ШКОЛЕ И ЗЕМЉОТРЕС КРАЉЕВО
SCHOOLS AND KRALJEVO EARTHQUAKE

Sistem DC90, 2015

Др Зоран Петрашковић
Жарко Петрашковић

The Ministry of Education of the Republic of Serbia, Belgrade
School Administration of Kraljevo, Zarko Milosavljevic, professor, Nenad Slavković, professor

FOREWORD

One would rather forget unpleasant events, but the citizens of Kraljevo, including me, will never forget the earthquake that struck the city of Kraljevo and its surroundings on 03.10.2010. The human casualties weren't numerous, but still, every human life is irreplaceable. However, life in the city had to take its course of renovation and construction of the demolished objects. Truly good people are rare, but fortunately for the citizens of Kraljevo good people did appear and in large numbers.

For us, the school board, back then headed by the chief Milosavljevic Zarko, the most important task was to get students back to classes in schools wherever that was possible and as soon as it was possible. The head of School Administration Zarko Milosavljevic showed great effort to solve this problem. In addition to the local government's help, the Ministry of Education, headed by the Minister Zarko Obradovic, provided the greatest possible assistance, both material and professional.

Only a day after the earthquake Zoran Petrašković our greatest expert in earthquake engineering appeared in the city with his associates. The city staff for the elimination of consequences of the earthquake instructed him to carry out a detailed examination and expertise of school buildings damaged by earthquake. The head of school administration appointed me to join PhD Zoran Petrašković and his associates in this painstaking work. We visited all the damaged school buildings and separate classes objects in the city and the nearby villages. Some schools were visited several times in order to record the existing situation and making project for their rehabilitation. Some school principals have had to be convinced to let the children back to school classrooms which were safe. Mr. Zoran Petrašković, apart from this selfless work with his associates, also donated rehabilitation projects for the most of the badly damaged schools in Kraljevo. He also brought the experts from the Institute of Seismic Engineering in Skopje with whom he carried out various studies on school buildings, and he also gave lectures intended for engineers from the local area in order to efficiently eliminate consequences of the earthquake. This humble man gave an immense contribution to eliminating the consequences of the earthquake in city and people Kraljevo should not forget that.

The chairman of the School Board, Kraljevo

Nenad Slavković

1. INTRODUCTION

The motive to write this illustrated monograph lies in the need to systematize the experience and the specifics of applied research on raising the safety of school buildings in Kraljevo, 2010, after the earthquake. These experiences can be useful to other regions that have been struck by earthquakes. As was the case with the earthquake in Pernik 2012, the Philippines in 2013, on the Greek island of Cephalonia in 2014 and Nepal, 2015.

The process of raising safety of school buildings in risky territories prior to strong earthquakes is of the greatest importance. In this regard, there are a lot of important activities in Mediterranean and Asian countries.

The experience of the Serbian Ministry of Education in efficient and expeditious elimination of the consequences of the earthquake in over forty-damaged buildings may be of particular use to governments of other countries.

The news of the earthquake in Kraljevo was received in the morning of 3.10.2010. In the Innovation Center System DC90 lab in Bolec near Belgrade. It was a signal to focus completely concentration on an action plan to record the state of buldings and eliminate the consequences of the earthquake. The very next day (the author of System DC90 Dr. Z. Petrašković with his assistant Vladimir Savic) we appeared in front of the Committee for emergency of Kraljevo where we got the first instructions. We reviewed the key facilities: hospitals, schools, business and residential buildings, churches, private buildings and historical buildings.

By the decision of headquarters we devoted our time solely to the detailed assessment and expertise of school facilities (40 buildings). Total dedication and permanent monitoring of the damaged structures because of the effects of numerous aftershocks are of particular importance. These are natural tests which can point to the essence of the damage and provide an answer to open questions. Each school was visited and assessed three to five times in the course of the two-month observation. The working day lasted twenty-four hours and we visited four to seven schools a day. Simultaneously the results from the field were analyzed and prepared for the conceptual and preliminary designs. The damaged schools were mostly masonry and after a detailed analysis, we decided to implement earthquake shock absorbers DC90 for hysteresis control of the structures' dynamic behavior, which achieved a significant degree of increased safety of the facilities. Unfortunately, conservative, more expensive systems were used on other buildings and according to the author they provide lower degree of safety. This was done by using reinforced concrete walls and solid carbon fiber.

