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AN INNOVATIVE PREFABRICATED BUILDING SYSTEM FOR THE SEISMIC REGIONS

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Abstract

At the end of a decade-long research work at the Moravamont plant in Gnjilane, a new completely prefabricated building system was created from reinforced concrete and prestressed precast elements on the track, which was called Moravamont 2000. Presented in paper final results demonstrates that the construction is well and rationally designed, that the construction behaviour for the maximum expected earthquake effects with a return period of 500 years, according to the criterion of regulation, is resistant and resistant to an earthquake without major damage.

Keywords: prestressed precast element, seismic action, structural system.

ИННОВАЦИОННАЯ СИСТЕМА СБОРНЫХ ЗДАНИЙ ДЛЯ СЕЙСМИЧЕСКИХ РЕГИОНОВ

Ж. П. Цукич

Реферат

В конце десятилетней исследовательской работы на заводе Moravamont в Гнилане была создана новая полностью сборная конструктивная система из железобетона и предварительно напряженных сборных элементов на линии, которая получила название Moravamont 2000. Представленные в работе окончательные результаты показывают, что конструкция хорошо и рационально спроектирована, и что поведение конструкции при максимальных ожидаемых сейсмических воздействиях с периодом возврата 500 лет, согласно критерию регулирования, устойчиво к землетрясению без серьезных повреждений.

Ключевые слова: предварительно напряженный сборный элемент, сейсмическое воздействие, конструктивная система.

Introduction

Moravamont Factory from Gnjilane (Figure 1) is one of the four factories in the Vemont system in the former Yugoslavia. In addition to the Vemont system, the factory Adrijamont and the IMS system of professor Branko Žeželj also have a factory. The factory owns its raw material base – quarry, concrete base, as well as modern mold hydraulics (flares), reinforcement, internal transport and all necessary contents, which can be seen from the attached documentation. In addition to adhesion pre stressing, it also has the possibility of expanding the basic product range by applying universal pre-precision on the track, as well as innovation within the system, as well as possible combinations. This idea of the combination was supported in 1982 by my professor Momir Krastavcevic in postgraduate studies in Nis.

The factory's position allows expansion of production capacities, which the author started in 1989, at the time he was at the head of Binačka Morava, but, unfortunately, the built structure was not put into operation, although the feasibility studies are still good for all new products today. The complex itself enables the creation of a universal concept of construction according to the system: concrete, metal, wood, which practically provides a leading position in the construction industry in the Balkans.

1. A new Structural System "Moravamont 2000"

From the solution [2, 3], it can be seen that distance between columns in both direction is taken 7.2 x 7.2 m, as with the IMS-50 prof. Branko Žeželj for comparison of the obtained results. The Tower program itself provided the complete data needed to dimension all elements: pillar, hollow plates, aP-plates (see Figure 2, 3). All data on the shifteing of the structure, as well as the percentage of the horizontal seismic forces transmitted to the canvas, were obtained – over 90%.

As it was shown in [2], starting from the assumption that pillars and inter-floor panels receive exclusively vertical load (static and dynamic) and panels (internal and facade) receive seismic load, there has been a new solution within innovated system (skeletal and panel) entitled Moravamont 2000.

For the new system, a complete static and dynamic calculation based on TOWER-system was done [2, 3]. It showed that all the elements of the system: pillars of 50/50 cm dimension, hollow core slabs of d = 200 mm and reserve panel of 250 mm in thickness satisfied all the action effects that were applied by the Codes.

To entire seismic effects was also transferred to precast reinforced concrete panel of 170 mm thickness and the supporting facade panel as well. The connection between pillars and prestressed – Panel is very simple (see Figure 3).

