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Project title:

STATIC AND DYNAMIC TESTING OF METAL BUILDING CONSTRUCTION IN EARTHQUAKE CONDITIONS WITH SERVO-HYDRAULIC MACHINE FOR STATIC AND DYNAMIC MATERIAL TESTING ZWICK Roell HB-250

Abstract: Testing of metal building constructions and their behavior in simulated earthquake conditions is very complex. It requires to take into account a great number of parameters and its results are needed to be as precise as possible regarding to the behavior of the structure in real earthquake conditions. This research presents a dynamic mechanical testing of window alternative construction panel in a protected historic building in earthquake condition. By changing the design of window panels, the rigidity and resistance to seismic shifts has been increased. This multidisciplinary problem was realized by cooperation of faculties of Mechanical Engineering, Architecture and Civil Engineering at the University of Belgrade.

1. Background

The Balkan Peninsula has a very complex tectonic feature. Seismic activity leads to consecutive devastating earthquakes in the region, which, as a result of traditional construction methods, destroy entire villages and lead to the loss of many lives. The region has an average of 6.3 earthquakes every year [1, 2]. According to the data of the Seismological Institute of Serbia, it is stated that our region is in the zone of moderate seismic activity - the strongest earthquakes can have magnitudes of 5.7 to 5.9 units in Richter scale or magnitudes on the surface up to 8 degrees of Merkali scale. Considering the affected area in general, they generally cannot cause total demolition of buildings but, eventually, render them unusable for life.

Having in mind, that almost all buildings of historic importance are protected by the law and the fact that they were built by the old construction technique, often without taking into account the integrity of structures in earthquake conditions, special attention should be paid to their reconstruction. The process of repairing and reinforcing such structures is often difficult, as such objects are subject to the Law under the jurisdiction of the local Institute for the Protection of Cultural Monuments of Republic of Serbia, according to which, it is not allowed to change neither the external nor internal appearance, i.e. their architectural and cultural-historical value Fig. 1. This paper presents a solution to increase the stiffness of a building by modifying the metal construction of window panels as a part of large window structures, as well as its mechanical testing in earthquake conditions [3].

Figure 1. Parliament building of Republic of Serbia

2. Introduction

For the purpose of solving multidisciplinary problem of building stiffness increasing, a special window structure was designed [4]. The purpose of the test was to determine whether the designed panel segments can withstand the projected loads and stresses within the permissible deformations, and whether such a structural solution can increase the rigidity and, consequently, the durability of the building under the act of seismic movements caused by an earthquake, taking into account the parameters of possible earthquakes for the area where the facility is located, obtained from the Seismological Institute of Republic of Serbia.

Structural engineers have come up with an innovative solution, tested by computer simulation, to fill the glass panel, embedded in a rubber sleeve, instead of ordinary glass within the existing steal frame (Figure 2) [4]. This fill may be either laminated glass (3×20 mm) or laminated polycarbonate - clirite. So far, neither glass or clirite, as structural materials, in the Republic of Serbia or in the world, haven't been used to receive and amortize seismic forces, with the aim of increasing the stiffness of the structural system.