We tested several types of schools for ambient and later for forced vibration, which provided us the information about the state of the structures (sounds and forms of oscillations, damping). These tests were carried out in cooperation with the Institute of Seismic Engeneering and engineering seismology IZIIS-Skopje (Prof PhD Ljubomir Taškov and Prof PhD Lidija Krsteska), the Republic of Macedonia and the American company Diggitex (Saso Atanasovski, B.Sc. civil engineer. And Tino Mihajlovik, B.Sc. civil engineer.)

Good organization of the Ministry of Education (Minister Prof. PhD Zarko Obradovic and associates) and contractors (Interklima-Vrnjacka Banja, Ramark-Čačak, Noveko-Vranje, VINKG-Kraljevo, Standard-Kraljevo, Pozega PRO engineers) trained for the use of modern and advanced System DC90 technology and special Shock Absorbers DC90 equipment gave particular techno-economic effects and increased the safety of schools. School Administration (Zarko Milosavljevic, professor and Nenad Stankovic, professor) and school principals played an important role in this process.

This monograph was designed and focused on a single topic and that is MASONRY SYSTEM SAFETY IN EARTHQUAKE CONDITIONS, through the prism of Kraljevo earthquake which made this subject especially popular.

3.REHABILITATION OF SCHOOLS DAMAGED BY EARTHQUAKE IN KRALJEVO ON 03. September 2010.

12th WORLD CONFERENCE ON SEISMIC ISOLATION, ENERGY DISSIPATION AND ACTIVE VIBRATION CONTROL OF STRUCTURES

Zoran Petraskovich, Vladimir Savic, *Research-productive Centre System DC 90, 11307 Belgrade, Smederevski put 67, Serbia, e-mail:* dc90@eunet.rs, *tel. 381 641145327*

ABSTRACT

Over forty schools were analyzed and System DC90 technology was chosen as the solution for their seismic rehabilitation. Analyzed schools were masonry, up to four floors with reinforced concrete skeletal structures. The paper shows the ways of researching, technology design and the work carried out through implementation of our technology. Shown are the technologic and design solutions for strengthening the walls, for stiffening the ceilings, for joining ceilings with walls, for vertical prestressing of the walls and for the interconnection of the walls. The technology is especially effective on a mass repair of masonry structures when taking into account the level of safety, cost and duration of rehabilitation.

1. INTRODUCTION

This research presents the application of technology of masonry and frame structures rehabilitation by means of DC90 System. After the examination of forty school facilities we elaborated the rehabilitation plan for twelve objects. Particular attention was devoted to the application of special equipment such as dampers (seismic energy absorbers) and to their effect on the control of hysteresis behavior of the objects. In this paper we will explain the basic characteristics of the 12 schools damaged by the earthquake in Kraljevo, Serbia on 03.11.2010, as well as the way of their rehabilitation.

List of schools:

- Elementary School - Četvrti kraljevački bataljon
- Elementary School - Dimitrije Tucović
- Elementary School - Jovo Kursula
- High School – Gimnazija
- High School – Ekonomsko-trgovačka škola
- Mechanical engineering High School -14. Octobar
- Agriculture-Chemistry High School –Dr. Đorđe Rakić
- Elementary School -Vuk Karadzić
- Elementary School -Dragan Marinković, Adrani
- Elementary School -Dragan Marinković, separated class in Popovichi
- Elementary School -Čibukovački partizani
- Technical High School -Nikola Tesla

2. THE BASIC CHARACTERISTIC OF THE OBJECTS AND DAMAGES AND OF THEIR SANATION

Presented below are the basic technical characteristics with pictures of typical damages, dispositions and shapes of vertical stiffeners and short description of objects’ conditions.

2.1. Elementary School - Četvrti kraljevački bataljon

Technical description of the damaged object:

- Dimensions of the base and floors : 10.4x63, BF+GF+2floors
- Construction system: reinforced concrete frame structure (cross-section columns 25x40cm cross-section beams 25x50cm.), cross grid 2.85m.
- Walls: bricks w= 25 cm.
- Foundation: strip footing foundations with columns on it, width 160 cm.
- Roof construction and cover: wooden construction, roof tiles
- Floor slabs: reinforced concrete w=12 cm.
- Floor (Inter-storey) structure: reinforced concrete, w=12 cm.

Presentation of existing damage on the structure: photo and description, with particular reference on the damage of the basic structural system. The extensive photo documentation shows that the secondary-wall systems suffered significant damage. The damage was due to the large deformability of the system, especially in the transverse direction. Poor quality of concrete walls and large distance between the concrete stiffening in the 60 m long building caused significant damage to the walls between classrooms. Deformation in the transverse direction exceeds the permissible deformation of reinforced concrete skeletal systems.
Figure.1. a wall with damages

Figure 1. Typical Damages and Dampers

The following pictures figure 2. to 4. show the disposition of vertical stiffeners, dampers and details of installation of vertical stiffeners.

