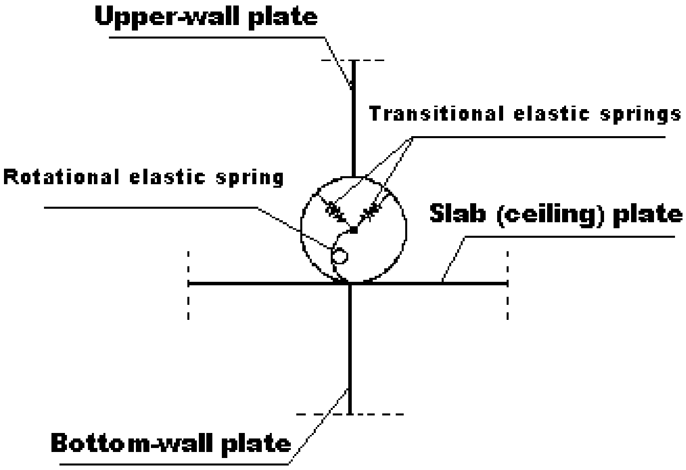


Fig. 4. Substitute model

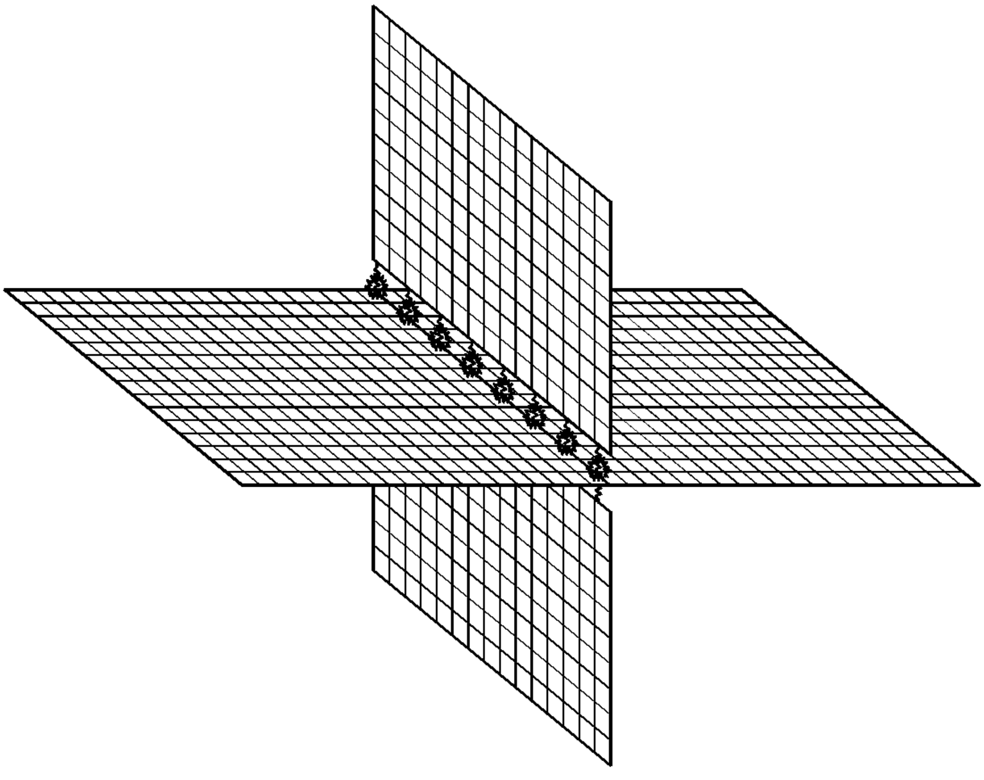


Fig. 5. FEM model of a horizontal joint

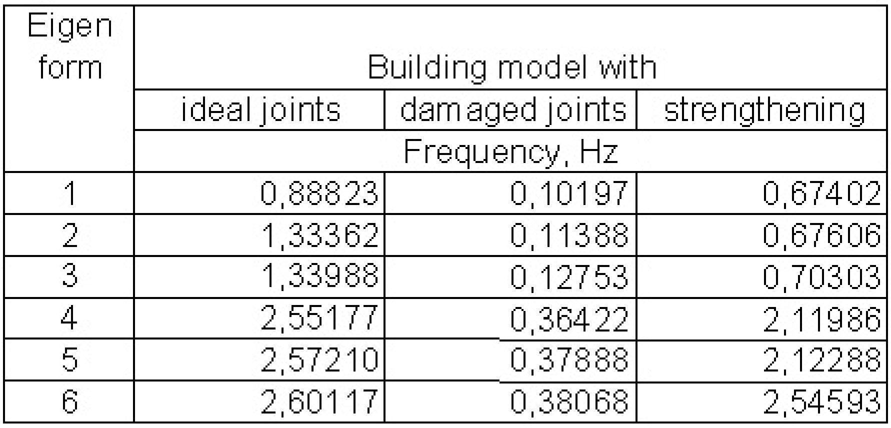
Now changing the stiffness of each spring it is possible to simulate different states of the whole horizontal joint – connection of wall and slab elements – from monolith to hinge with possibility of sliding which was a good approximation of damaged elements in real prefabricated building. Many analyses were carried out considering cracks and stresses distribution in horizontal joint. But the main subject was how these damaged joints effect on dynamic characteristics of the whole building before and after strengthening.