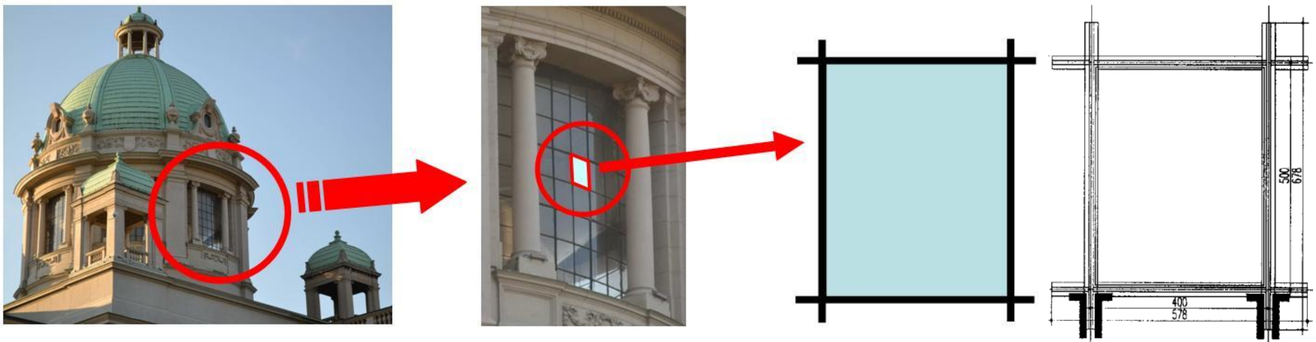


Figure 2. Test object and position of test panels

3. Experiment setup

For the purposes of testing, special attention was paid to design and construct a series of special tools, of high rigidity, which prevented their micro-elastic deformations from affecting the test results, Figure 3.

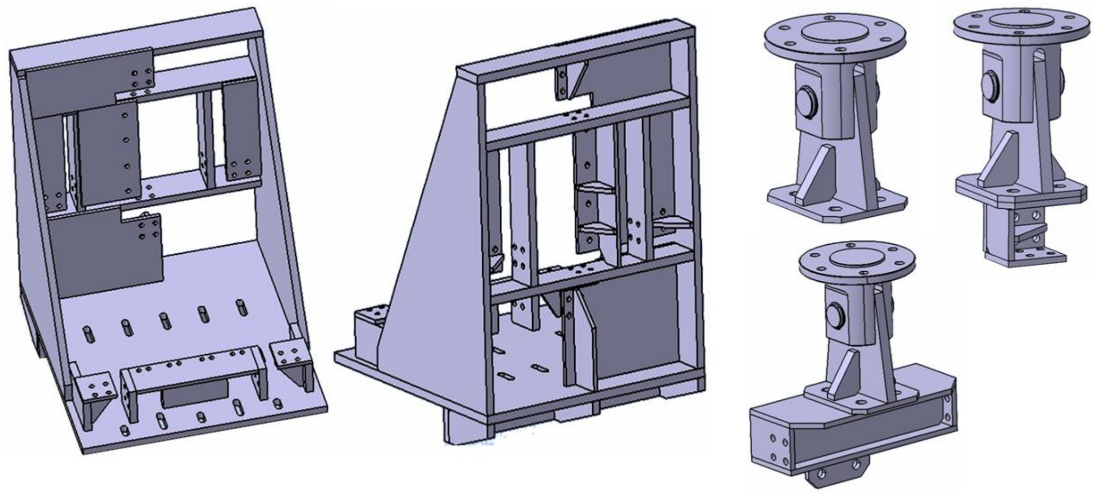


Figure 3. Layout of the main tool and a series of tools with a joint for load introduction

As input parameters for these tests, the data obtained from the calculation were used, which are in accordance with the data obtained from the Republic Seismological Institute and correspond to the parameters of the expected earthquakes, as well as the values of forces acting on the panel due to the influence of the rest of the structure. According to the calculation results, it was decided that the full intensity of the dynamic work force (amplitude) was equal to the nominal load ($F_a=P_r=P_n=33$ kN). Based on the data, adequate load spectrum was formed for each test, which defined the frequency, period and intensity of the expected earthquake, according to the accelerogram of the expected seismic impacts, as well as the duration of the earthquake. Fig. 4. The varied parameters were: values of dynamic forces, number of cycles, load time and type of stress.

