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

TECHNOLOGY OF SEISMIC SAFETY BY SISTEM DC90 ON MASONRY AND HISTORICAL BUILDINGS

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ABSTRACT

In first part of paper it presents the research laboratory of Innovating Center Sistem DC90. Then show objects realized with this technology. A special aspect is placed on historical buildings. Reinforcing elements can be installed into the walls of construction, can be installed at the external or internal wall sides. Displaying the results of laboratory tests and testing of repaired facilities. Using device-dampers in masonry structures is controlled the hysteresis behavior of structural elements. Problem of Hysteretic behavior of structural elements in the field of a small number of cycles is particularly analyzed in terms of accumulation of dilatation.

Keywords: Dampers, cyclic plasticity, strengthening, historical buildings

1. INTRODUCTION

Innovation Center for Seismic Engineering System DC90, Ltd. is registered as an innovation organization in the Ministry of Innovative science. In our laboratory for modeling and dynamic testing we exploring and innovating new devices and equipment to protect buildings from earthquakes. Our invention are protected by patents (13 patents at homeland and abroad P48040, Patent in USA No. 10/555,131, from 31.10.2005; patent in Australia No.AU 2003254327A1 from 2004.11.23. MP 123-97; MP 124-97; MP 125-97; MP 126-97 , P 323/03, P 2010/0227, , P 2010/0228, , P 2010/0229). The products sold across four continents (America, Asia, Africa, Europe), fig1., which achieves sustainable development.

Figure 1. Assortment of Dampers Systema DC90

2. LABORATORY CAPACITY OF THE „DC 90 SYSTEM“ INNOVATION CENTRE

Hydraulic system for dynamic model testing and high force testing of the quasi dynamic alternative strain of the DC90 System Damper.

The system provides the possibility of testing in five positions:

1. 800x2400mm vibro-platform, for the models of up to 1 tonn weight and dynamic loading in free time record of 15 Hz frequency and ±30mm displacement or in real time seismic record.
2. Axial in-frame dynamic testing (push and pull mode) of the members up to 2000mm length by forces up to ±20 kN, frequency up to 15 Hz and maximum displacement up to ±30mm. Random dynamic strain P(t) and X(t).
3. Testing of the models of up to 3000x2500mm dimensions by horizontal dynamic loading at random level of height from 0 to 2500mm by the actuator of the above mentioned dynamic characteristics.
4. Testing of the linear constructions of up 600x2000x3000mm dimensions by vertical dynamic loading by the vertical actuator of the above mentioned dynamic characteristics.
5. Quasi dynamic testing of the construction members of up to 5000x3000x1000mm dimensions by alternative loading (push and pull mode) in vertical frame by maximum force up to ±5000kN and maksimum amplitude of displacement of 530m.

Figure 2. Laboratory for model testing

Figure 3. Damper Tipe ″Vogzal″ in the frame for testing

3. COMPLETED FACILITIES BY TECHNOLOGY OF SISTEM DC90

3.1. Modeling of the Response of Unreiforsed Structural Masonry of Beauharnois powerhouse-Canada

Primary objective: To present the Hydro-Quebec's advancement in non-linear static and dynamic analysis of masonry structures, to examine in particular the meso- and macro-scale approaches for analysis of brick masonry and to apply them to analysis of an existing hydraulic structure
Hydro-Quebec's methodology applied in analysis of unreinforced masonry structures

1. Evaluation of mortar and brick properties employed in the detailed (meso – scale) analysis
   In-situ and lab testing
2. Homogenisation
   Simulation of tests or of "representative volume element" (REV)
3. Modeling of the structure using homogenised elements (macro-scale approach)
   Verification and calibration of the model – comparison with measured displacements; ambient vibration tests and comparison
4. Definition and application of the Static and the Seismic Loadings
5. Numerical analyses
   Elastic static and dynamic analysis and verification of violation of the "plastic stress field"

Nonlinear static and dynamic analysis and evaluation of structural stability

6. Reinforcements (if required)

Dumpers

Reinforcement of deficient elements

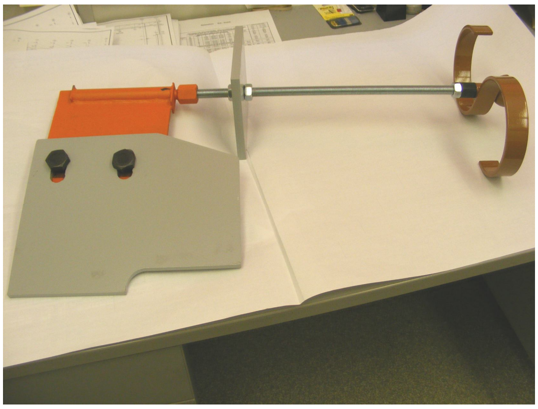

Figure 4 . Dampers for Beauharnois powerhouse, Canada

Figure 5. Model of the wall of hydro-generator "Beauharnois" in 1:3 ratio on vybro-platform

Machine hall power plant Beauharinois is a monument of culture. Facade wall thickness is 100 cm, height 24.00 m and length of 1 kilometer.