3 DYNAMIC CALCULATIONS

3.1 Natural frequency results

After preparing three main building models: 1st – with ideal horizontal joints, 2nd – with degenerated horizontal joints and 3rd – strengthened construction, natural frequency analysis was carried out. It appeared that natural frequencies values of the building with degenerated (damaged) horizontal joints are much lower then for two others buildings. Table 1 shows a comparison of calculated natural frequencies results for all three building models.

Table 1 Comparison of natural frequency values



Eigen form	Building model with		
	ideal joints	damaged joints	strengthening
	Frequency, Hz		
1	0,88823	0,10197	0,67402
2	1,33362	0,11388	0,67606
3	1,33988	0,12753	0,70303
4	2,55177	0,36422	2,11986
5	2,57210	0,37888	2,12288
6	2,60117	0,38068	2,54593

To diagnose the dynamic state of the building one can calculate a global damage coefficient δ_M developed in [5] and [6], described by Eq.1:

$$\delta_M = 1 - T_0/T_M \qquad (1)$$

where: T_0 – first natural period of an ideal building, T_M – first natural period of a building with strengthening or damaged joints.

Corresponding values of δ_M are: for the 2nd building 0,885 and the 3rd building 0,241. It shows the global change of dynamic characteristics comparing with an ideal building.

In Table 1 it is shown that without a technical expertise of the structure state it is not possible to define properly dynamic characteristics of a building.

3.2 Spectral response analysis and results

Natural analysis is the first step in diagnosing of the building structures under paraseismic loads. Following, it is necessary to prepare adequate dynamic loads. *LUSAS FEM System* uses spectral response method, so an accelerometer read-out is needed to determine a spectral curve.

In Figure 6 an example of a read-out from an accelerometer is shown. X-axis shows time of the quake in *sec* and Y-axis amplitude of acceleration in *m/sec*^{2}.

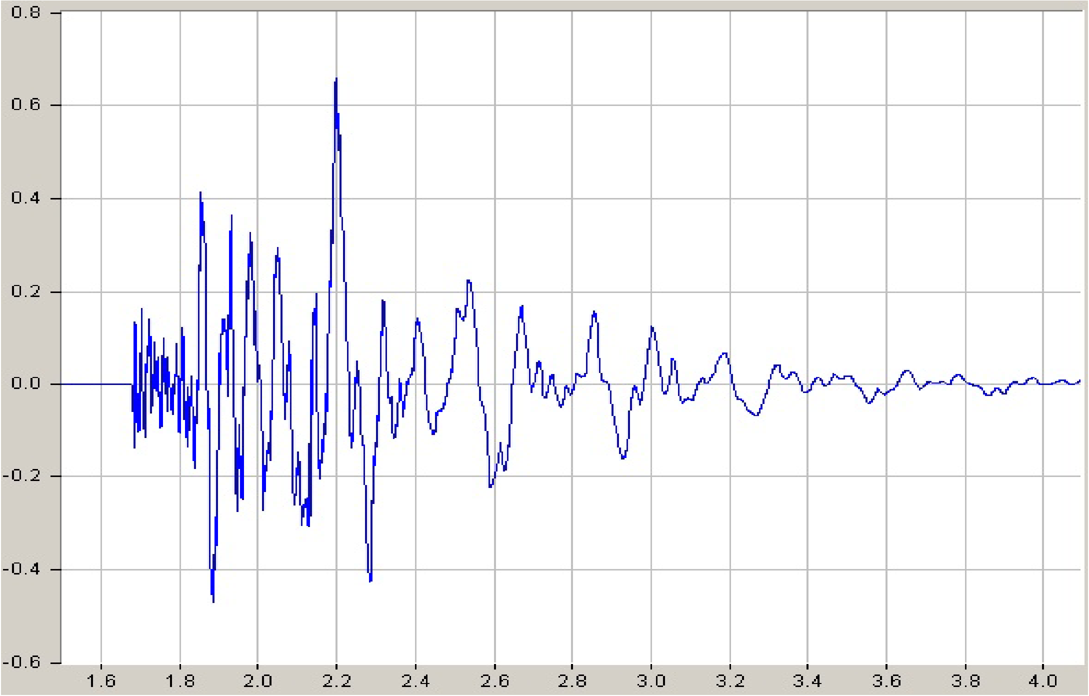


Fig. 6. Accelerometer read-out

In Figure 7 a spectral curve calculated from Figure 6 is shown. X-axis shows frequency in *Hz* and Y-axis amplitude of acceleration in *m/sec*^{2}.