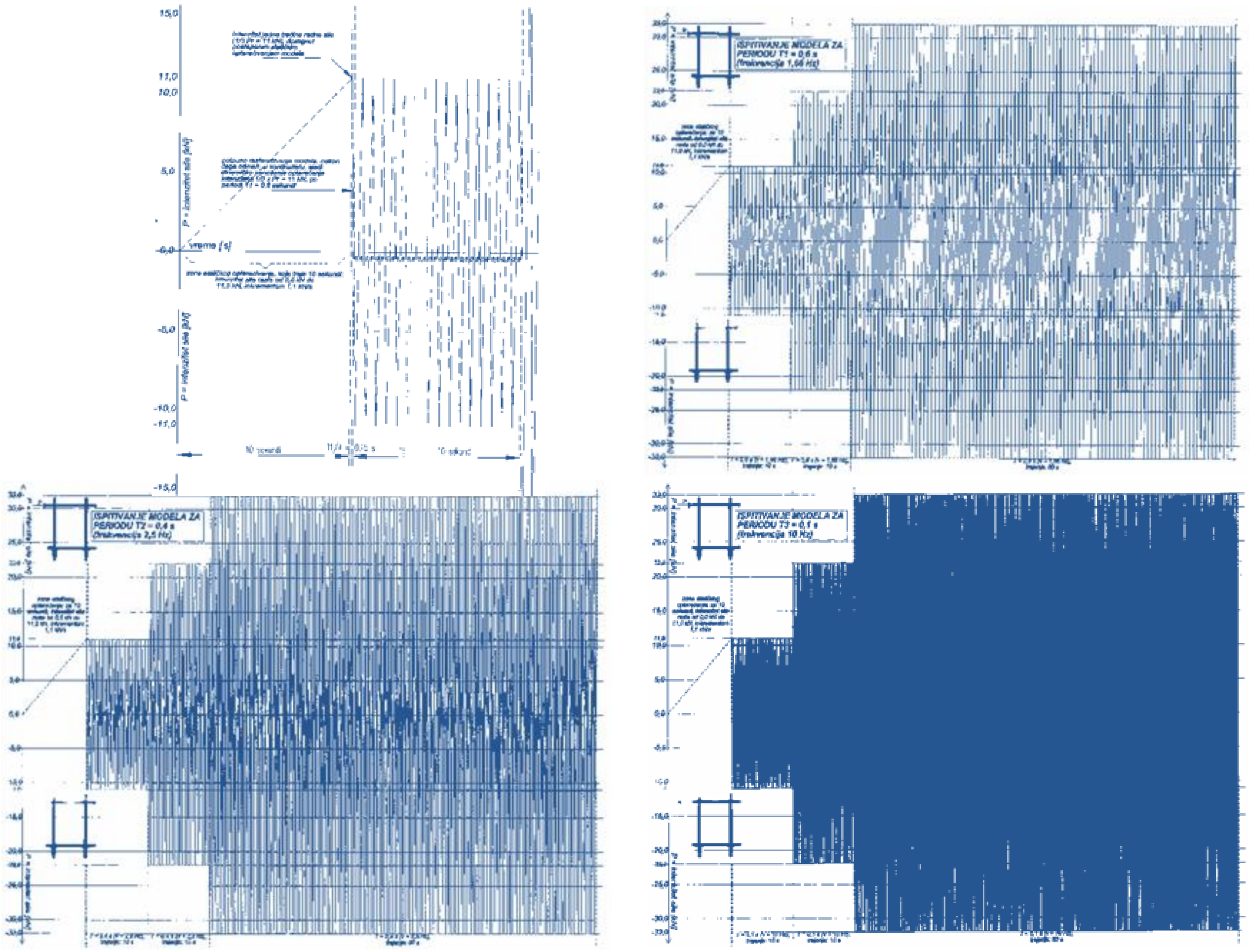


Figure 4. Some of the load spectrums used for panel testing

The experiments were performed on a real model of the basic single structural element, a 40×50cm panel, materialized from a three-layer laminate glass/clirite with a total thickness of 60mm, framed by a steel frame, with a layer of hard rubber between the glass/clirite and steel.

The following static and dynamic tests of test panels were performed:

- Case 1. - Load-side tests in the plane of the panel, Figure 5a;
- Case 2. - Bending tests perpendicular to the plane of the panel, Figure 5b;
- Case 3. - Torsion tests around the axis of the panel, Figure 5c;

