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REPORT ON RESEARCHOF DAMPERS - ABSORBERS OF SEISMIC ENERGY SYSTEM DC 90

No. 108/06-03-02

Orderer:	**“ SYSTEM DC 90”, 11000 Belgrade, Vele Nigrinove 1**	
Orderer request:	**VTI no. 08/1236-1 dated 02.04.2013.**	
Sample:	**9 dampers HQM**	
Way of sampling:	**Sampled by user:** **Yes**	**Sampled by laboratory:** **No**
Data of sampling:	**08.04.2013.**	
Research method:	**Dynamic research**	
Surrounding conditions:		
Research equipment:	**Servo-hydraulic plucker MTS**	
Measuring equipment:		
Measuring uncertainty:		
Research period:	**(from 08.04. till 09.04. 2013.)**	

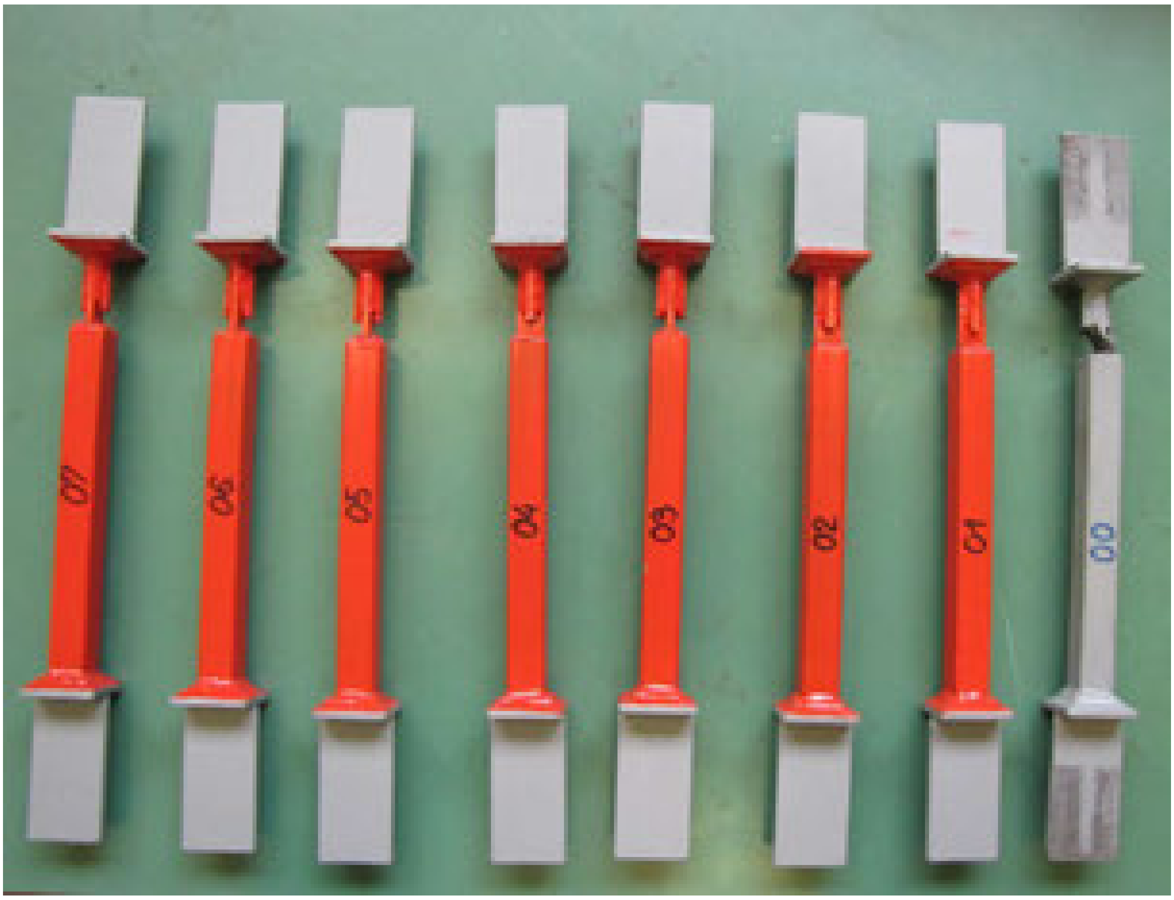
CONTENT:

	RESEARCH	SUPERVISED BY	AUTHORIZED BY	STAMPED BY
Function	Head of project	Head of laboratory	Head of sector 3	Head of sector 06
Name and surname	**Dragutin Georgievich, Bc. engineer**	**Rade Konyikushich, Bc. engineer**	**Stevan Maksimovich, PhD.Bc. Engineer**	**Voyislav Devich, Bc. engineer**
Signature				
Name and surname	Independent researcher **Srdja Perkovich, Bc. engineer**			
Signature				

1. RECEIVED SAMPLES

The orderer of the service has delivered 9 dampers-absorbers of seismic energy HQM of System DC 90 for research.

View of received samples is given on the picture 1, out of which 00 has already been tested and sample 08 has been set in mouth of a plocker for research.



Picture 1 Dampers – absorbers of seismic energy HQM

2. ORDERER'S REQUEST

To fulfill dynamic research of dampers – seismic energy absorbers HQM, of System DC 90 according to the submitted Research program. Research results should give the quality appreciation of the submitted samples from the aspect of energy amortization.

3. RESEARCH PROCEDURE

Research has been done on plucker of servo-hydraulic system MTS, Picture 2. Ends of laboratory samples are clenched by claws of the plucker for flat samples, so that influence of their deformations on measuring results is almost neglectable.

This system of maximum range 150mm and force ± 500 kN, can work in control:
Овај систем максималног хода од 150 mm и силе ± 500 kN, може да ради у контроли:

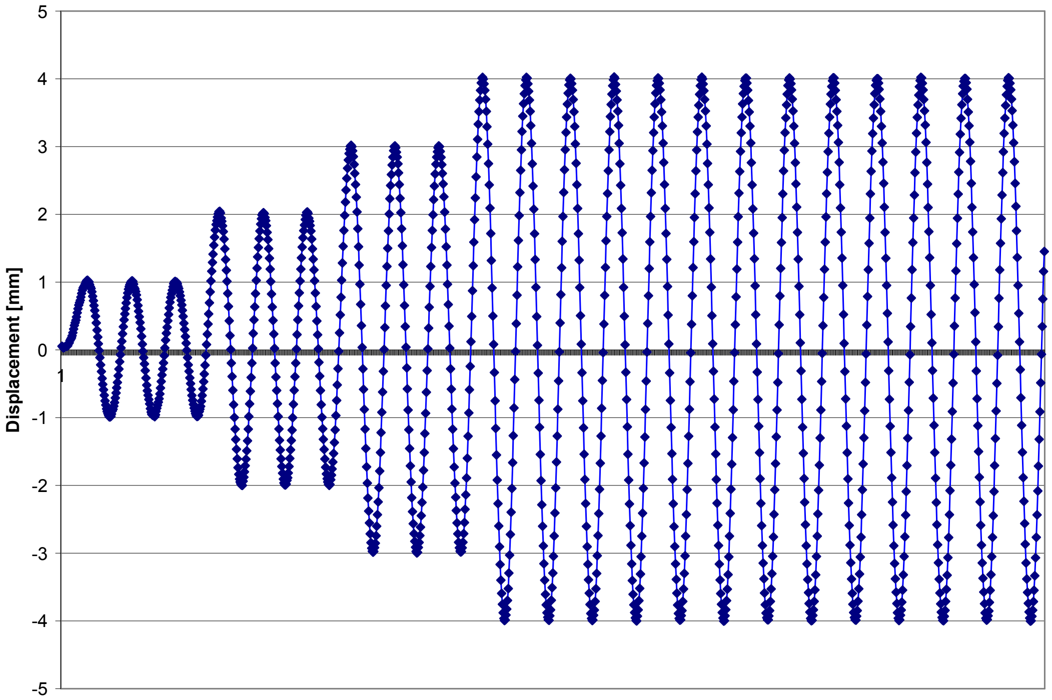
- of force,
- dilatation and
- walk of actuator's kernel

Picture 2 Servo-hydraulic system MTS

Research has been done in control of kernel movement, which in this case is deformation of research sample. The defined regime of research has been entered in program of PDP computer, and sinusoid change of movement has been managed by generator of function. The measured values (of force and and motion of actuator) are sent from MTS device over A/D convertor to PC computer. The data processing of measuring has been done by Microsoft EXCEL program.

Research has been done with frequency of 1 Hz, and acquisition of measuring data has been 60S/s (sample – sample in second) so that for one cycle of load at 1 Hz it registers 60 points by channel. Picture 3, which represents the short segment of change of the deformation of sample, shows number of points of acquisition of measuring data.

Because of plenty of measured data, in the report are given only the summarized diagrams and original data and the complete analysis are given in electric (digital) form.



Picture 3 Change of deformations in the first 22 cycles with points of data acquisition.

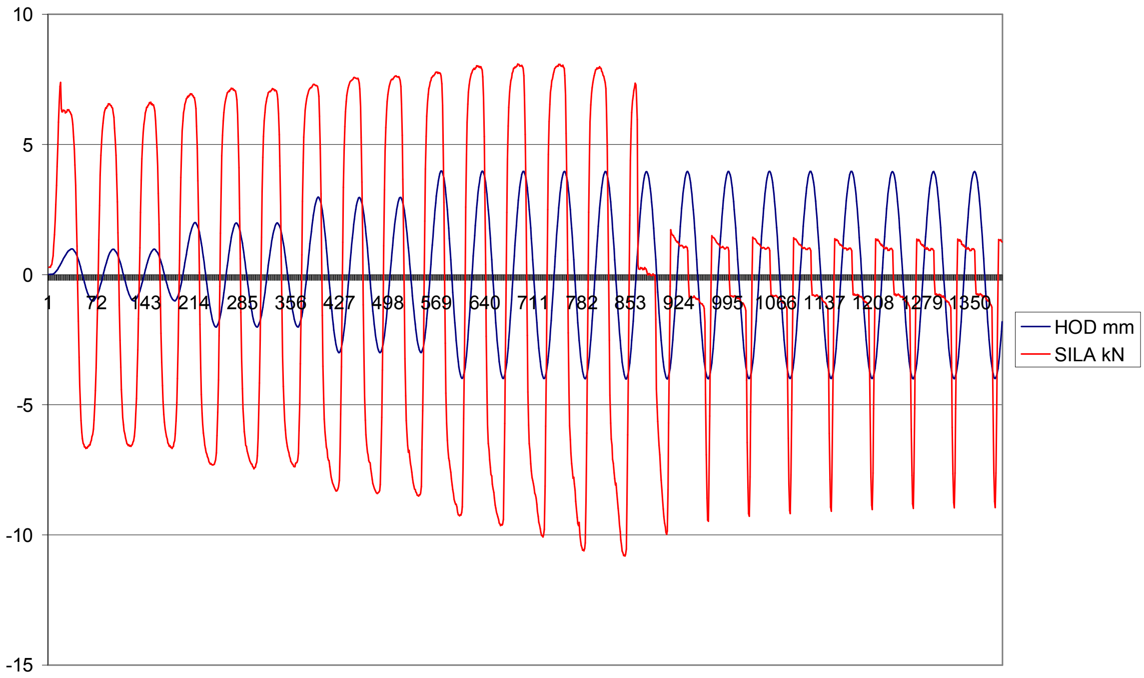
4. FIRST GROUP OF SAMPLES WITH LOAD SPECTRUM SAMPLES 0, 1, 5, 6, 7 and 8

4.1 Research

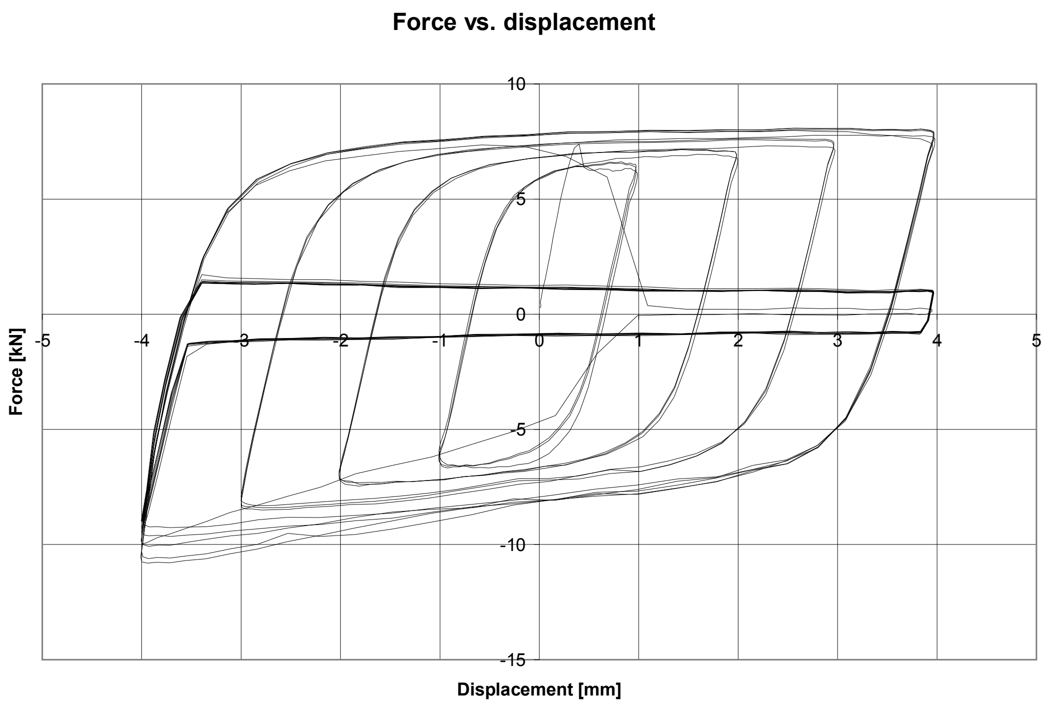
Load has begun by three cycles with deformation amplitudes of ± 1 mm, ± 2 mm, ±3 mm and ± 4 mm, till first appearance of breaking (force decrease). After that had been 250 to 300 cycles with ± 5,5 mm amplitude. If even then it didn't lead to complete destruction of the sample, amplitude has been increased to ± 9,5 mm in order to register the post-collapse condition of the sample.