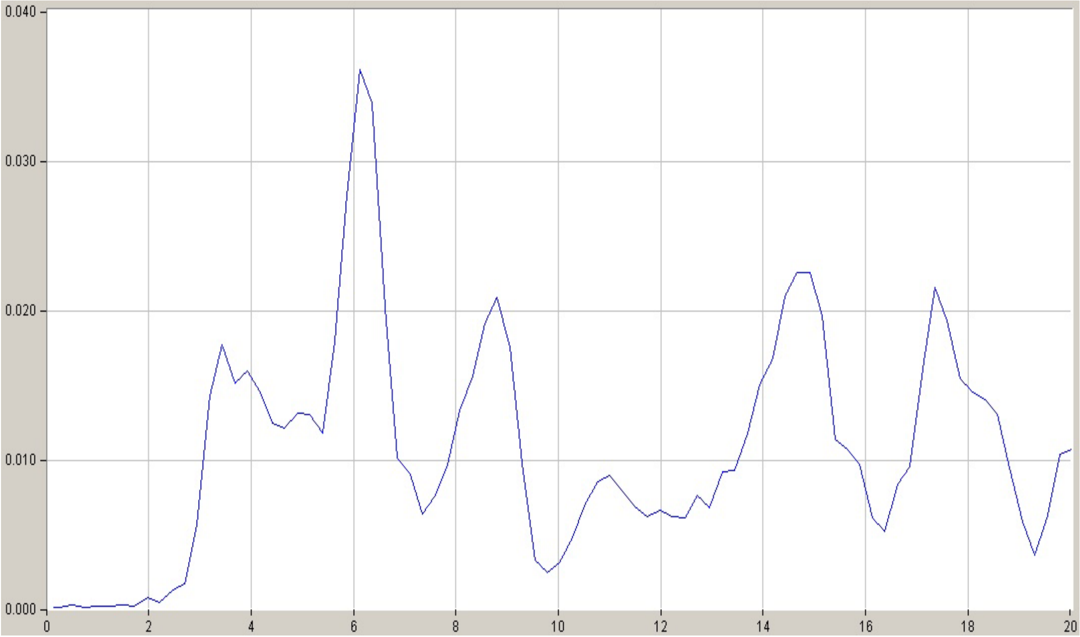


Fig. 7. Spectral curve

This spectral curve entered into *LUSAS FEM System* accordingly, let's load the structure with a cinematic forcing. System uses the CQC (Complied Quadratic Combination) method to calculate the building response. It is possible to see response animation and read which eigen form is a dominated one. Comparing displacements and stresses in characteristic nodes for different structures (meaning with different state of joints) it is possible to diagnose which building is more flexible on such a quake and also to define if the strengthening system is well designed. Table 2 shows displacement results in one node (situated at the top corner of the building) for different paraseismic tremors. Because it is still not decided which parameter is suitable to describe univocally paraseismic quake we used the maximum value of the ground acceleration read from the accelerometer read-out.

Table 2 Comparison of displacements

State of the building structure	Max. value of the acceleration read from an accelerometer read-out in one horizontal direction mm/s^2	Displacement direction		
		horizontal		vertical
		mm		
damaged joints	250	4,5	1,6	8,2
strengthened building		0,6	0,4	0,8
damaged joints	570	201	26,2	16,4
strengthened building		3,2	0,4	0,3
damaged joints	800	64,7	8,4	5,3
strengthened building		1,1	0,2	0,1

As it is shown in Table 2 a tremor with smaller value of acceleration can evoke bigger displacements.

4 CONCLUSIONS

Response of the building structure not only depends on the maximal value of ground acceleration but also on the frequency corresponding to these acceleration and natural frequencies of the structure. To diagnose properly if a tremor is dangerous for a building we have to know all the parameters of a structure and also all the parameters of a tremor. If paraseismic tremors occur often they may lead to slow degradation of the so called "weak places" in building structures, especially when it is made from prefabricated concrete and has mixed cement mortar and steel bar joints.

The numerical model of such a structural joint of elements in prefabricated building was developed. Along with structure technical state diagnosis, this model was used to define the real structural response to a paraseismic tremor. This research was made in order to check properly of structural safety of buildings situated in areas with underground mine exploitation.

In diagnosing (defining building behavior and its respond to a tremor) and designing complex structures it is necessary to use computers and specialized software.

Finally, computer modeling is useful when we want to check if the proposed strengthening system for the building is able to carry out all the loads, especially paraseismic tremors.

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