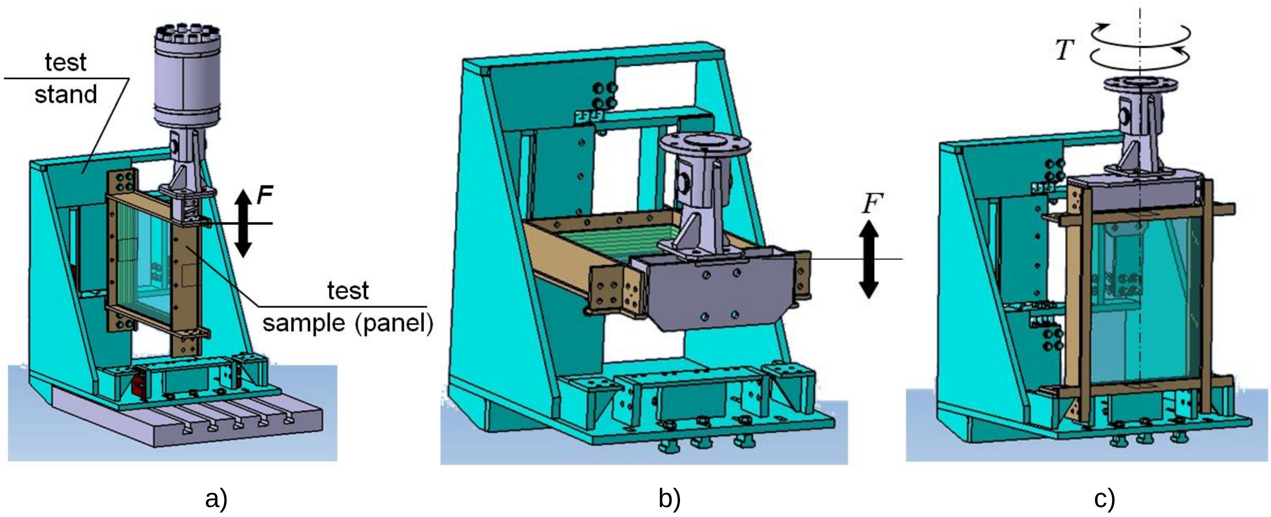


Figure 5. Position of window panel and test stand on the testing machine and load direction

4. Window panel static and dynamic testing

Static and dynamic tests of panels of both materials (glass/clirite) were performed on a servo hydraulic machine for dynamic and static material testing ZWICK Roell HB-250, Figure 6, at the Department of General Mechanical Design, Faculty of Mechanical Engineering, University of Belgrade, in Machine Element and System Testing Laboratory – LIMES.

Figure 6. Servo hydraulic machine for dynamic and static testing ZWICK Roell HB - 250

The static tests of the test panel were performed first, by tensile and compressing loads, gradually introducing the load in the lateral plane of the panel (Figure 5a) to a value corresponding to the calculated endurance limit of the test component. The experimental results showed a great match with the analytical values.

Considering the fact that the panel is a very complicated construction with complex geometry and three different materials in contact and welded joints, the matching of the results indicates that all parameters and limitations of the complicated calculation were chosen correctly. One of the diagrams of static tests and photographs of panels after testing to fracture are shown in Figures 7 and 8.