Pic. 4 represents history of deformation change and force of sample no.5. in first 23 cycles, while pic.5. shows histeresis – change of force of the same sample in function of deformation in the same interval of time.

Although after 15. cycle, it had come to degradation of damper, it didn't come to the complete destruction of the sample, which still receives load to pressure. Research has been continued with 300 cycles with amplitude ± 5,5 mm, and then the amplitude has been increased till ± 9,5 mm, while around 340 cycles it camo to complete destruction of the sample.

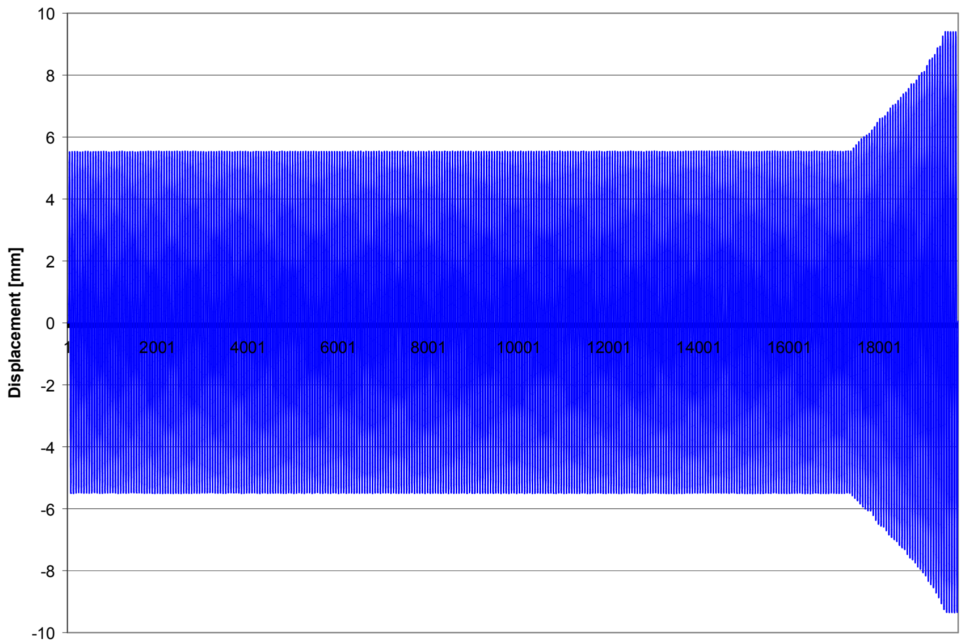


Pic 4 History of deformation change and force of sample 5 during first 23 cycles.

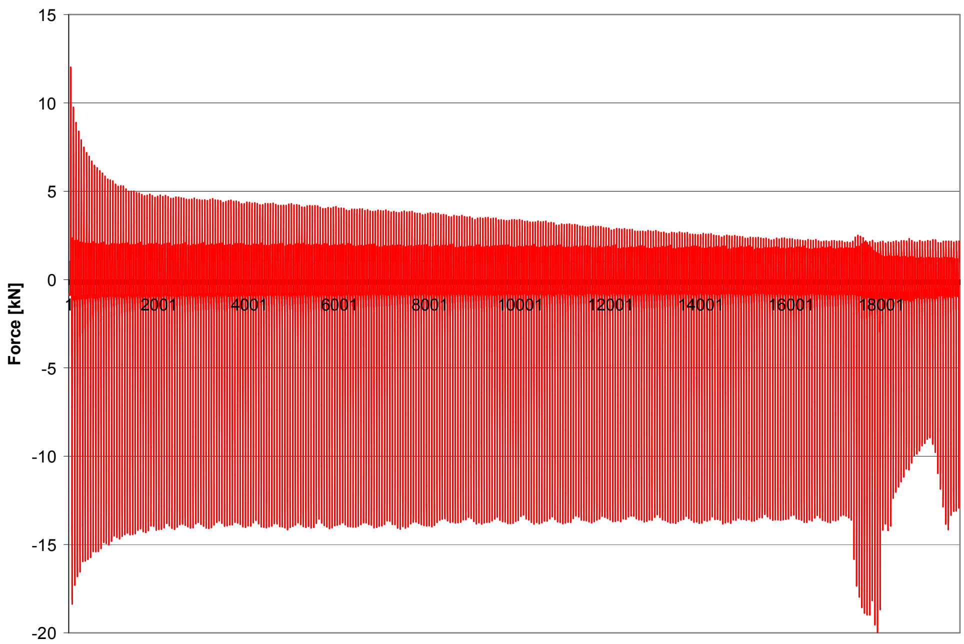


Pic. 5 Hysteresis of sample 5 in first 23 cycles.

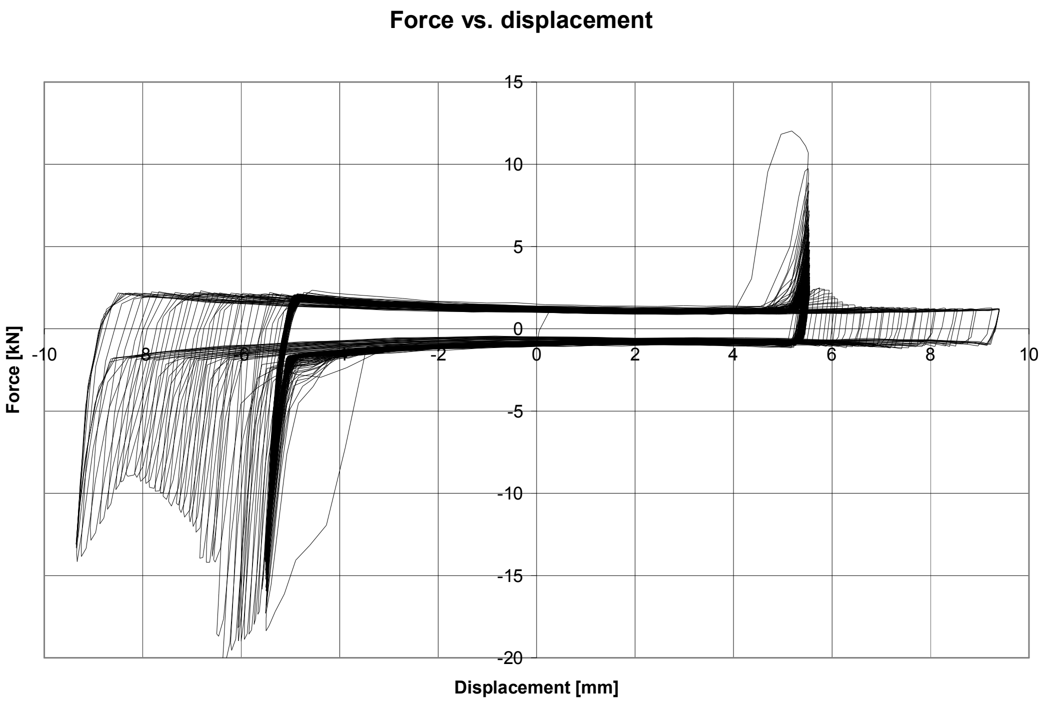
Picture 6 shows history of deformation change, and pic. 7 change of force of sample no. 5 in the followng 340 cycles of post-collapse research, while pic. 8 shows hysteresis – change of force of the same sample in function of deformation in same interval of time.



