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Republic of Serbia
Ministry of Defense
Material resources sector
Administration of Defensive technologies
Millitary Technical Insitute
1 2 JUN 2009 Пов. бр.026/ 979-10
године
Belgrade

Report on testing results,
presented by –

SISTEM DC 90
Vele Nigrinove 1,
11000 Belgrade,

Based on your letter no. 243/09 from 22.05.2009. as an attachment to this act, we present to you the Report on dynamic testing of the delivered specimens of damper - absorbers of seismic energy developed by system DC 90.

Attachment as in text.

ZB/DR

MTI Deputy Director
Colonel
Dusan Dr. Rajic, civil eng.

Delivered to:
- Title
- Archive 026

MILITARY TECHNICAL INSTITUTE
Laboratory for experimental strength
Belgrade, Ratka Resanovica 1, Phone (011) 2508-774, fax (011) 2508-474

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Ref: 026/

REPORT

DYNAMIC TESTING OF DELIVERED SPECIMENS OF DAMPER – ABSORBER OF SEISMIC ENERGY, DEVELOPED BY SYSTEM DC90

Chief of the
Laboratory for
Experimental strentgh

Burzić dr Zijah, Civil Eng.

Agreeing:
MTI Deputy Director
Colonel
Dusan Dr. Rajic, Civil Eng.

Belgrade, jun 2009.

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REPORT ON TESTING OF DAMPERS - ABSORBERS OF SEISMIC ENERGY DEVELOPED BY SYSTEM DC 90

no. 026/979

Customer:	**"SYSTEM DC 90", 11000 Belgrade, Vele Nigrinove 1**	
Customer order:	**no. 243/09 from 22.05.2009.**	
Specimen:	**Damper HQ L and HQ M**	
Way of sampling:	**Sampled by the customer:** yes	**Sampled by laboratory:** no
Specimen reception date:	**25.02.2009.**	
Testing method:	**Dynamic testing**	
Environmental conditions:		
Testing equipment:	**MTS Servo-controlled Hydraulic System**	
Measuring equipmnet:		
Measuring uncertainty:		
Testing period:	**(from 26.05 to 26.05.2009)**	

CONTENTS:

	Developed by	**Reviewed by**	**Approved by**
Function	Head of the project	Head of the laboratory	Head of the laboratory
Name	**Dragutin Georgijevic Civil eng.**	**Dr. Zijah Burzic, civil eng.**	**Dr. Zijah Burzic, civil eng.**
Signature			

TESTING IS ORDERED BY

"SYSTEM DC90" - Research, Consulting, Engineering and Technology Transfer Company, Belgrade, Vele Nigrinove str., 1 in accordance with the order form dated 02.04.2009.

1. DELIVERED SPECIMEN

To conduct a test the customer delivered the type "Canada" damper (the absorber of seismic energy developed by "SYSTEM DC90").

The view of the delivered damper specimen (the absorber of seismic energy) is represented on Figure 1.

Figure 1. View of Damper type "Canada" (absorber of seismic energy).

2. CUSTOMER ORDER

The Customer ordered to conduct the dynamic loading test on type "Canada" damper (the absorber of seismic energy developed by "SYSTEM DC90") according to the Test Program. The testing results of the delivered specimen should meet the quality requirements in the aspect of the energy damping.

3. TESTING PROCEDURE

The testing is performed by means of MTS Servo-controlled Hydraulic System, Figure 2. The edges of the testing specimen are fixed by the jaw clutches designed for the round specimens, thus the influence of the deformations virtually has no effect on the testing results.

Figure 2. MTS Servo-controlled Hydraulic System

The maximum range of the system is ± 500kN. The System works in the following modes:

- Force (energy) control mode,
- Strain control mode,
- Actuator step control mode.

The testing is performed in the displacement control mode (the deformation of the testing specimen).
In advance defined testing mode was input in PDP PC program, while the sinuous alteration of dislocation is realized by function generator. The recorded data (the values of the force and actuator step) measured by MTS System are transmitted to PC through A/D converter.

Microsoft EXCEL software has been used to process the obtained measured data.
The testing started at 2 Hz frequency level, the data acquisition frequency was 100 samples per second, so that after one cycle of loading at 2 Hz 50 points per channel are obtained

Figure 3. illustrates the brief segment of specimen deformation variations as well as the number of measured data acquisition points .
The loading started with three cycles of ±1mm, ±2mm, ±3mm deformation amplitudes respectively, followed by 322 cycles of ±4mm deformation amplitude. Although the complete destruction of the specimen was not noticed the testing was finished after 331 cycle.

Figure 4 presents the complete time history of the specimen strain (over 16000 points). Figure 5 presents the alterations of force and deformation of the specimen during first 20 cycles.

To avoid the huge amount of the obtained data only summary graphical diagrams are presented in the Report, while the original measured values and complete analysis are given separately in e-form.

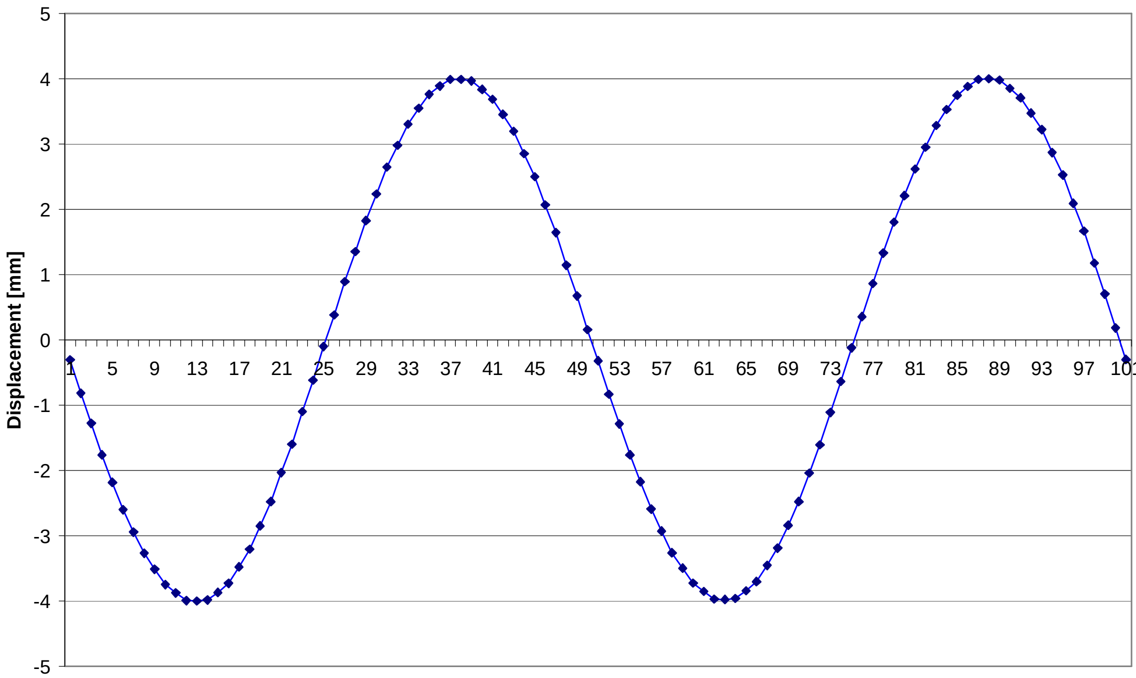

Figure 3. Brief segment of deformation variations recorded at data acquisition points