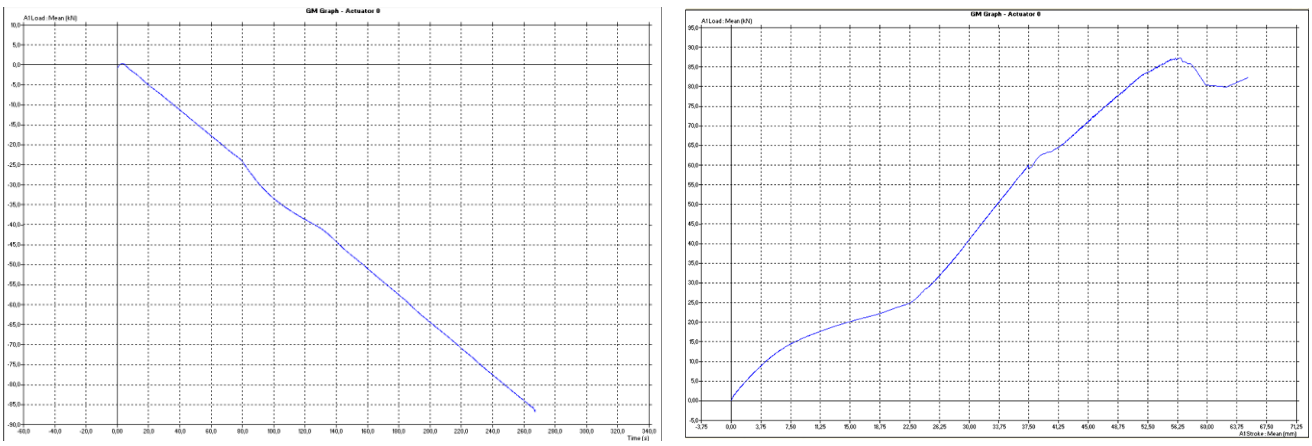


Figure 7. Compression and tensile test diagrams

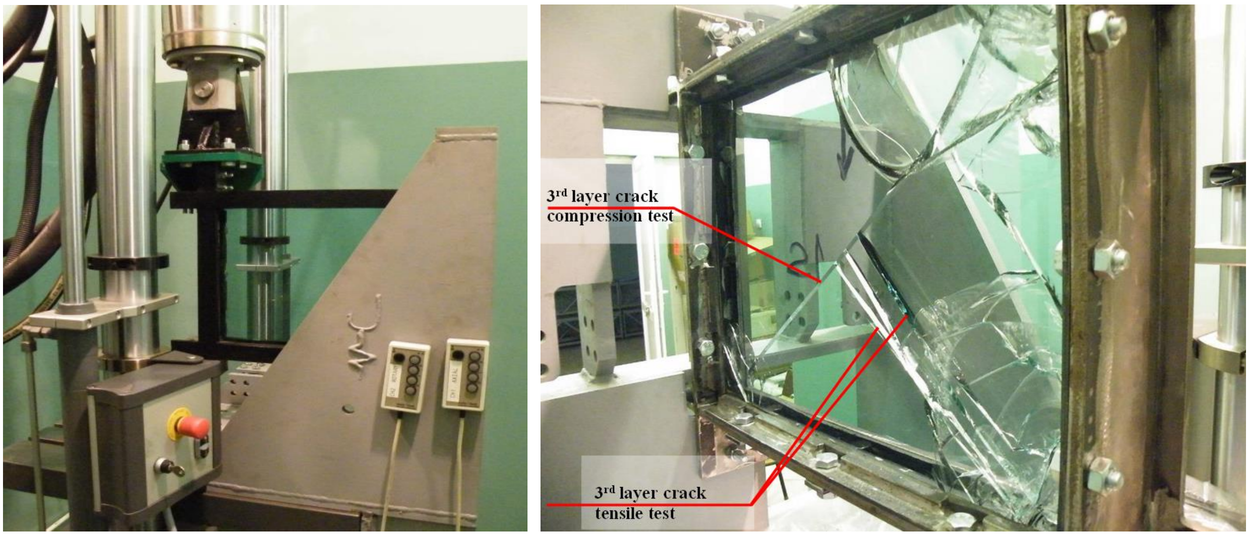


Figure 8. Photography of panel before and after static test

As the same mathematical model of the panel construction test was used in the dynamic calculation, which showed high level of coincidence with the experimental results of the static tests, the dynamic tests were continued without adjusting the parameters. The loads of several expected earthquakes characteristic were simulated, with variations in amplitudes, duration, and number of cycles. Some of the many results are presented through diagrams in Figures 9 - 11.