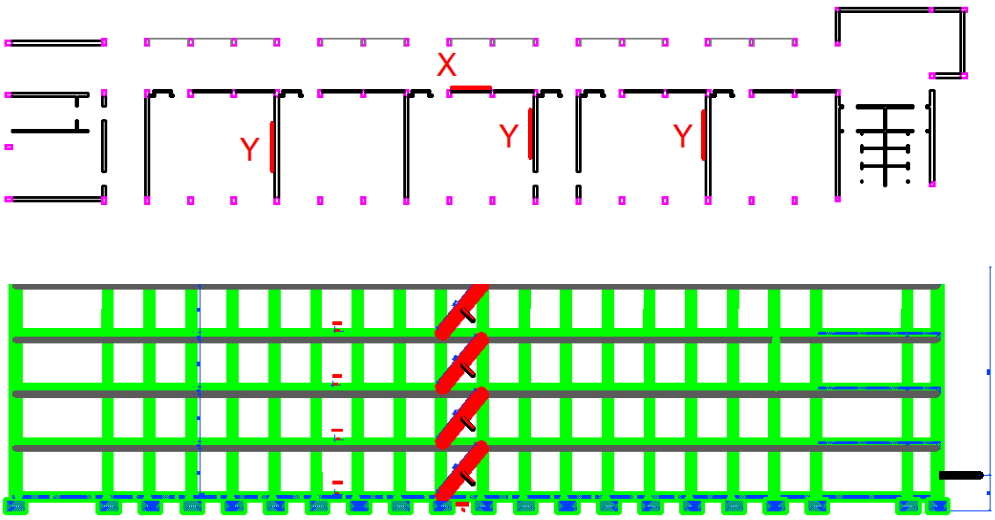

Figure 2. The Disposition and Shape of Vertical Stiffeners at X direction

Figure 3. A Part of the Delivered Equipment - Dampers
Figure 4. Connecting the diagonal with a Damper and verticals by welding

Figure .5. Vertical stiffening in longitudinal Y-direction diagonal square cross-section 260x160x7 with damper. Force in damper +-1100 kN, displacement +-5mm.
Figure 6. A detail of anchoring the diagonal in Y-direction with a damper, decorated with works of students during Arts classes

2.2. Elementary School -Dimitrije Tucović

Technical description of the damaged object:

- Dimensions of the base and floors: 12.50x42.00 m. GF+2, floor high 4.50 m.
- Construction system: masonry structure, without vertical columns
- Walls: bricks w= 50cm, mortared, without thermal insulation
- Foundations: strip foundations, reinforced concrete
- Roof construction and cover: wooden construction, roof tiles
- Floor slabs: wooden construction, with cane ceiling
- Floor (Inter-storey) structure: reinforced concrete, small ribs