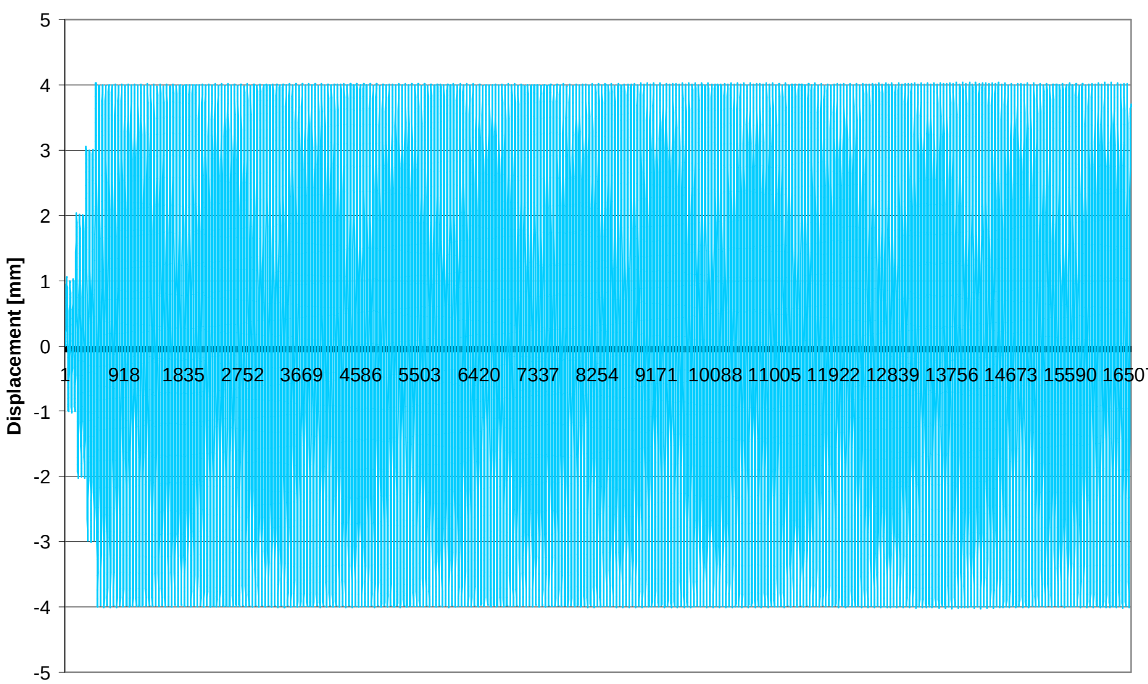

Figure 4. Time history of specimen strain variations.

5. TESTING RESULTS

The testing results are represented on the following Figures:

- Figure 6, Maximum/minimum displacement versus Number of cycles,
- Figure 7, Maximum/minimum force versus Number of cycles,
- Figure 8, Force versus displacement (hysteresis),
- Figure 11, Absorbed energy versus Number of cycles.

At deformation levels of ± 1mm, ± 2mm, ± 3mm and 6 cycles of ± 4mm the strain force is practically constant that is about 8kN (see Figure 7). During the following two cycles the Force decreases to 1.4 kN and keep that value till the end of testing. The reaction of the specimen to the push loading differs. The Force reaches the local maximum value after each strain increase and then decreases. During the first cycle the value of Force is 8kN at strain level of ± 1mm, during the third cycle the value of Force is 7.5kN. At ± 2mm strain level the Force decreases from 8.4kN to 7.5kN, at ± 3mm strain level the Force decreases from 13.9kN to 12.7kN. The maximum Force against push loading is 18,2 kN at first cycle ± 4 mm, then during the next 10 cycles it gradually decreases up to 13 kN and keep the value till the end of testing. As it shown on the diagrams the final fracture of the element that takes the pull loading occurred between 16th and 18th cycle, nevertheless the damper continued to take the significant push loading. The damper continue to take the pull loading by construction members friction.

Figure 8 indicates that there are two type of hysteresis: before and after the damper fracture. At the beginning of testing, during the first 16 cycles, the hysteresis area is very large (see Figure 9), while starting from 20th cycle till the end of testing the hysteresis area decreases significantly(see Figure 10). The absorbed (damped) energies correlate respectively. Figure 9 confirms the statement. The increase of deformation of damper specimen during the first 16 cycles is followed by the similar growth of the absorbed energy during each particular cycle. After the 18th cycle the absorbed energy vs. number of cycles is linear, but after the 140th cycle the gradient lightly decreases.