Pic. 6 deformation changes in 340 cycles of post-collapse research.



Pic. 7 Force change in 340 cycles of post-collapse research.



Pic. 8 Hysteresis of sample 5 in 340 cycles of post-collapse research.

4.2 Processing and analysis of research results

Research reluts shown:

In first 23 research cycles

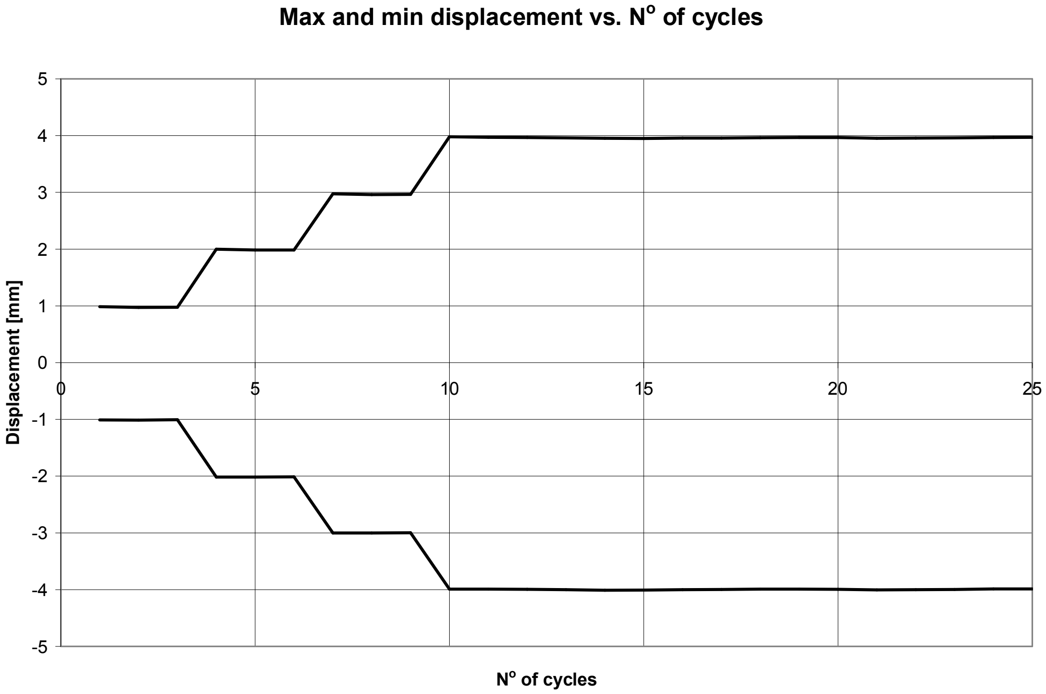
- Maximum/minimum deformation in function of cycle number, Picture 9,
- Maximum/minimum force in function of cycle number, Picture 10,
- Absorbed energy in function of cycle number, Picture 11,

In 340 cycles of post-collapse research

- Maximum/minimum deformation in function of cycle number, Picture 12,
- Maximum/minimum force in function of cycle number, Picture 13,
- Absorbed energy in function of cycle number, Picture 14.

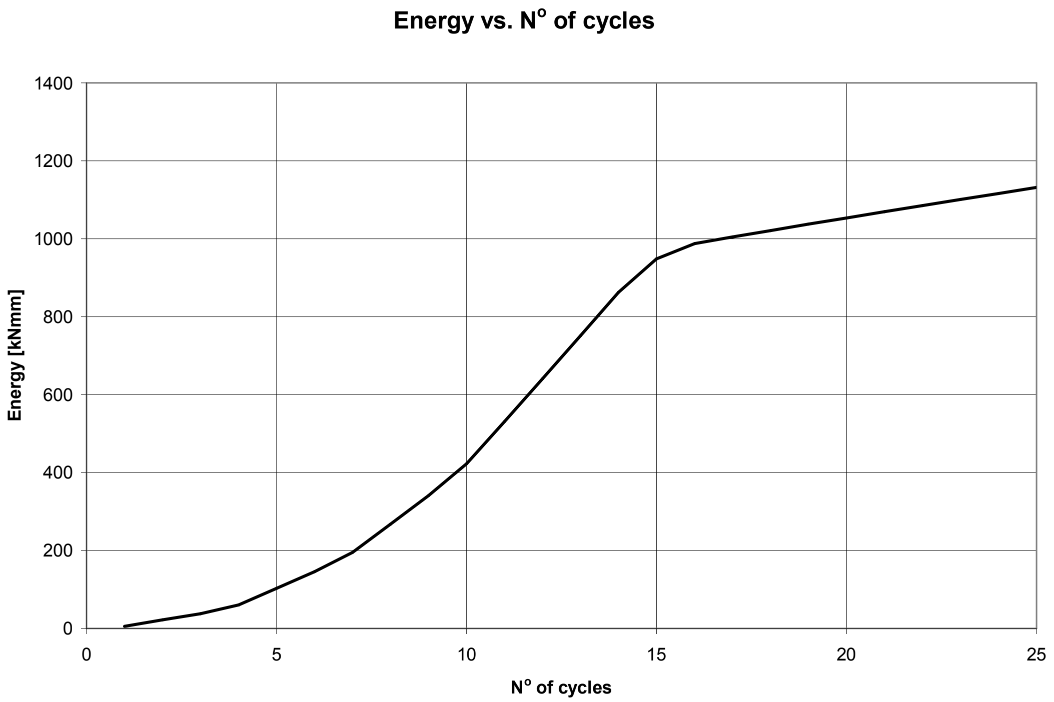
At deformations by three cycles ± 1 mm, ± 2 mm and ± 3 mm, as well as in following five cycles ± 4 mm, force increases, and in 15. cycle there is degradation of the sample, pic. 4 and 10. At pic. 5 is seen that hysteresis is pretty stable and it has a great surface, i.e. it well amortizes energy till 15. cycle. From 15. cycle there is degradation of the sample, force significantly decreases, especially to tightening.