On next couple of figures damages and the way of retrofit are shown

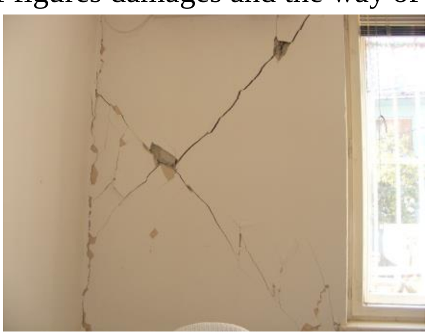

Figure 7. Typical Damages, X cracks, and Dampers

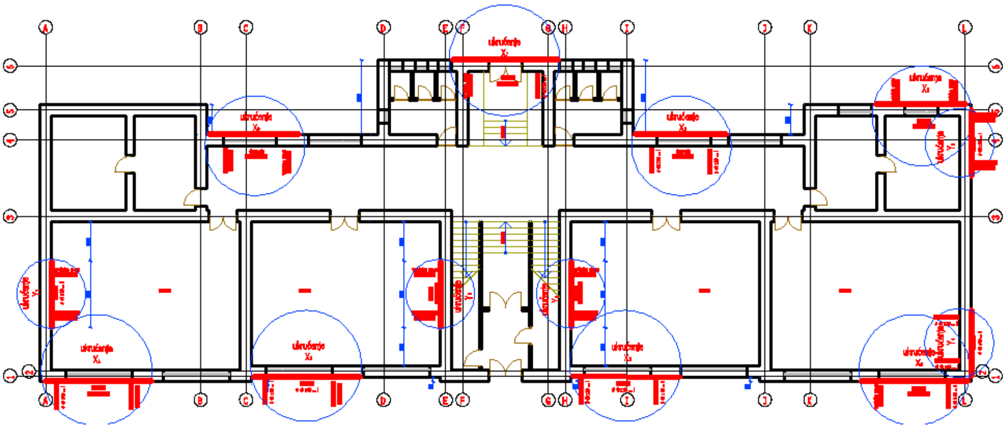

Figure 8. The Disposition of stiffeners

Figure 9. The Shape of Stiffeners

Figure 9. shows the ortho-photo shot of the facade with marked vertical stiffeners. The building was damaged badly with crossed diagonal cracks between windows.

2.3. Elementary School - Jovo Kursula

Technical description of the damaged object:

- Dimensions of the base and floors: 10.80 x 60.19m. GF+1, floor high 4.30 m.
- Construction system: masonry structure, without vertical columns
- Walls: bricks w= 25cm, mortared, without thermal insulation
- Foundation: strip foundations
- Roof construction and cover: wooden construction, roof tiles
- Floor slabs: wooden construction, with cane ceiling
- Floor (Inter-storey) structure: reinforced concrete, small ribs

Presentation of existing damage on the structure, photo and description, with particular emphasis on the damage of the basic structural system:
The old part of the school was made of masonry construction with reinforced concrete corners around windows, with the partition wall in the hallway made of brick on the outer side. The wall wsa unstable

and the ground and first floor were not allowed for use until rehabilitation. The pillars are made of brick. The inner columns were badly damaged and degraded.

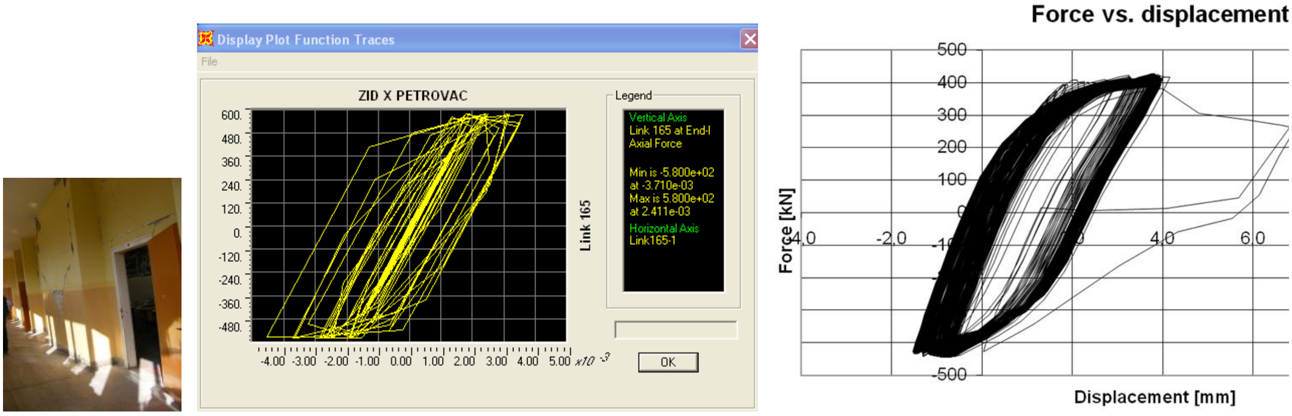

Figure 10. Typical Damages and Dampers (design and test)