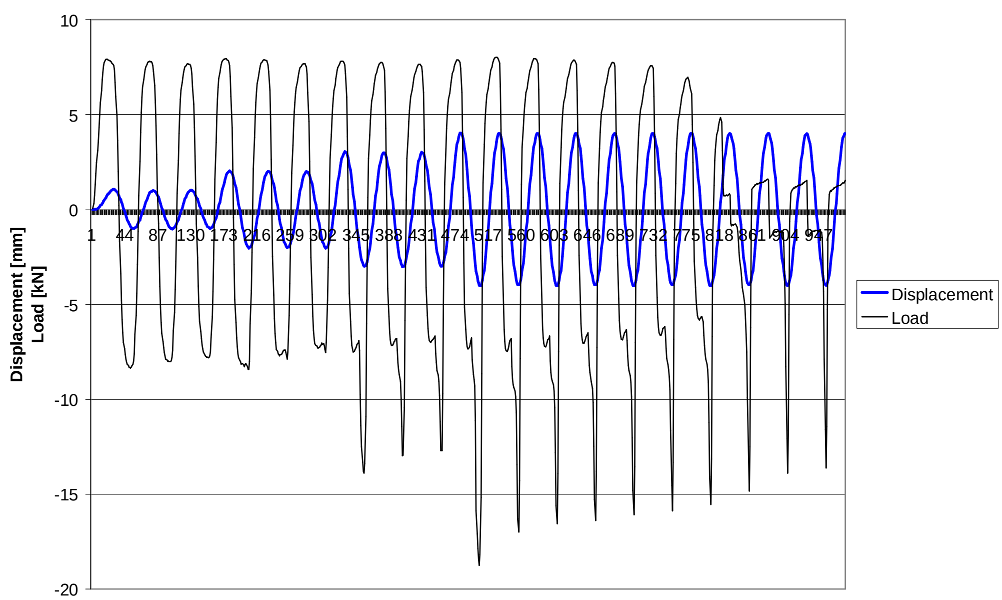

Figure 5. Force and deformation variations at specimen, from 1st to 20th cycle

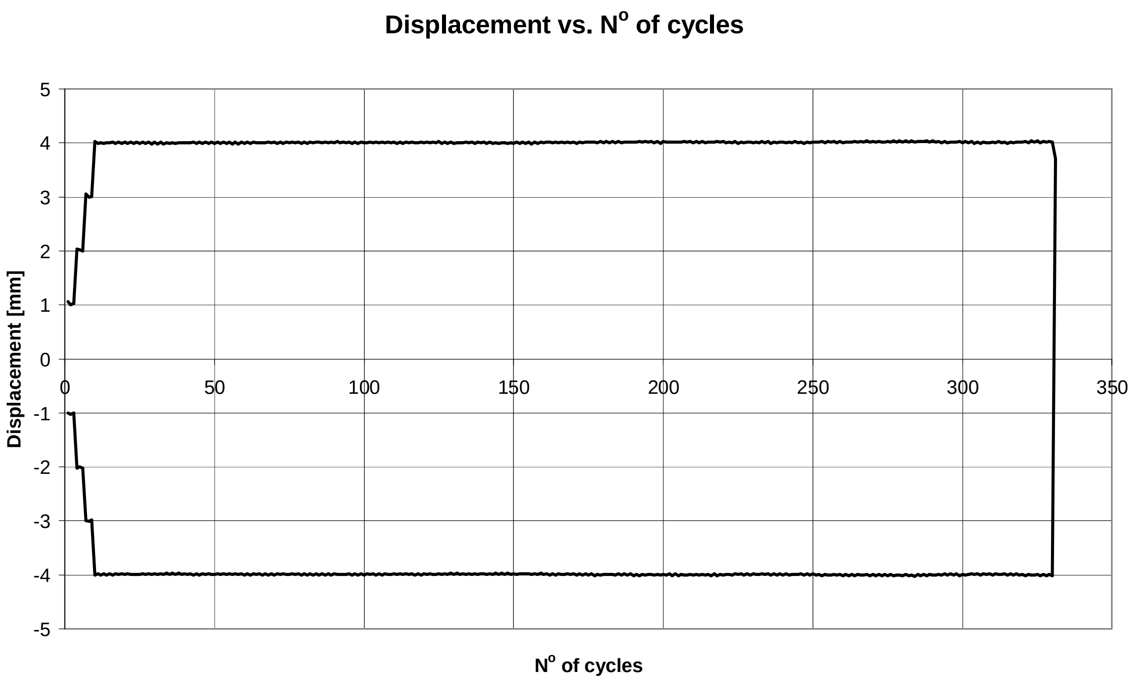

Figure 6. Maximum/minimum displacement vs. Number of cycles

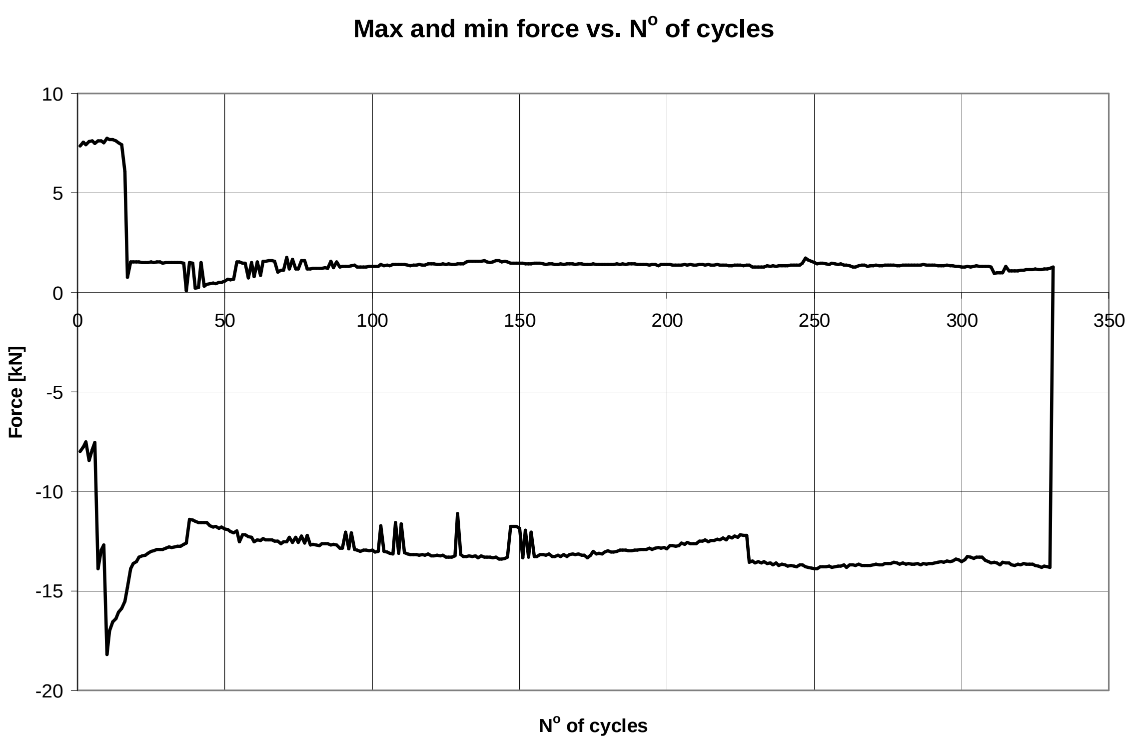

Figure 7. Maximum/minimum force vs. Number of cycles

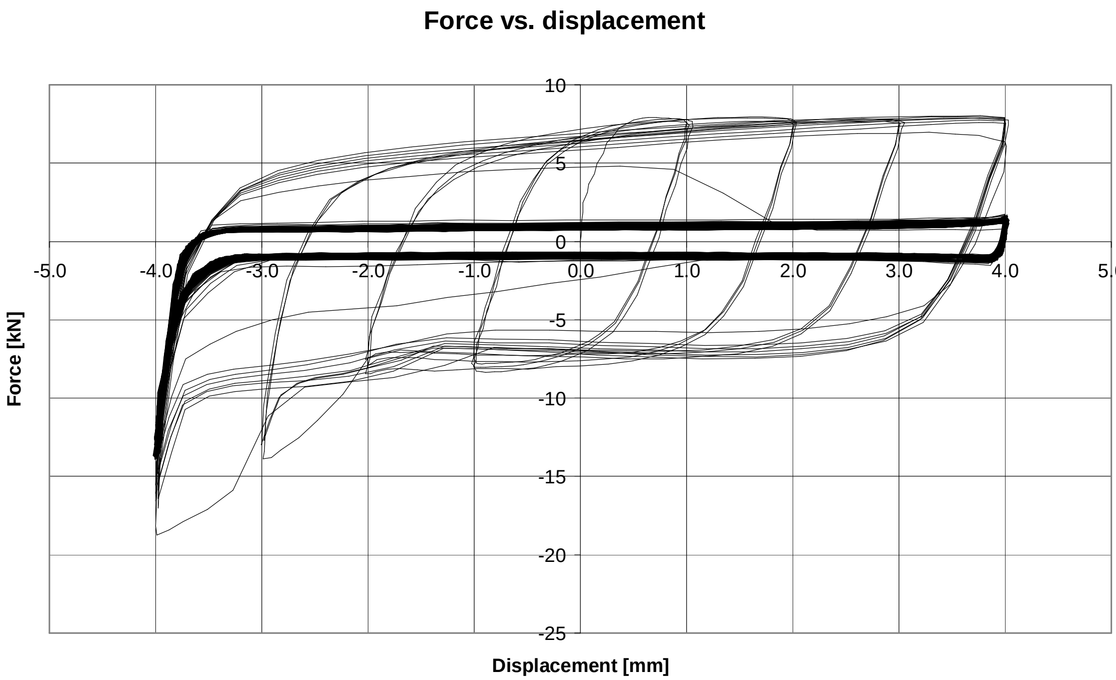

Figure 8. Force vs. displacement (hysteresis), all cycles

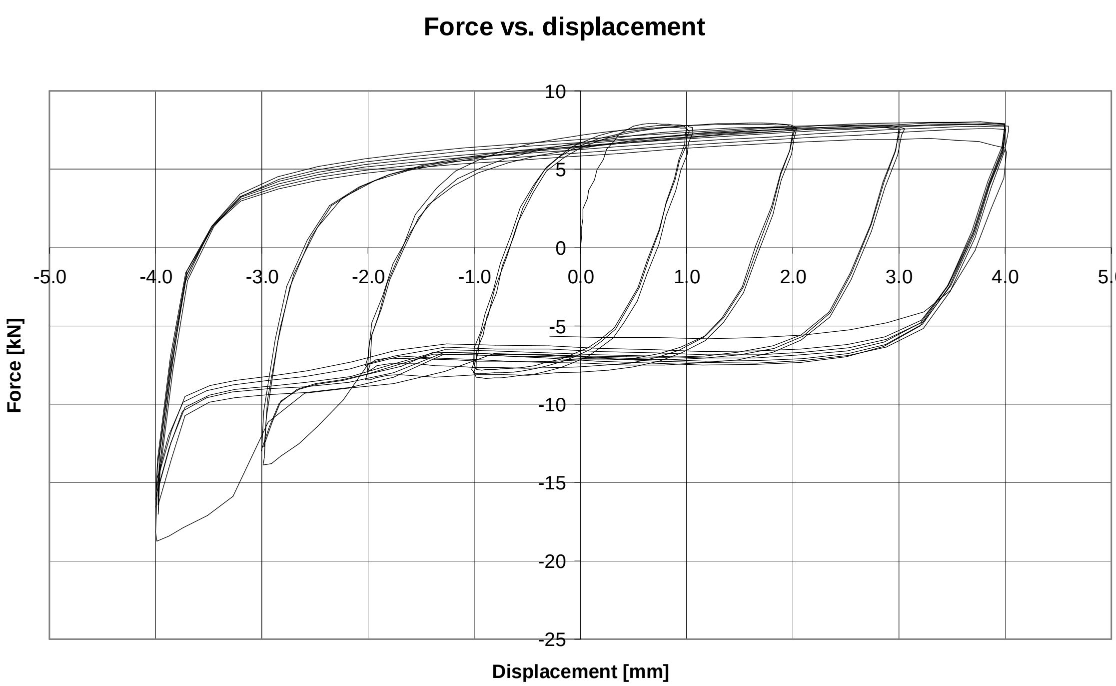

Figure 9. Force vs. displacement (hysteresis), first 16 cycles

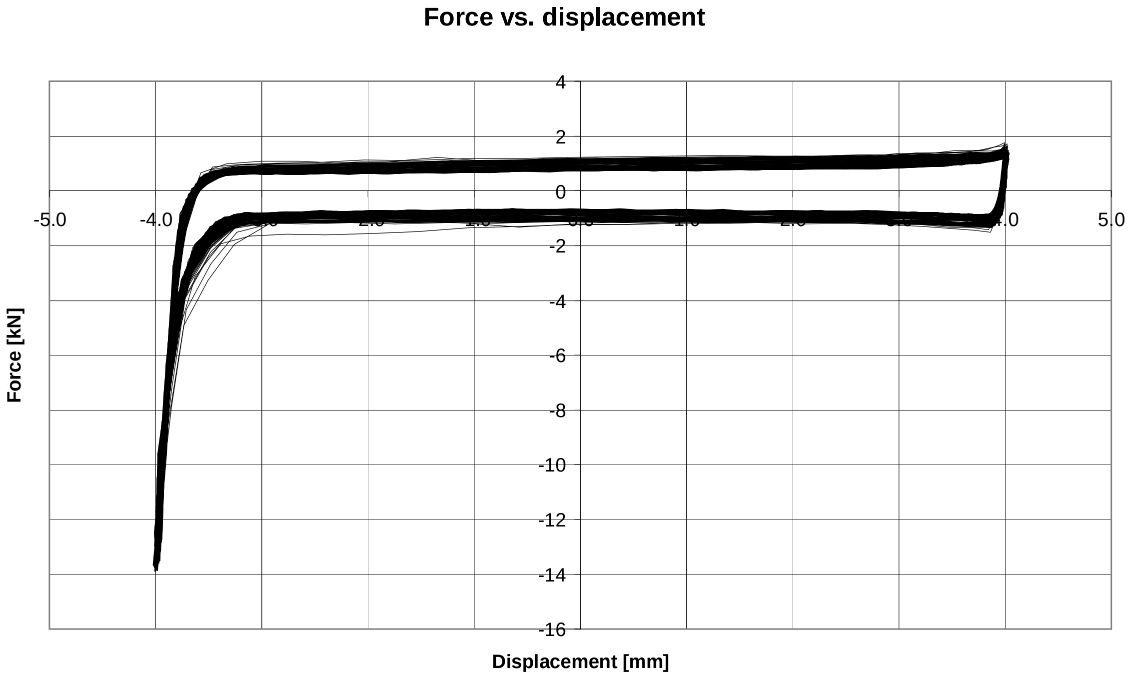

Figure 10. Force vs. displacement (hysteresis), from 18st to 331rd cycles

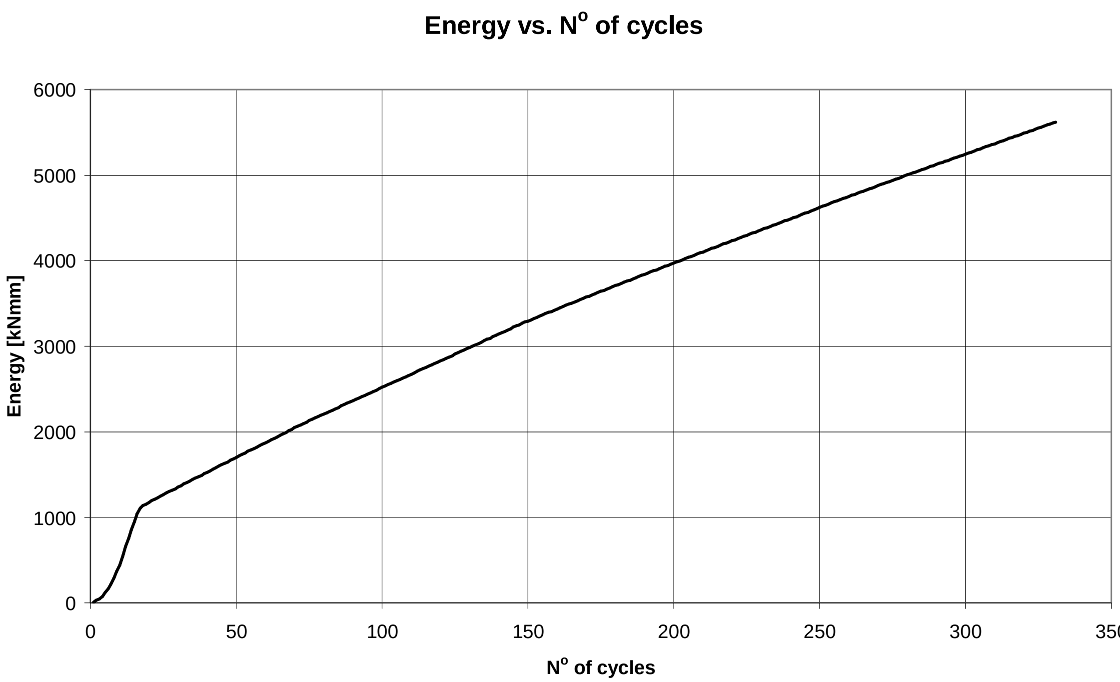

Figure 11. Absorbed energy vs. Number of cycles

Accumulated dilatation

Δl_u	$\lvert\Delta\varepsilon_u\rvert$	n_{cyc}	$\Sigma\lvert\Delta\varepsilon_u\rvert$
mm			
±1	0.01	3	0.06
±2	0.02	3	0.12
±3	0.03	3	0.18
±4	0.04	8	0.64
	Σ	**17**	**1.00**

$\left|\Delta\varepsilon_i\right| = \left|\frac{\Delta l_i}{l}\right|$ **-** accumulated dilatation during a semi-cycle

where

Δl_u – is the length increase (decrease) during a cycle,
l – is the length of the test specimen of 100 mm and
n_{cyc} – is the number of cycles.

Total accumulated dilatation is 1,00 during 17 loading cycles on a length of 100 mm on a dog bone Damper DC 90 type HQM.

5. CONCLUSION

The objective of the testing was to investigate the quality of the specimen in aspect of energy damping as well as to check the calculated domain of usage of the damper.