It can be seen at pic. 8 where the surface of hysteresis is getting smaller, i.e. amortization of energy is getting weaker. At pic. 11 is seen change of gradient of energy curve.

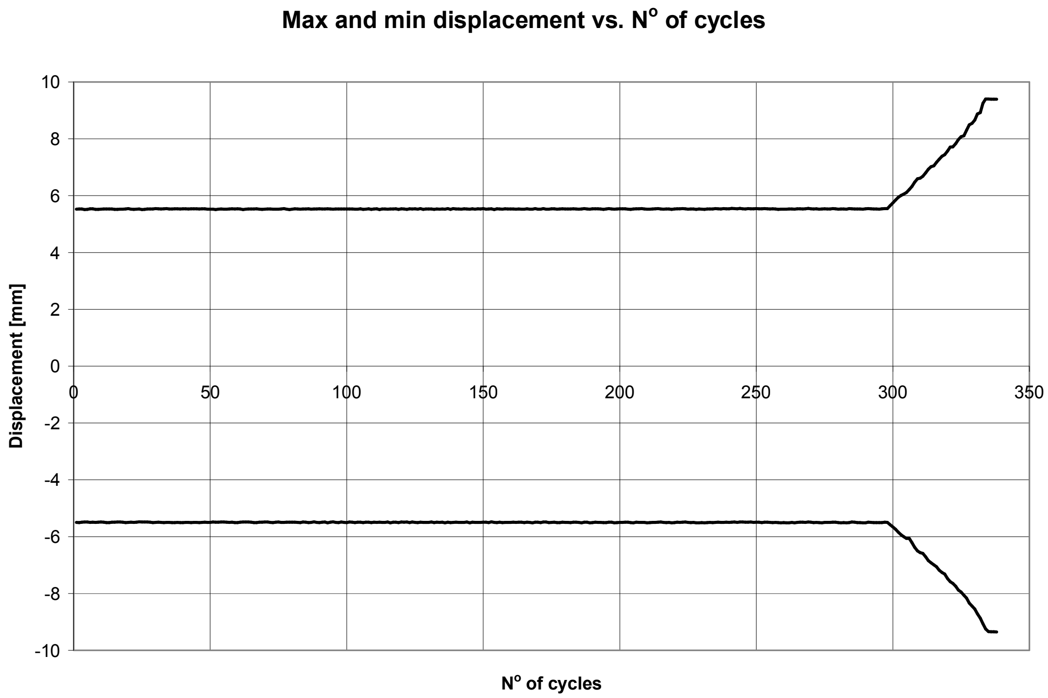


Picture 9 Maximum/minimum deformation - start

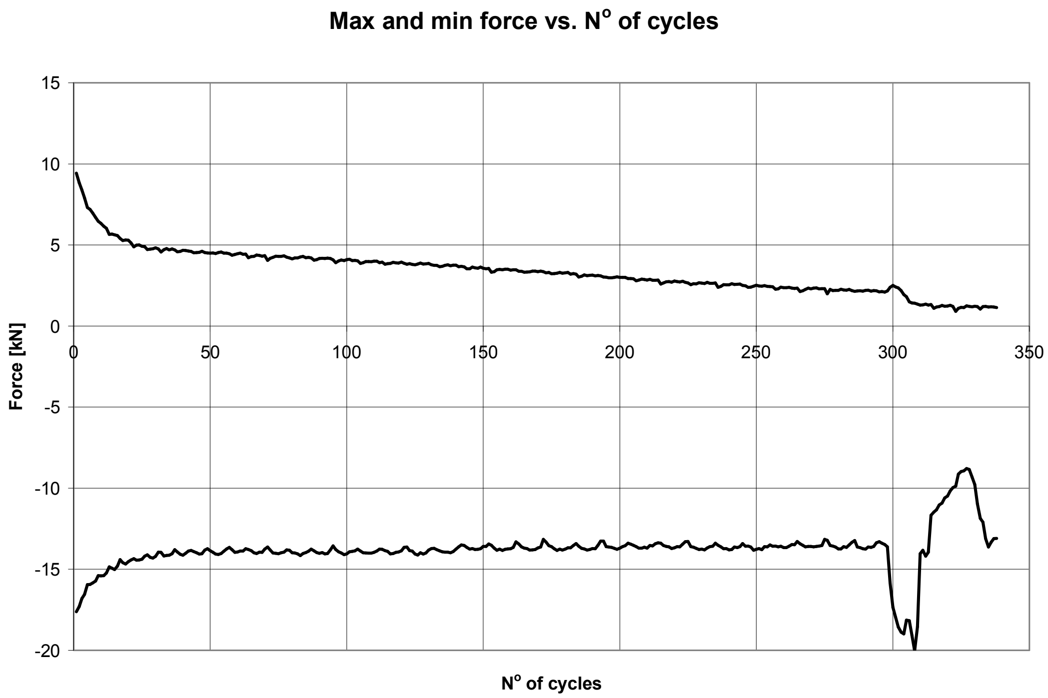
Picture 10 Maximum/minimum force - start