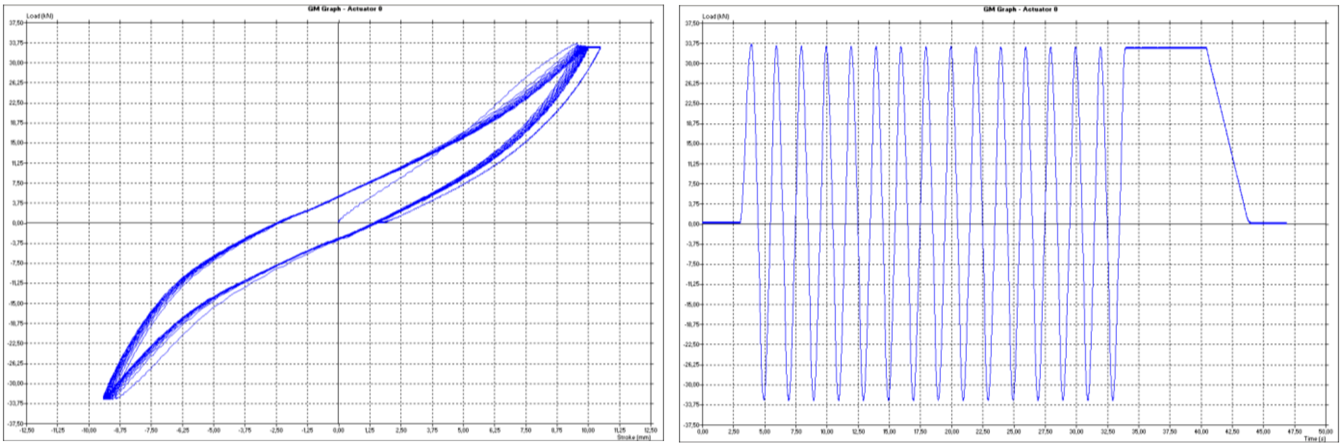


Figure 9. Dynamic testing: ν_1 = 0.5 Hz, F_D = ±33 kN, 15 cycles, duration 34 sec

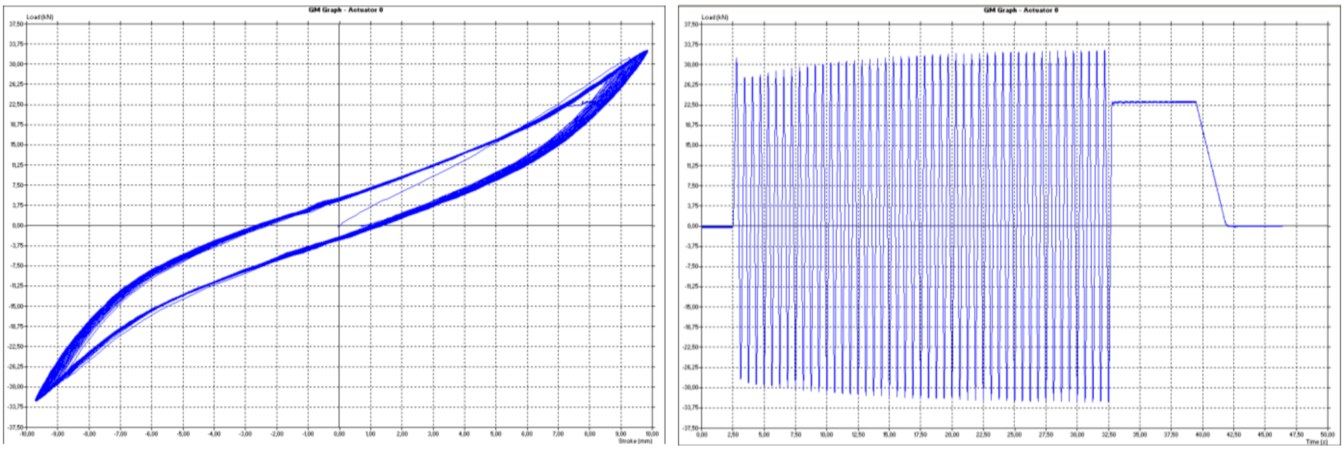


Figure 10. Dynamic testing: ν_1 = 1.6 Hz, F_D = ±33 kN, 48 cycles, duration 34 sec