The damper specimen withstood 331 cycles of loading mostly at ± 4 mm and maximum loading up to 8kN (-18.7kN), the damping capacity of the specimen was very effective. As far as the testing was interrupted after 331 cycles before the final fracture of the specimen it is obvious that the damper would continue to absorb the energy according to the linear law.

The total amount of the absorbed energy is 5620kNmm, 1200kNmm of them were absorbed during the first 20 cycles.

The recommended application domain of the tested damper is ± 4 mm.

It should be also noted that the damper has very high plastic capacity of the material (post collapse capacity) even after the degradation of the construction and lower level of pull capacity

TESTING IS ORDERED BY

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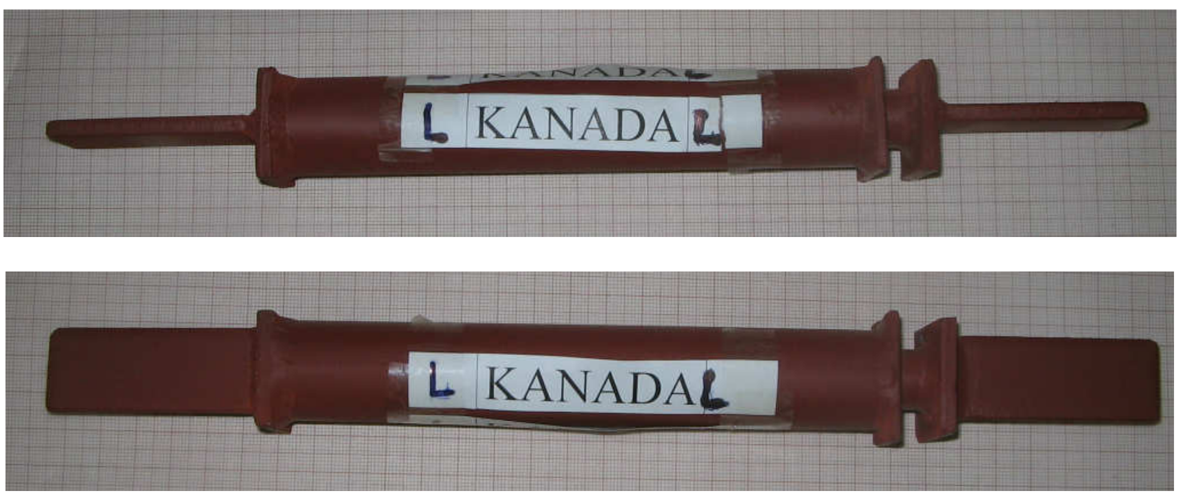

Figure 1. View of Damper type "Canada" (absorber of seismic energy).

2. CUSTOMER ORDER

The Customer ordered to conduct the dynamic loading test on type "Canada" damper (the absorber of seismic energy developed by "SYSTEM DC90") according to the Test Program. The testing results of the delivered specimen should meet the quality requirements in the aspect of the energy damping.

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Figure 2. MTS Servo-controlled Hydraulic System

The maximum range of the system is ± 500kN. The System works in the following modes:

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Microsoft EXCEL software has been used to process the obtained measured data.
The testing started at 2 Hz frequency level, the data acquisition frequency was 100 samples per second, so that after one cycle of loading at 2 Hz 50 points per channel are obtained

Figure 3. illustrates the brief segment of specimen deformation variations as well as the number of measured data acquisition points .
The loading process began with 3 cycles of deformation amplitudes of ± 1 mm, ± 2 mm, ± 3, ± 4 and ± 5 mm, followed by 92 additional cycles with an amplitude of ± 5,5 mm. Even though after the 15th cycle, at the deformation of ± 5 mm, the specimen was destroyed completely, the testing was stopped after the 107th cycle. Figure 4 represents the complete history of dilatation of the tested specimen (over 2600 points), while figure 5 shows the changes in force and deformation of the test specimen during the first 20 cycles.

To avoid the huge amount of the obtained data only summary graphical diagrams are presented in the Report, while the original measured values and complete analysis are given separately in e-form.

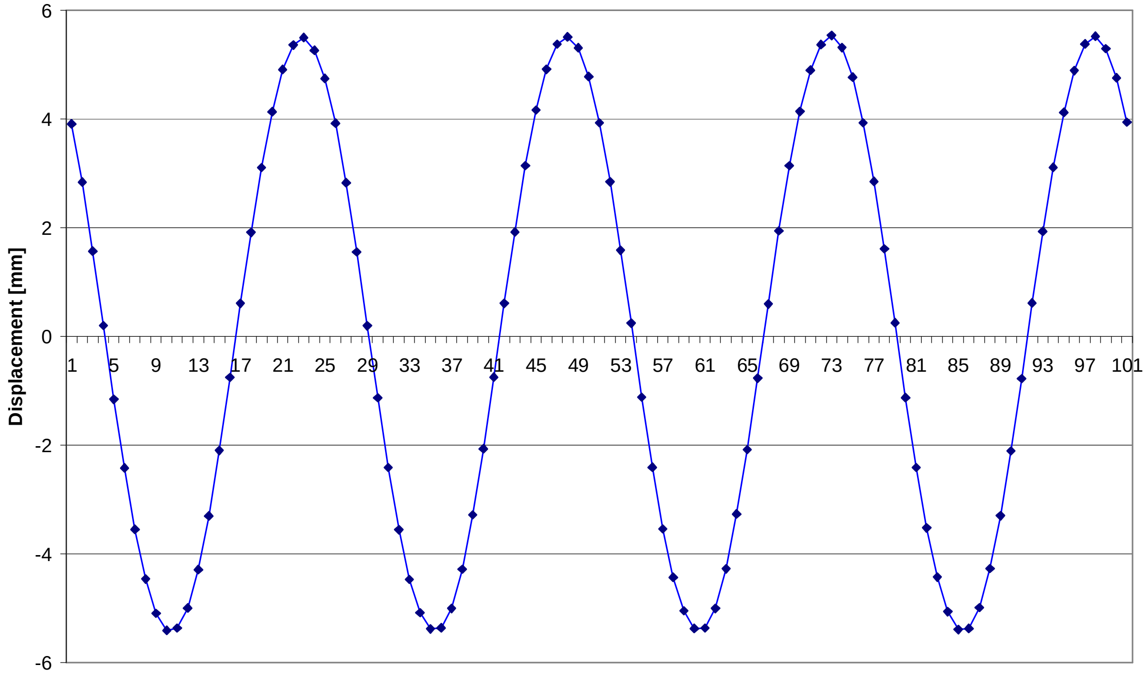

Figure 3. Brief segment of deformation variations recorded at data acquisition points