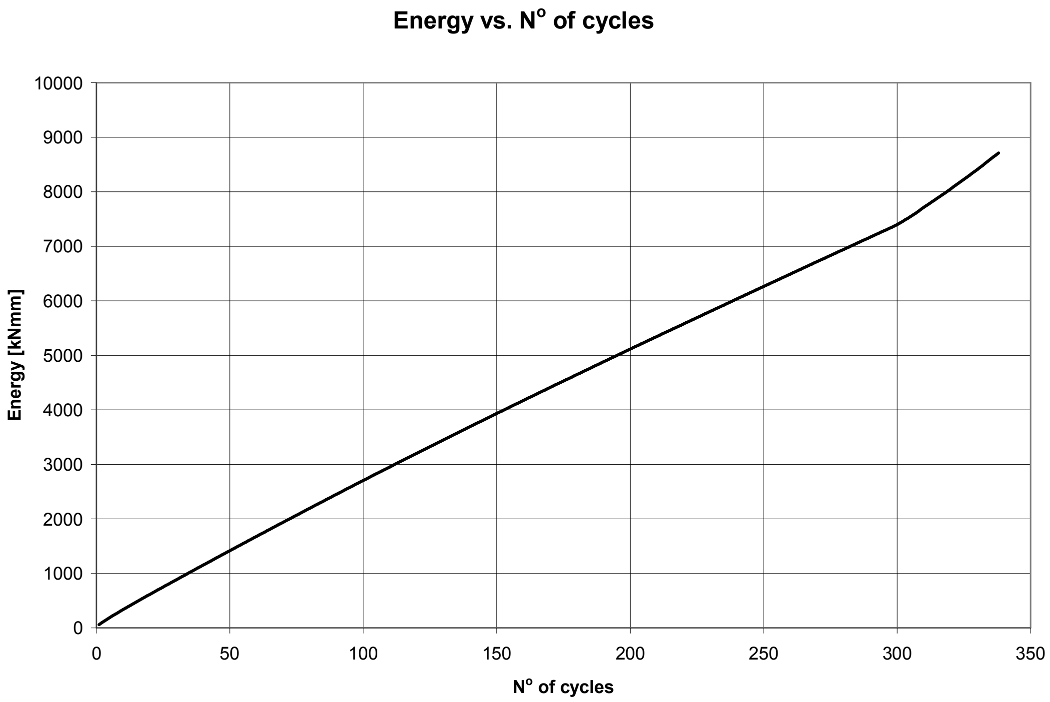
Picture 11 Absorbed energy – start



Picture 12 Maximum/minimum deformation - postcollapse



Picture 13 Maximum/minimum force - postcollapse



Picture 14 Absorbed energy – postcollapse

Accumulated dilatation of sample 5

Δl_i	$\lvert\Delta\varepsilon_i\rvert$	n_{cyc}	$\Sigma\lvert\Delta\varepsilon_i\rvert$
mm			
±1	0.0087	3	0.05
±2	0.0174	3	0.10
±3	0.0261	3	0.16
±4	0.0348	6	0.42
	Σ	**15**	**0.73**

$\left|\Delta\varepsilon_i\right| = \left|\frac{\Delta l_i}{l}\right|$ – accumulated dilatation in one half-cycle

где je

Δl_i – prolongation (shortening) in one cycle,
l – length of experimental sample where dilatation is developed in 115 mm and
n_{cyc} – cycle number.

Total accumulated dilatation is 0,73 in 15 cycles of load at length of 115 mm dog-bone Damper DC 90 of type HQM.

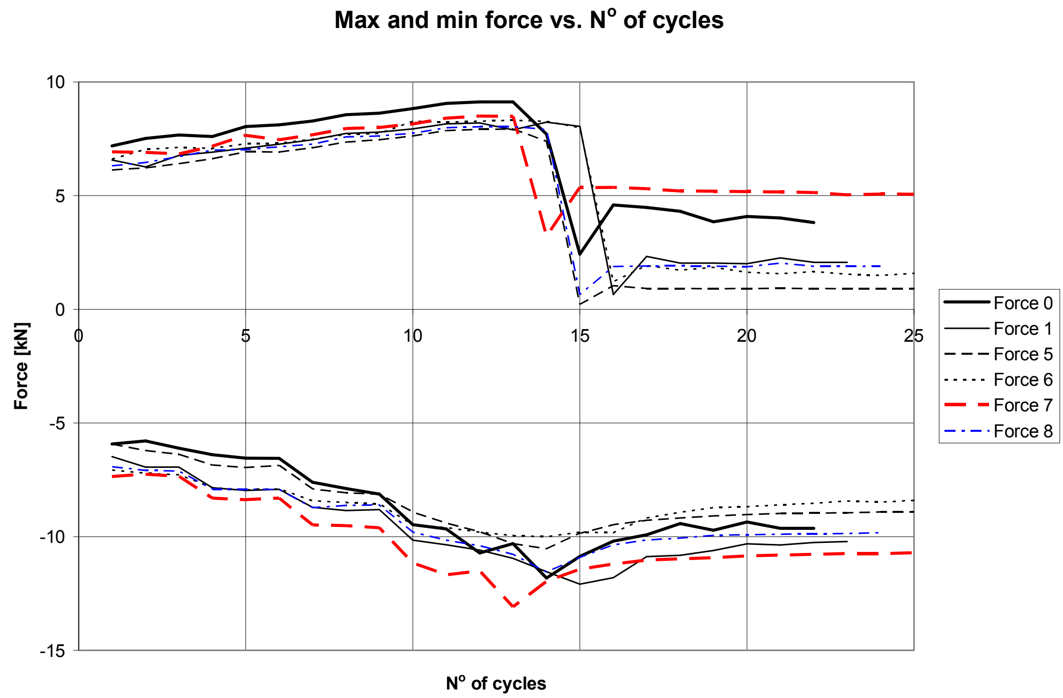
4.3 Comparison of resluts of first sample group

Samples 0, 1, 6, 7 and 8 have been treated by the same load spectrum as the shown sample 5. As we expected, there haven't been significant changes between samples. Pic 15 shows the comparative results of measured forces of all the six samples and picture 16 absorbed energies of the samples. Number of cycles prior to first breakage is equal for all the samples and absorbed energies are practically the same.

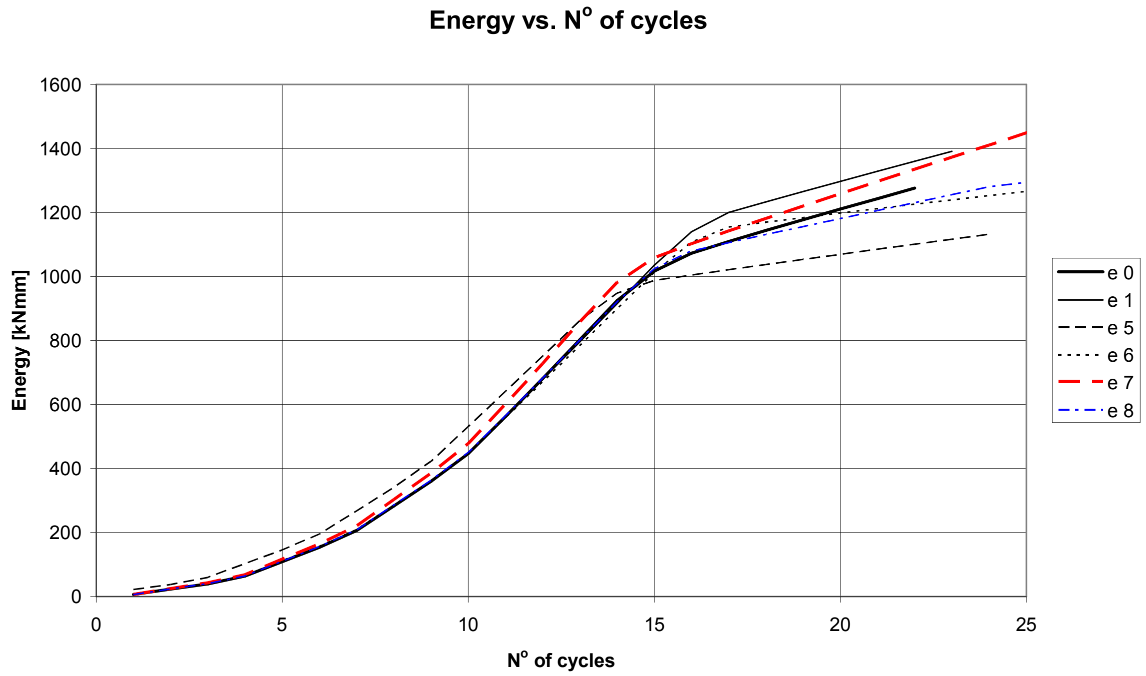
Damper no.	No. of cycles prior to collapse	Force F	$\Sigma\|\Delta\varepsilon_i\|$	Absorbed energy in 15 cycles
		kN		kNmm
0	15	+9.1/-11.8	0.73	1017
1	16	+8.2/-12.1	0.80	1035
5	15	+7.9/-10.5	0.73	948
6	16	+8.3/-10	0.80	1013
7	14	+8.5/-13	0.66	1058
8	15	+7.9/-11.5	0.73	1024