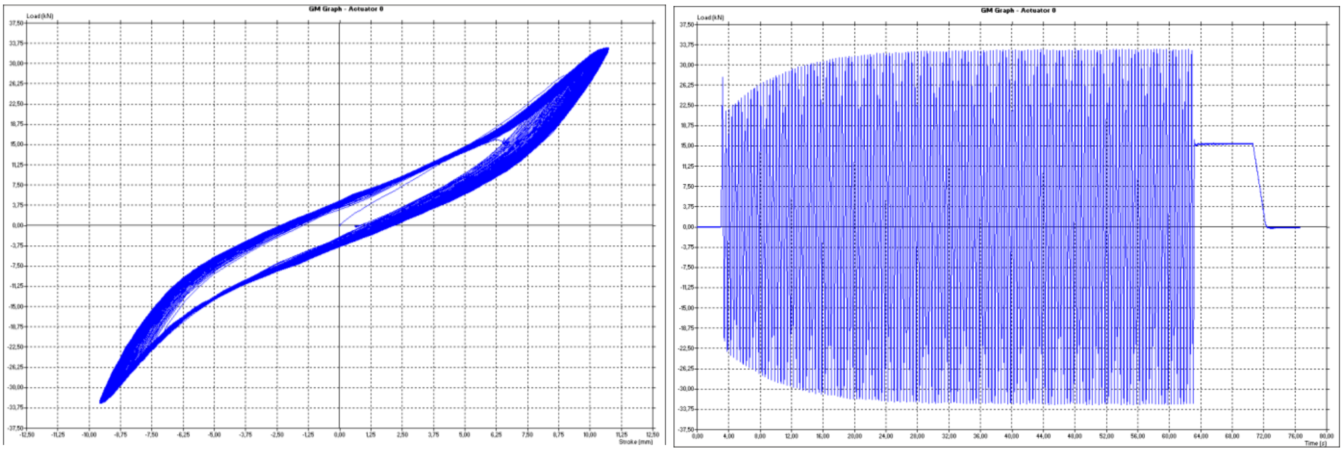
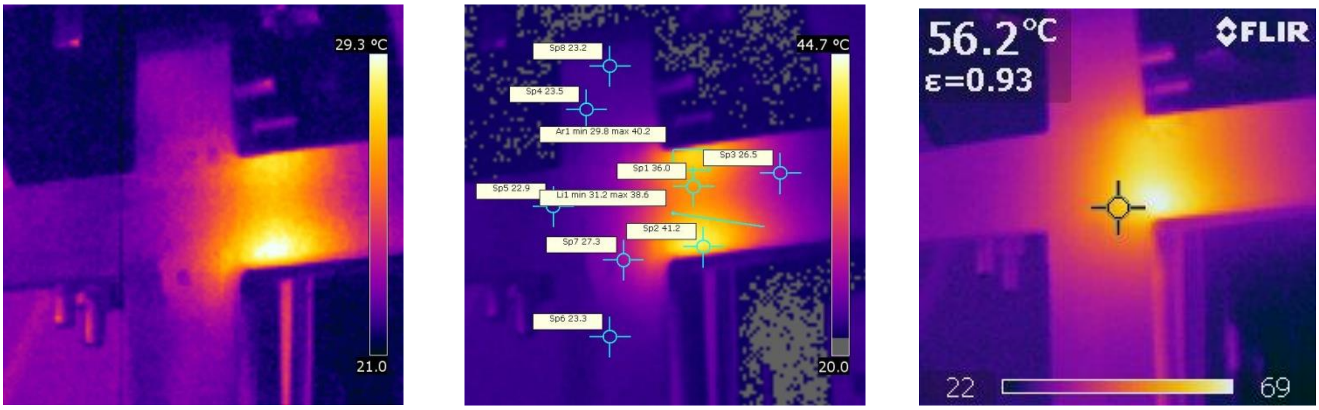


Figure 11. Dynamic testing: ν_1 = 2.5 Hz, F_D = ±33 kN, 150 cycles, duration 63 sec

During the test, the dynamic effect of the force, showed an increase in temperature in the corners of steel frame. Therefore, thermal imaging tests were also conducted to establish the correlation of the temperature increase with the test parameters. This research was performed using FLIR equipment, Fig. 12. It has been established that, the expansion of the metal structure due to the increase in temperature, does not affect the test results.



First 15 sec. Middle of the experiment End of the experiment

Figure 12. Some of the thermal imaging during dynamic testing

5. Conclusion

These experiments have shown that it is possible to test and predict the behavior of metal structures in earthquake conditions - using carefully calculated load spectrums. The results of the calculations and the results of very extensive experimental testing have provided the basis for further research as well as the possibility to use metal windows frames and glass/clirite panels in reinforcement and protection of historic importance buildings.

6. References

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