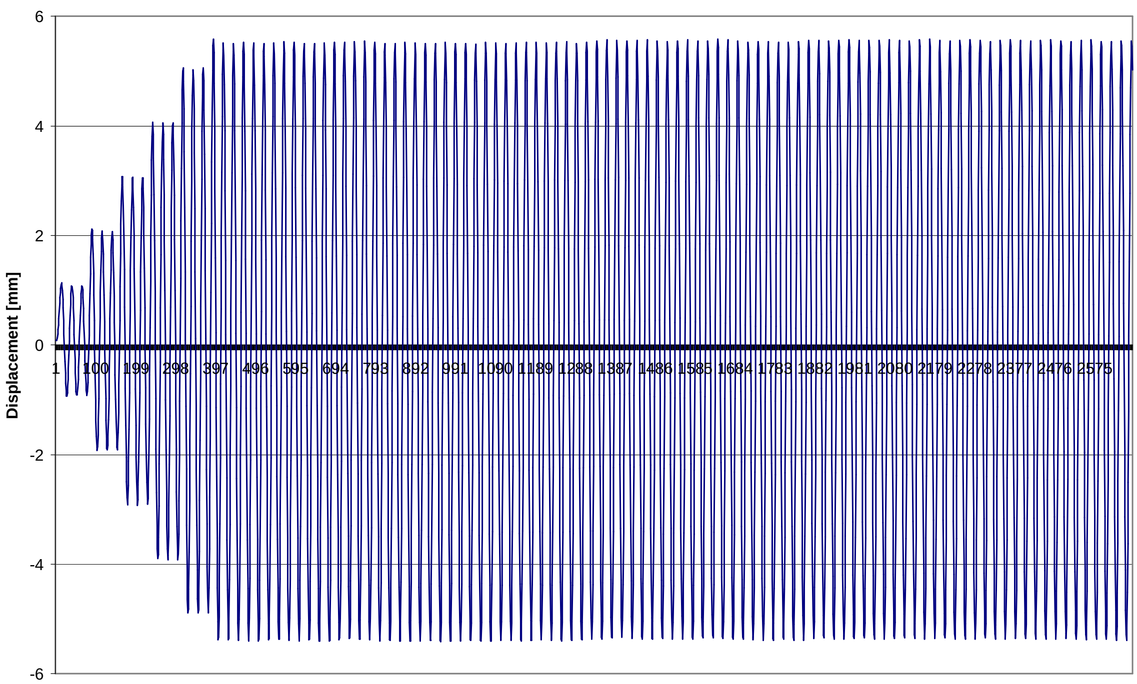

Figure 4. Time history of specimen strain variations.

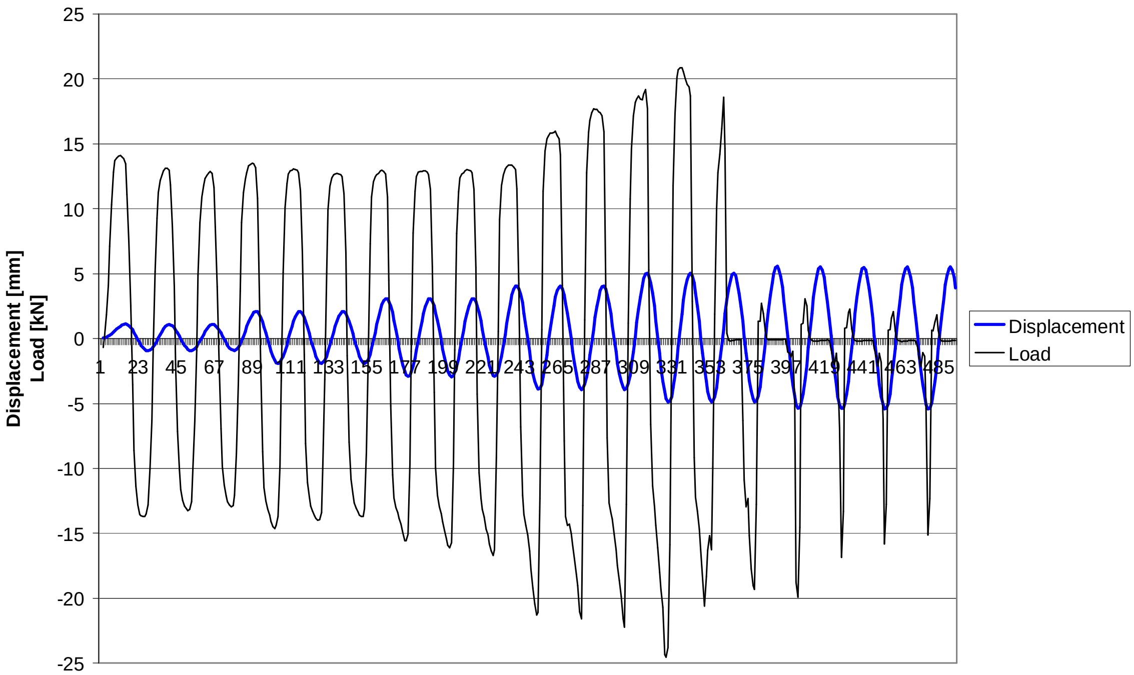

Figure 5. Force and deformation variations at specimen, from 1st to 20th cycle

4. TESTING RESULTS

Testing results are represented on the following diagrams:

- Figure 7, Maximum/minimum deformation vs number or cycles,
- Figure 8, Maximum/minimum force vs number of cycles,
- Figure 9, Force vs deformation (hysteresis)
- Figure 12, Absorbed energy vs number of cycles.

At deformation levels of ± 1 mm and ± 2 mm the force is slightly decreasing, at ± 3 mm there is a slight increase and hints of pressure degradations, and at ± 4 mm and ± 5 mm the force is growing with noticable construction yielding. During the fifteenth cycle (± 5 mm), there was a break on the outer part of the tube (figure 6), which lead to the tube not being able to take any more pull loading, however the dumper still could take considerable push loading. This load decreased from 20 kN to around 8-9 kN for the next 30 cycles at deformation level of ± 5,5 mm.

Figure 9 clearly shows two types of hysteresis, before and after damper degradation. At the start of testing, during the first 15 cycles (figure 10), hysteresis areas are large, where as in the following stage of testing until the end (figure 11), these areas are significantly smaller. This is also the relation between dampened energies. Which is even more noticable in figre 12. As the damper deformation increases during the first 15 cycles, so does the dampened energy of single cycles. After the 16th cycle, the dampening energy is a linear function, where as after the 50th cycle the gradient is slightly lower.