Number of cycles prior to breakage is conditionally determined because those cycles prior to breakage are irregular and it's hard to judge which is the last. Of great significance is also that in post-collapse stadium, even at high increase of force (deformation), dampers absorb a lot of energy.

By examining those six samples, a good repeatiness of series behaviour has been proved and results of those research can be used when designing dampers for real objects.



Picture 15 Maximum/minimum force of all six samples



Picture 16 Absorbed energy of all six samples

5. SECOND GROUP OF SAMPLES WITH CONSTANT AMPLITUDE SAMLES 2, 3 и 4

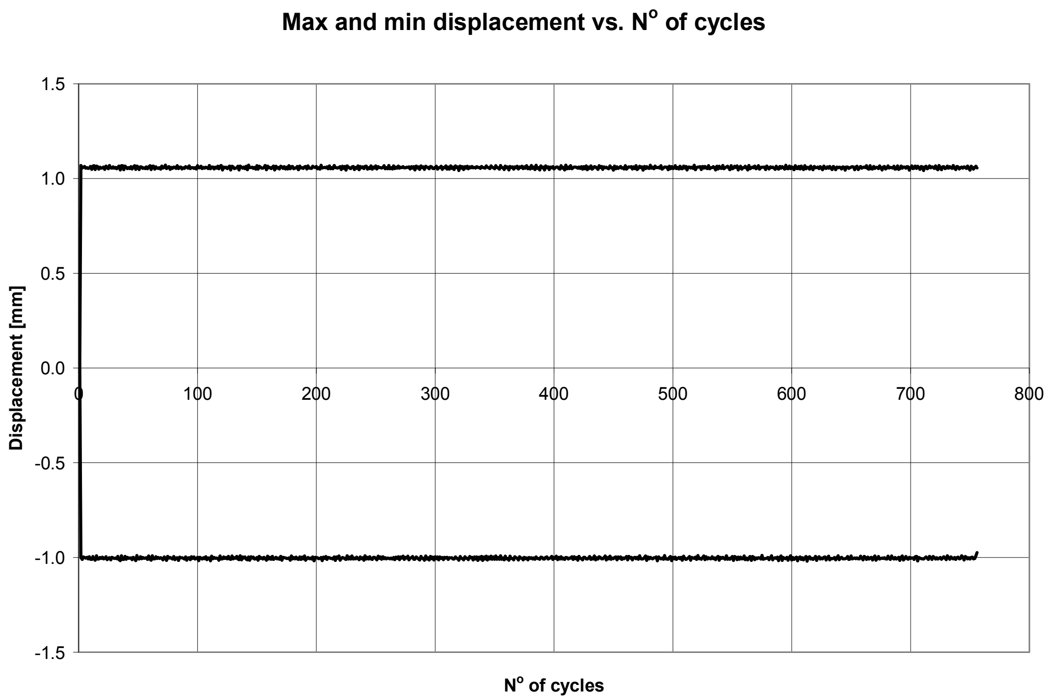
5.1 Sample 2

Sample 2 has been tested with constant amplitude of dilatataion ± 1 mm. Pic. 17 shows maximum and minimum deformation, where can be seen that deformation in tensioning is bigger for 6%. Force in first 50 cycles has slightly decreased, pic 18, after that it was constant till 736. cycle, and then in the following 4 – 5 cycles, a brakage of sample occured. It can be seen on pictures 20 to 22 where hysteresis are shown, in first 500 cycles on picture 20, stable hysteresis on picture 21 and hysteresis from 736. to 756. cycles at picture 22.

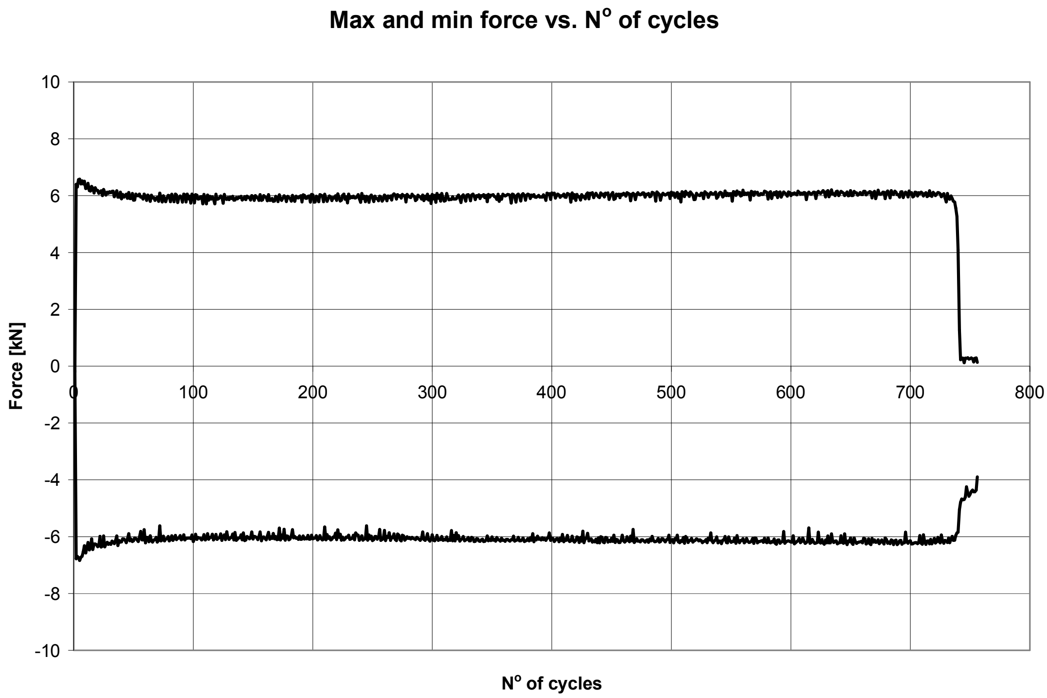
Breakage has practically occured after 740 cycles, which can be seen on a diagram of absorbed energy, pic. 19.