Figure 1 – Moravamont complex in Gnjilane

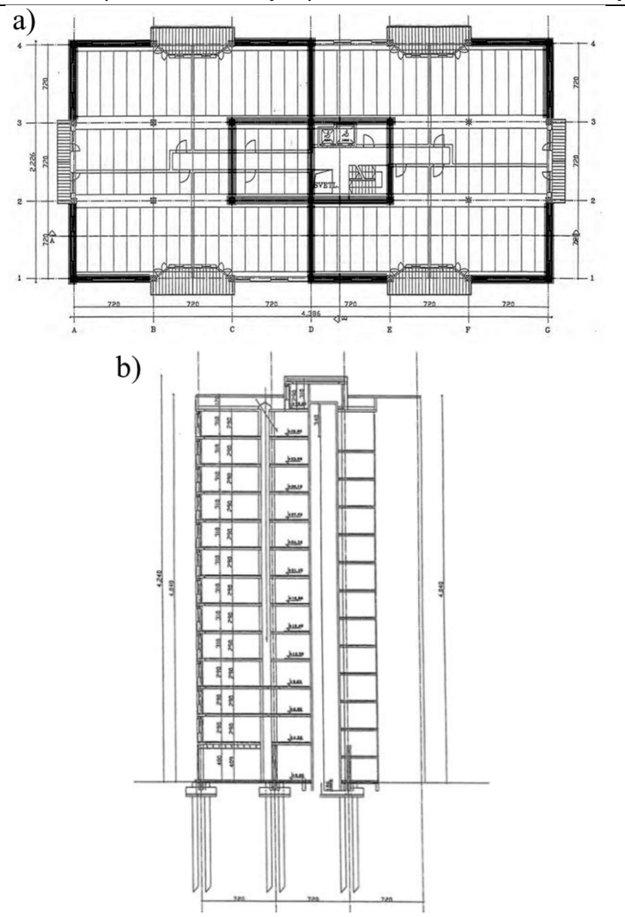

Figure 2 – Basis (a) and cross-section (b) of the R+12 building

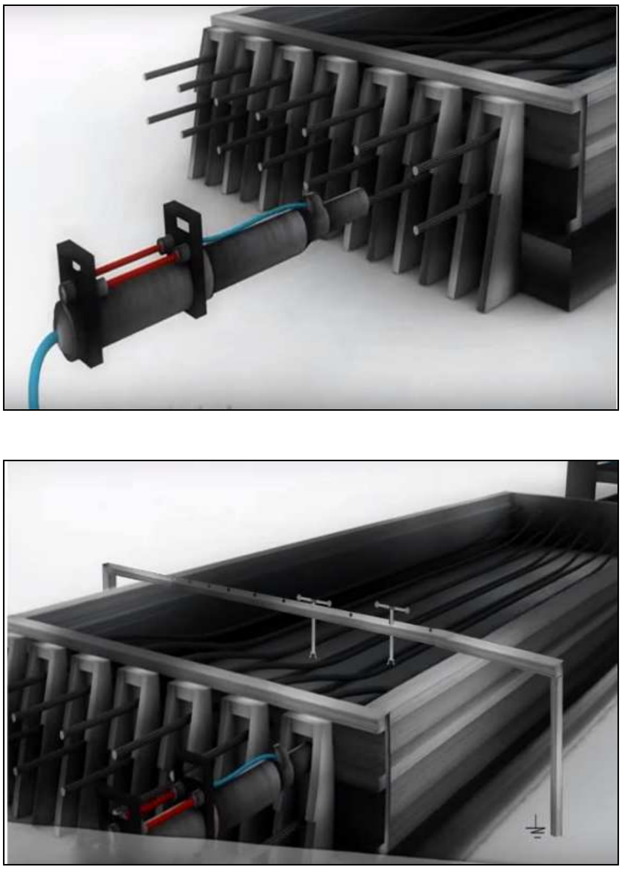

Figure 4 – Runaway mold detail made by solution of engineer Mr. Cuckić

According to [2] such newly formed system, actually takes the best qualities of framed and panel system with Moravamont system and with minor technological changes, it becomes economical and simple entirely prefabricated montage construction system.

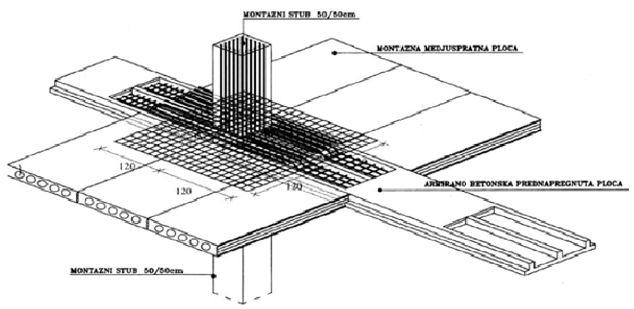

Figure 3 – Connection between the elements of "Moravamont system 2000" prestressed P-plate

The idea of universal prestressing on trails [1] which allows huge savings (especially with surface elements of P-panel) is the addition of the technology of this new system Moravamont 2000 [3].

Unlike the existing technology of prestressing where the wires were placed only in a linear mode, and had to be wedged with rubber hose due to a big negative tension at the end of truss, in the new solution the wires are moved under a small angle until negative axis of elements, so as to follow "fizo" line of the truss by its length. The appearance of pivot force on the trail (see Figure 4) is eliminated by the abutments on the trail because the force are small due to the deflection angle (5-10º) – Hoyer system.

2. Analysis of the Structural System

In [2, 3] the results of spatial structural elastic analysis for seismic effects according to the regulations for seismic activity – level IX have been presented. During the procedure, the necessary dynamic features of the structure design have been obtained, along with all the elements need for the evaluation of the structural conditions and the analysed structural system as a whole. The obtained results of analysis are the initial data for non-linear dynamic analysis of the facility structure conduction.

2.1 Models of hysteresis behavior of assembly systems

The reinforced concrete installation systems with their specificities, both by type of construction and system connections, vary quite a lot and it is difficult to establish "general models" that would apply to all systems of reinforced concrete assembly systems. In such cases, experimental and analytical research is needed with the introduction of system characteristics in the formulation of hysteresis and other dependencies for analysis in non-linear areas of the construction work during strong earthquakes and other causes and loads that lead constructions to the nonlinearity work area.