Figure 6. A broken test specimen

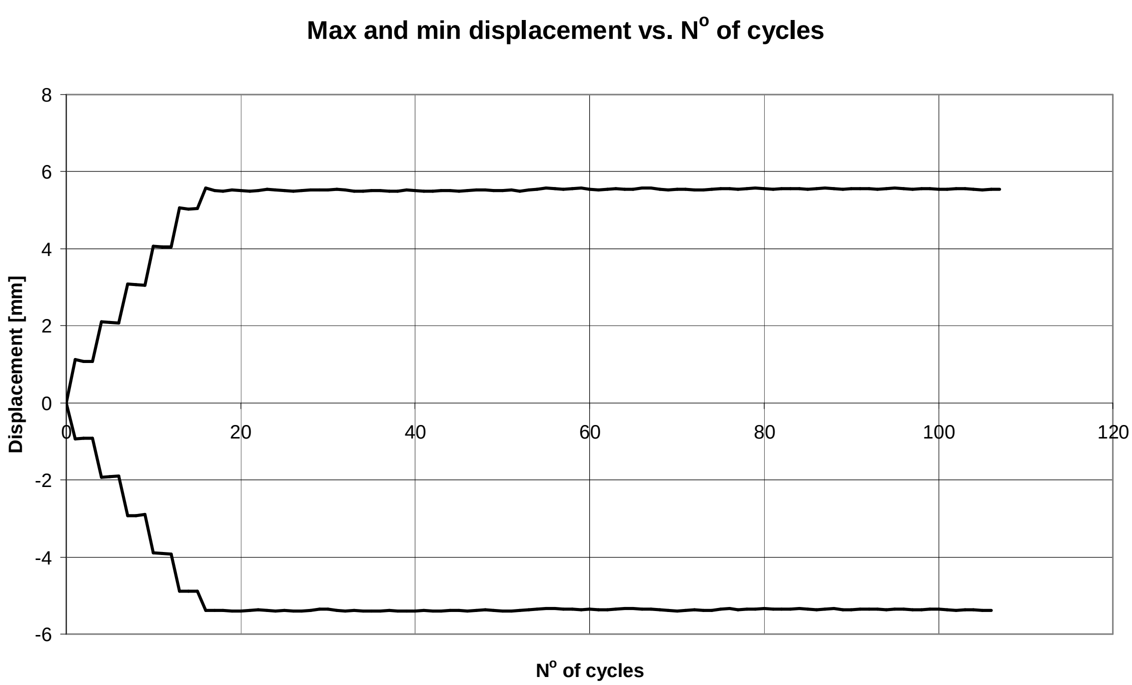

Figure 7 Maximum/minimum deformation vs number of cycles

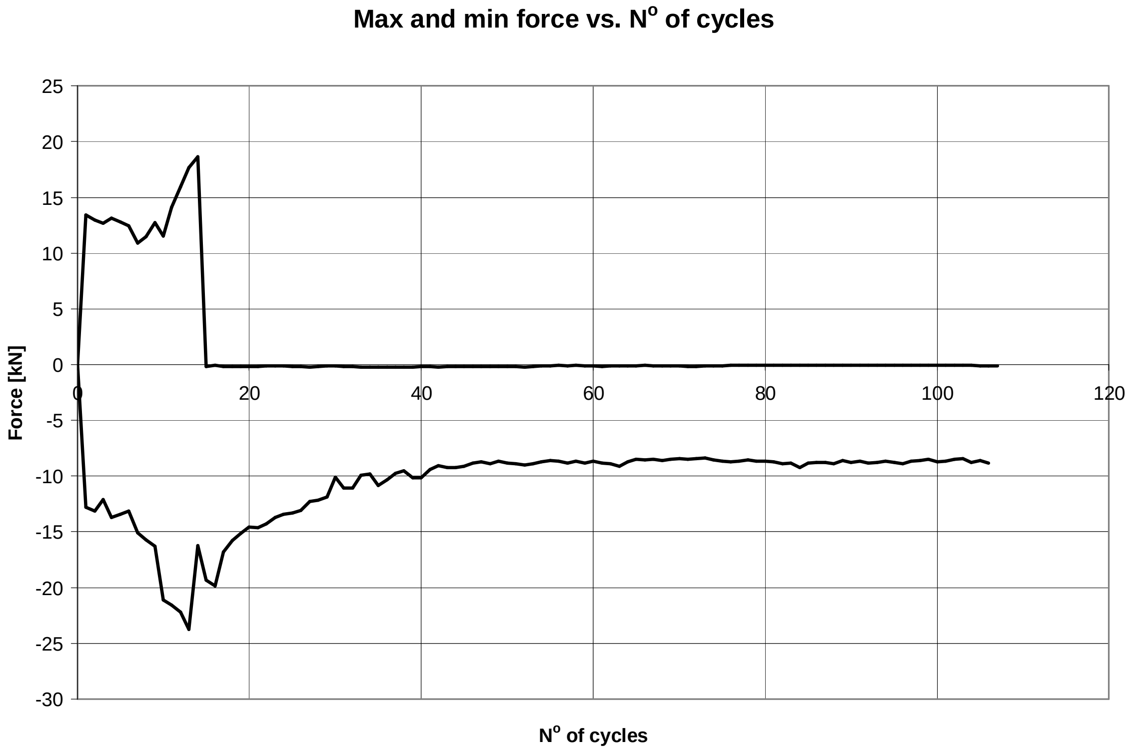

Figure 8 Maximum/minimum force vs number of cycles

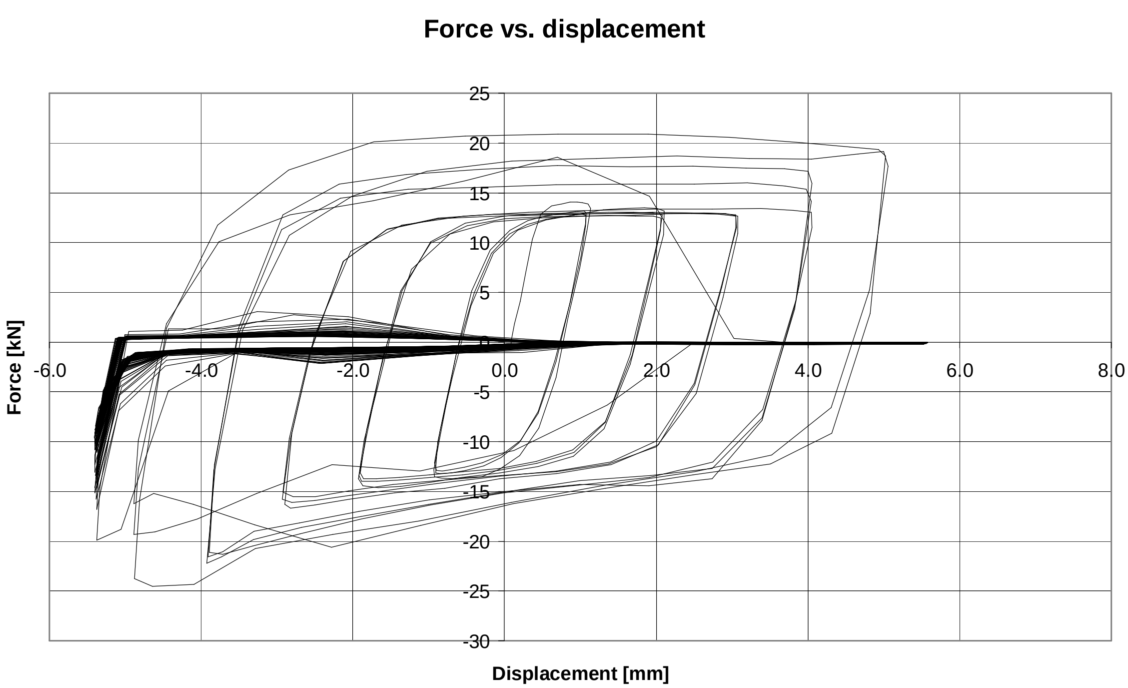

Figure 9 Force vs deformation (hysteresis) for all cycles

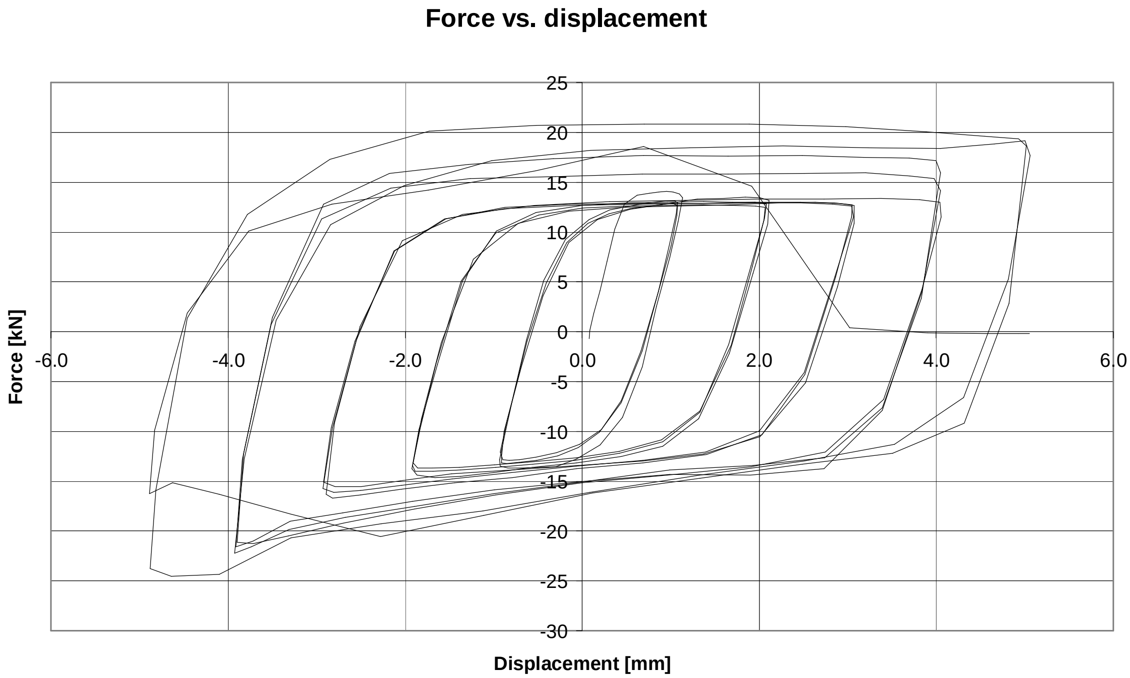

Figure 10 Force vs deformation (hysteresis) during the first 15 cycles

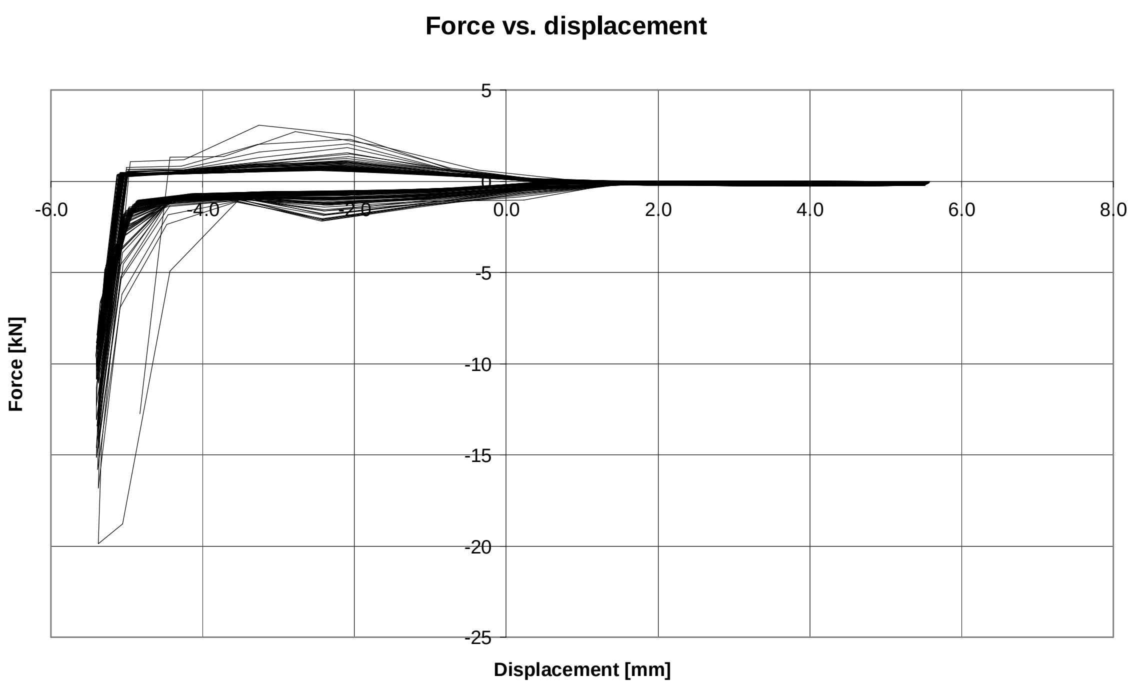

Figure 11 Force vs deformation (hysteresis), cycles 16 to 107

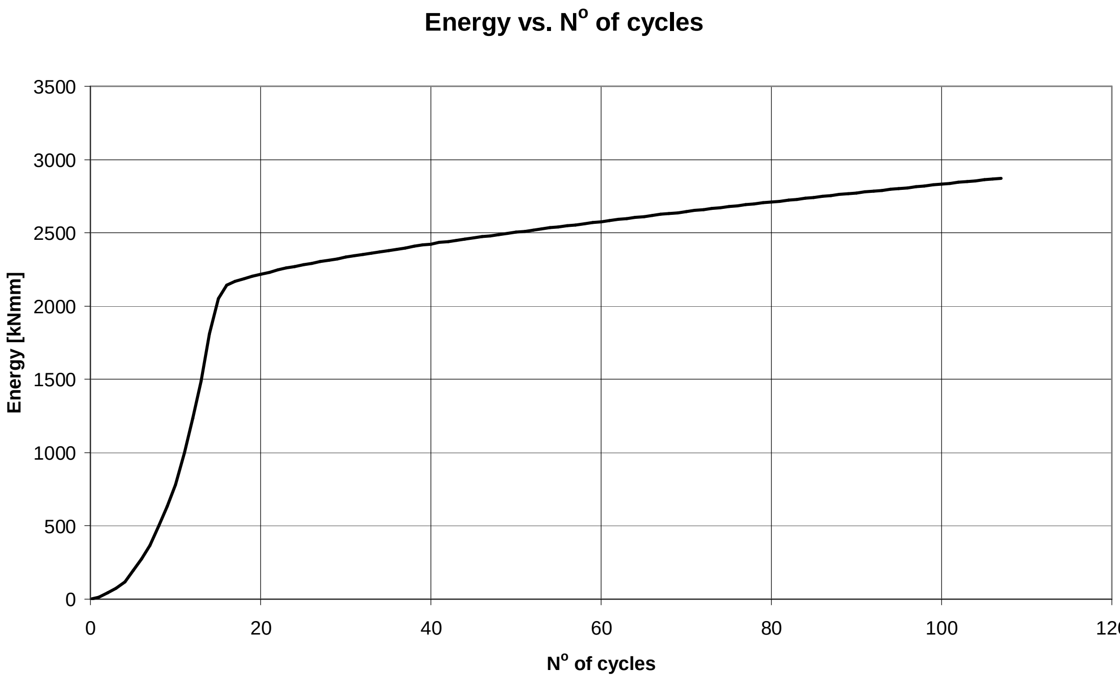

Figure 12 Absorbed energy vs number of cycles

Accumulated dilatation

Δl_u	$\lvert\Delta\varepsilon_u\rvert$	n_{cyc}	$\Sigma\lvert\Delta\varepsilon_u\rvert$
mm			
±1	0.01	3	0.06
±2	0.02	3	0.12
±3	0.03	3	0.18
±4	0.04	3	0.24
±5	0.05	2	0.20
	Σ	**14**	**0.80**

$\left|\Delta\varepsilon_i\right| = \left|\frac{\Delta l_i}{l}\right|$ **-** accumulated dilatation during a semi-cycle

where

Δl_u – is the length increase (decrease) during a cycle,
l – is the length of the test specimen of 100 mm and
n_{cyc} – is the number of cycles.

Total accumulated dilatation is 0,80 during 14 loading cycles on a length of 100 mm on a dog bone Damper DC 90 type HQL.

5. CONCLUSION

The objective of the testing was to investigate the quality of the specimen in aspect of energy damping as well as to check the calculated domain of usage of the damper.

Damper was tested for a total of 107 loading cycles, with maximum at ± 5,5 mm, and maximum loading of + 19 kN (-24 kN), during which it absorbed the energy very effectively. During the 15th cycle a break occured in the outer part of the tube, which resulted in its inability to take pull loading, but the damper continued to take significant push loading.

The total amount of dampened energy is 2870 kNmm, out of which 2100 was dampened during the first 15 cycles.

Recomended area of use of the tested damper is up to ± 5 mm.

It is also important that this damper hase a high material plasticity reserve (post-collapse capacity) even after the construction degradation, when it can no longer take pull loading.

Report is prepared by

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Dragutin Georgijevich, Civil Eng.

ON BEHALF OF MTI
DIRECTOR

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Dr. Zijah Burzic, Civil Eng.