3.2. Finnish Embassy in Algeria

At the residence of the Finnish ambasador are implemented several technologies. For vertical stiffening were applied dampers in the walls. Horizontal prestressing of floor slabs construction shrinkage compensators. Vertical prestressing of tower with shrinkage compensators and dampers . At figure 6. and figure 7 are shown forms of vertical stiffeners.

Figure 6. Facade 1.

Figure 7. Facade 2.

Building area of 2300 m2 was retrofit in 25 days in Algeria in 2005.

4. HYSTERESIS BEHAVIOR IN THE FIELD OF SMALL NUMBER OF CYCLES

Dampers for DC 90 system were tested by variable loading on MTS servo-hydraulic closed-loop machine Vojnotehnickog Instituta VTI-Beograd . Typical dampers that have been tested are shown at figure 8.

Figure 8. Typical dampers of DC 90 system

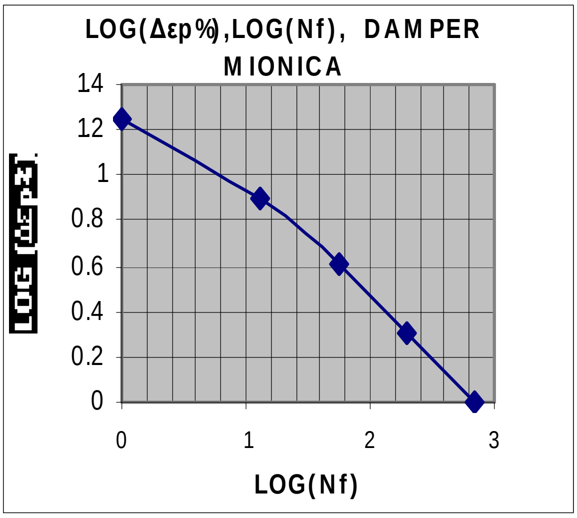

Figure 9. Number of cycles - accumulated strain diagram for „Mionica" Type Damper

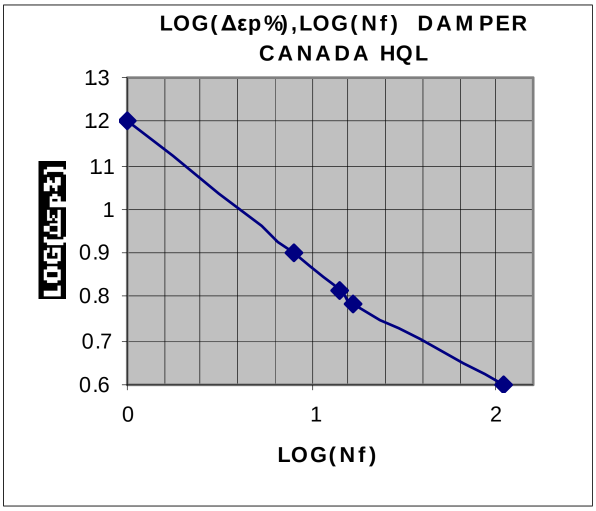

Figure 10. Number of cycles-accumulated strain diagram for "Canada HQL" Type Damper.

The Figure 9. and 10. demonstrates the relation N, ε for „Canada HQL“ Type of Damper. The construction mechanism demonstrates the similar behavior as the “Mionica” Type Damper, the present experimental diagram is used for needs of numeric analysis and damper design. Considering relation of dilation accumulation compared to the number of cycles and the phenomenon of the fall of stiffness compared to the size of the accumulated dilatation it is possible to predict the hysteresis behavior of construction at the moment of earthquake.

4.1. Modeling of Hysteresis Behavior in a Small Number of Cycles

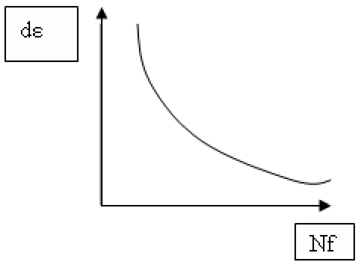

Figure 11. Diagram: Average accumulated dilation dε , number of cycles Nf

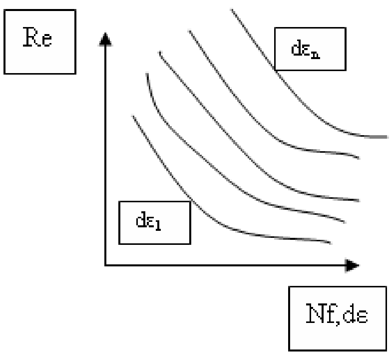

Figure 12. Diagram: Elasticity limit Re, number of cycles Nf average accumulated dilation dε, (instead of elasticity limit, Re can be seen some other parameters such as the coefficient of friction, viscous damping coefficient, the force of adhesion, e.t.c.)