It should be pointed out that in the world scale it can be concluded that these studies were carried out on a small scale and related to the determination of the characteristics of the system, such as the detailed surveys of the assembly system Rad, Belgrade (basically, the original French Balance system was modified, and just for the needs defining the terms and conditions of the construction work in seismic conditions).

This extensive and specific experimental and analytical research carried out at the IZIIS Institute in Skopje and in the Research Center of the UC Berkeley, USA (within the cooperative research project Academy of Sciences of Yugoslavia and USA 1984/1989) confirmed the expected assumptions as well as the real behavior of the assembly systems during real earthquakes, prefabricated reinforced concrete structures are also suitable for earthquake areas, both in the elastic and non-linear fields of operation, understandable to certain requirements and the adaptation of the system and the bond system.

Based on the results of these investigations given in the above literature [2, 3], the general model of hysteresis behavior is presented in Figure 5.

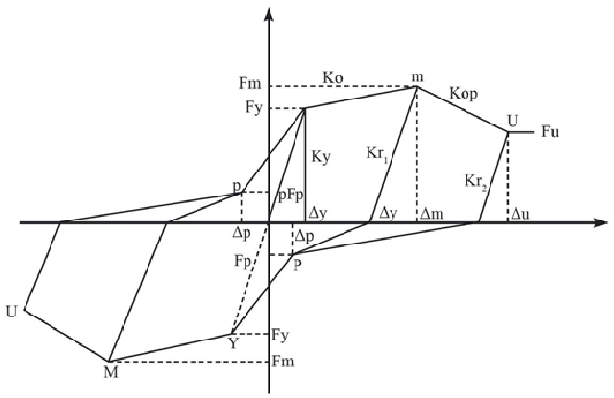

Figure 5 – Model of degrading stubbornness of IZIIS (Author: P. Gavrilović)

Although this model refers to pure panel assembly systems - (with almost ideal matching of experimental and analytical hysteresis dependencies), this is also accepted in this research paper for nonlinear analysis of a system that is not purely paneled, but the basic seismic effects are accepted just by the panel walls are parts of the system, such as pillars, hidden beams, and others in the transmission and gravity function. A more detailed explanation and discussion of the obtained results given in [3].

From a detailed analysis of the construction of representative object models (R + 4, R+8, R = 12) with the characteristic links of the system for seismic effects according to our valid regulations for the earthquake intensity of 500 years return period (IX degrees MCC scale) and elastic analysis for seismic and the gravitational load clearly shows that seismic loads are dominantly received and transferred to rigid panel walls, and that flexible systems of columns and frames follow deformations, but do not enter the degree of non-linearity.

This is why the hysteresis model (see Figure 6) of prefabricated panel systems has been adopted in this analysis of non-linear behavior for various seismic effects and that it provides quite satisfactory results.

2.2 Ductility requirements

According to [2], line $U(\Delta y)$ in the diagram Figure 5, 6 shows the capacity i. e. the elastic strain limit of each floor; line $U(\Delta u)$ – the ultimate line that marks the structural failure inception, i.e. boundary state and the limit strain capacity after which the failure starts. As was shown in [ ], structure field of operation between these two lines represents a non-linear structural behaviour during expected earthquakes.

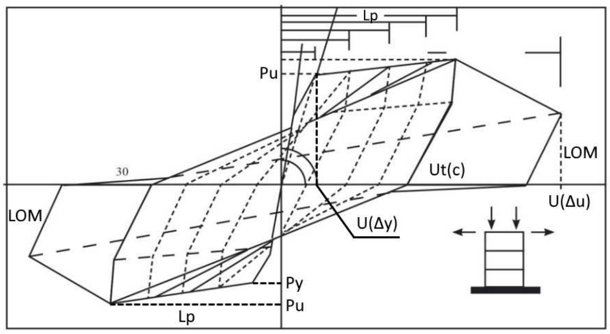

Figure 6 – Sided hysteresis dependence of prefabricated panel systems

Non-linear analysis is carried out according to the DRK Programme of the Institute for Earthquake and Seismology Engineering, University "St. Cyril and Methodius", Skopje and results of the non-linear analyses are presented in [2, 3].

A brief summary, before the analysis of the whole structural system is that the ratio $\mu_{tag} = U(\Delta d_j) / U(\Delta y)$ is ductility capacity and it is within the limits of 3.5 – 4.0 for designed new structural system. As it was stated in [2] it is expected and rational solution in case of the proposed structural system. The strain ratio on each floor devided by elastic strain gives value of required ductility $\mu_{tag} = U(\Delta d_j) / U(\Delta y)$, that is, the obtained strain in any floor devided by elastic strain gives us the required ductility of a certain floor for the specified earthquake effect.

Conclusions

Based on structural analyses of the proposed new structural system the following main conclusions can be formulated:

1. All strain (for all floors) are between elastic and boundary ones, which means that the structure operates in non-linear conditions but without failure. The highest required ductility is on the first floor, and its value is equal 4.0;
2. Proposed structural system is well and rationally designed and structural behaviour is resistant during the expected maximum earthquake activity with a time interval of 500 years recurrence according to the Regulation criteria and it can resist the seismic effects without a major damage.

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