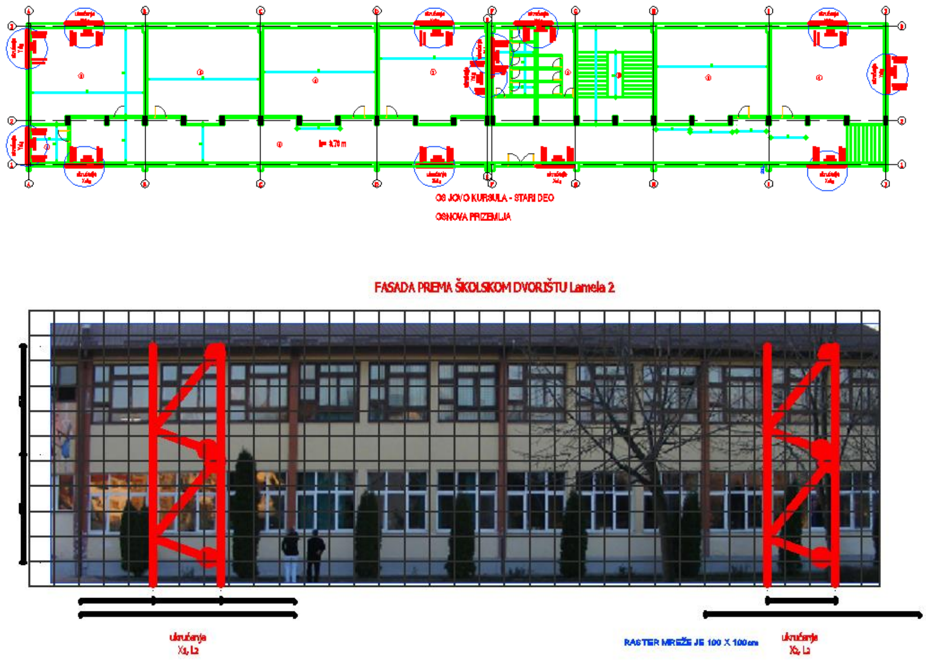

Figure 11. The Disposition and Shape of Vertical Stiffeners

2.4. High School – Grammar School and Economic and trade school

Technical description of the damaged object:

- GF+3, floor high 3.70 m.
- The facility is basically made up of three parts. The end part's (Lamella 1) dimensions are 22,80 x 20,10m with the basement.
- The central part's dimensions are 33,45 x 23,44m without basement, with increased height of ground floor because of the sports hall. All three parts are divided by dilatations.
- Construction system: masonry structure, without vertical columns
- Floor (Inter-storey) structure and Floor slabs are „Avramenko" type .
- Foundations: Strip footing and spread footing foundations

Presentation of the existing damage on the structure, photo and description, with particular reference to the damages of the basic structural system:

The school consists of three constructional parts separated with dilatations. Objects previously strengthened with concrete in transverse direction. There was a need for longitudinal capacity reinforcement of facade walls. During the period of observation progressive increase in cracks in the walls was apparent, particularly in the facade wall in the space between windows.

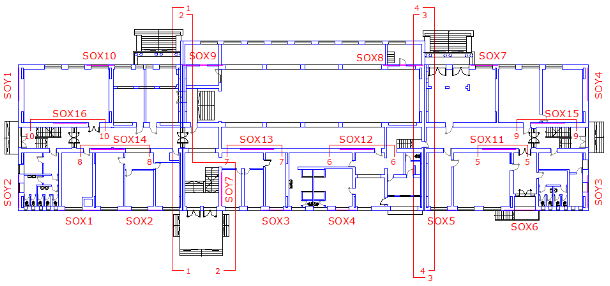

Figure 12. The Disposition of Stiffeners

Figure 13. Typical Damages

Figure 13. Beginning of retrofit

Figure 14. The Disposition and Shape of Vertical Stiffeners

2.5. Mechanical engineering High School -14. October

Technical description of the damaged object:

- GF+1, floor high 3.70 m.

- Basically the facility is complex and consists of three parts. The central part (lamella 1) has a “T” shape, dimensions 57,3mx17,0m+29,0mx17,5 m and two end parts (lamella 2) dimensions 17,0x42,0m are without dilatations.
- Construction system: Lamella 1, masonry structure, without vertical columns, floor (Inter-storey) structure and floor slabs are „Avramenko“ type.
- End parts, which had been reconstructed and upgraded (lamella 2) are a mixture of skeletal and masonry systems with massive floor (Inter-storey) structures and steel roof constructions.
- Foundations: Strip footing and spread footing foundation.

On the next couple of figures damages and the way of retrofit are shown.

Figure 14. Typical Damages

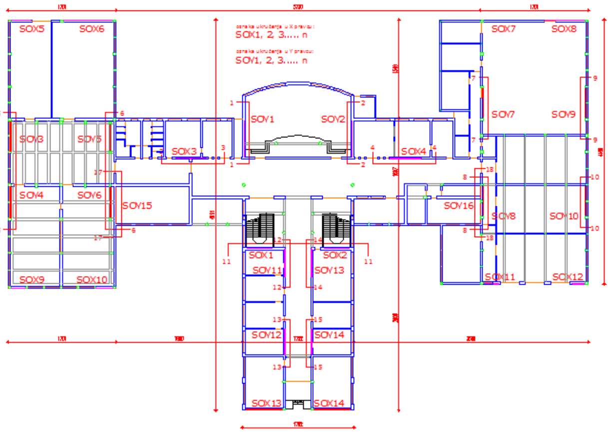

Figure 15. Disposition of stiffeners

Figure 16. Shape of stiffeners

2.6. Agricultural High School –Dr. Đorđe Rakić