This behavior is typical for the earthquake effects where the structure or certain parts lose there integrity only after a few cycles of stress. Without taking this fact into account its impossible to explain this phenomenon. The procedure of calculation with taking the effects of the accumulated dilation consists of two steps:

a. By experimentes make the curves shown at figure 11and figure 12.

b. At every cycle of construction movement total accumulated dilation suppose to be calculated. It is sure that its increase with every number of cycles. For each of the current situation and the known values of (Nf, dε) read the corresponding value Re.

Change of the value Re is very slow and practically no change in the field of a large number of cycles where its fall coming sharply. But the change of the value Re in the field of accumulated dilatations with small number of cycles is large, gradual and very important. Each new cycle is calculated with the new hysteresis configuration depending on the size Re. Of course this is a simplified rheological treatment but on the other hand, trying to use simple rheological models and show a real and very complex behavior of materials under cyclic loading. Identification of key and most important parameters is essential for quality modeling.

This is especially important field for numerical modeling of new structures. The combination of numerical and experimental research is very grateful and useful. Especially in terms of price, quality (the essence of the problem) and the time required for one or another researches (numerical and experimental).

5. THE NEW DESIGN OF 3D DEVICE DC90

At base facilities isolation it is required of the construction supports to have controlled hysteresis behavior. The three-axial hysteresis-steel sliding joint support device is made to achieve this function of controlling the force and displacement. Control of displacement is made by the metal hysteresis damper so the fatigue phenomenon is considered.Device is composed of sliding plate fixed to the structure and connected to three orthogonally placed hysteresis dumpers fixed to the support (see Figure 13.).

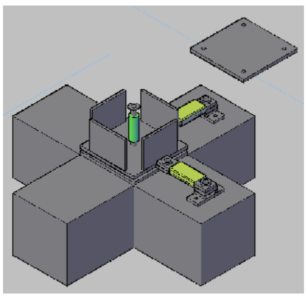

Figure 13. 3D Damper Device

In both horizontal directions the energy dissipation is achived by: a) friction of sliding plate and the supporting surface and b) the yielding of steel device in the horizontal dumpers. The dissipation in the vertical direction is accomplished by the vertically positioned hysteretic dumper. The dumper is adequate and may be included as a part of the support or joint in a structural system. The facts defining damper is figure14, and figure.15.

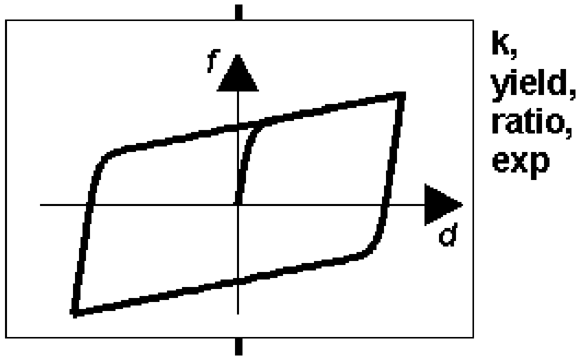

Figure 14. Limit of elasticity,

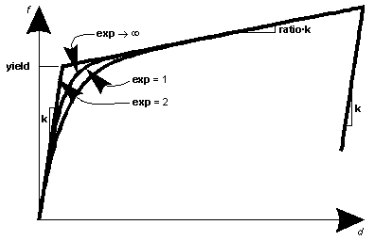

Figure 15. Stiffness of elements

relation of stiffness in elastic zone and after it – ratio k
exponent by which the diagram is approximated – exp.
(ε_{yield}, σ_{yield}) strain and stress in limit yield
Dumper type Mionica +:
k=128,712.87 kN/m
yield=120 kN
ratiok=0.11
exp=2
The fact defining Damper: SUPPORTS Sliding and histereteretic Dampers in three directions (X, Y, Z)
K=130,000.00 kN/m to 200,000.00 kN/m (for forces 80 to 500 kN)
yield=10 kN to 5.000 kN
ratiok=0.03 to 0.17
exp=2 to 3
displacement 1 mm to 200 mm.

6. CONCLUSIONS

The new design of 3D Device DC90 lets you control the movement of construction support in three directions. Detail experimental model and numerical research of hysteresis behavior in the field of small number of cycles can make the effects of this device to increase the safety of the facility. Using of developed and tested devices DC90, such as multilayer metal hysteresis damper, line dumper and sickle dumper, this research can be solved in optimal time and with acceptable costs. The wall testing of the diagonals proves that diagonal combined with the damper likewise withstand the pull and push loading even after wall cracks appearance. This fact indicates that the system can be applied on masonry constructions of historical value. Experimental testing of the constructions with or without DC 90 System shows the alterations of dynamic performances of the system and the way to improve safety and ability to withstand the significant seismic and dynamic forces. The further development and research can be carried on in the direction of new materials with improved plastic features, strain capacity, and less and less inside imperfections. The testing and dynamic analysis provide the possibility to consider the low cycle fatigue effect from the aspect of accumulated strain, number of cycles and local and global stability of the construction members and construction integrity.

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