Accumulated dilatation l = 115 mm

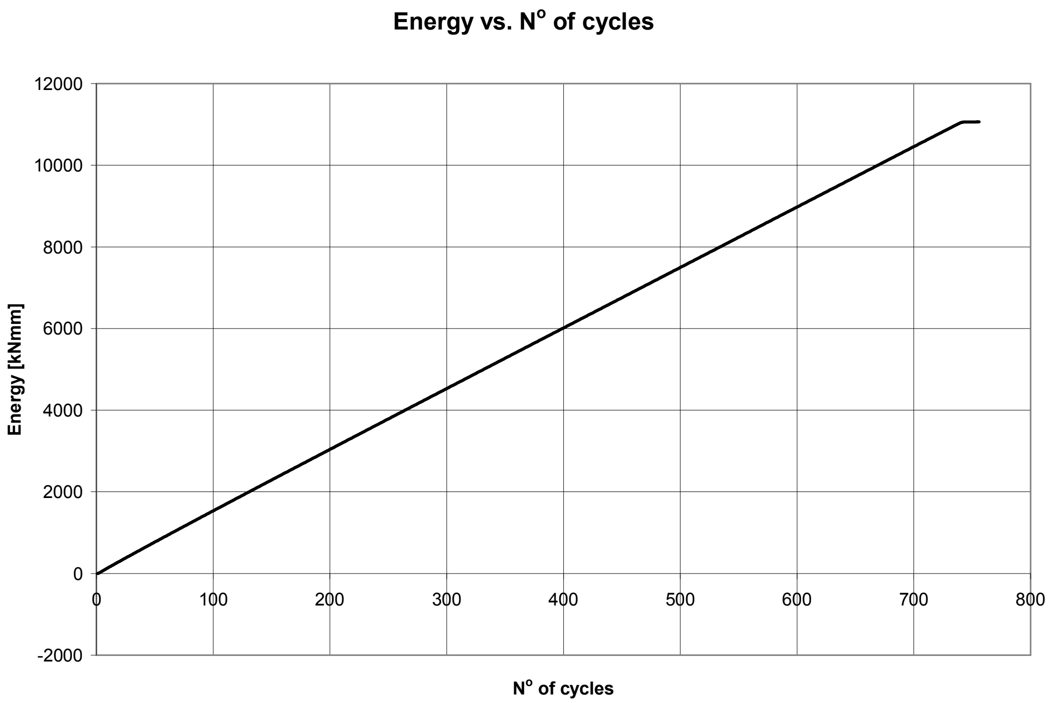
Δl_i	$\lvert\Delta\varepsilon_i\rvert$	n_{cyc}	$\Sigma\lvert\Delta\varepsilon_i\rvert$
mm			
±1	0.0087	740	12.87



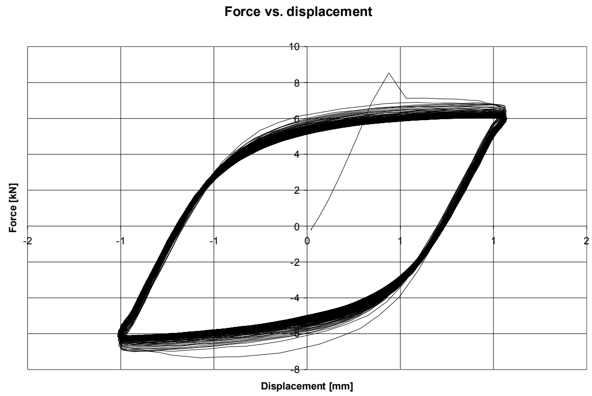
Picture 17 Maximum/minimum deformation



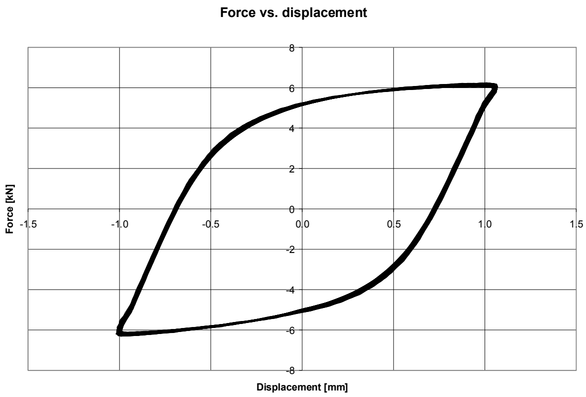
Picture 18 Maximum/minimum force



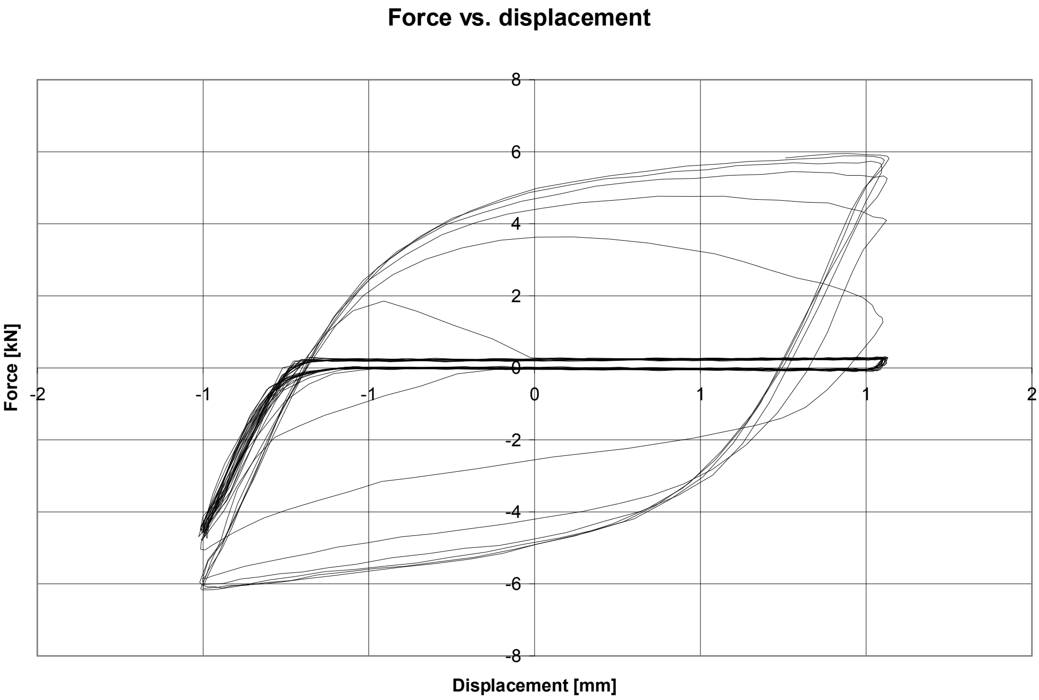
Picture 19 Absorbed energy



Pic. 20 Hysteresis in first 500 cycles



Pic. 21 Stable hysteresis



Pic. 22 Hysteresis 736 to 756 cycles

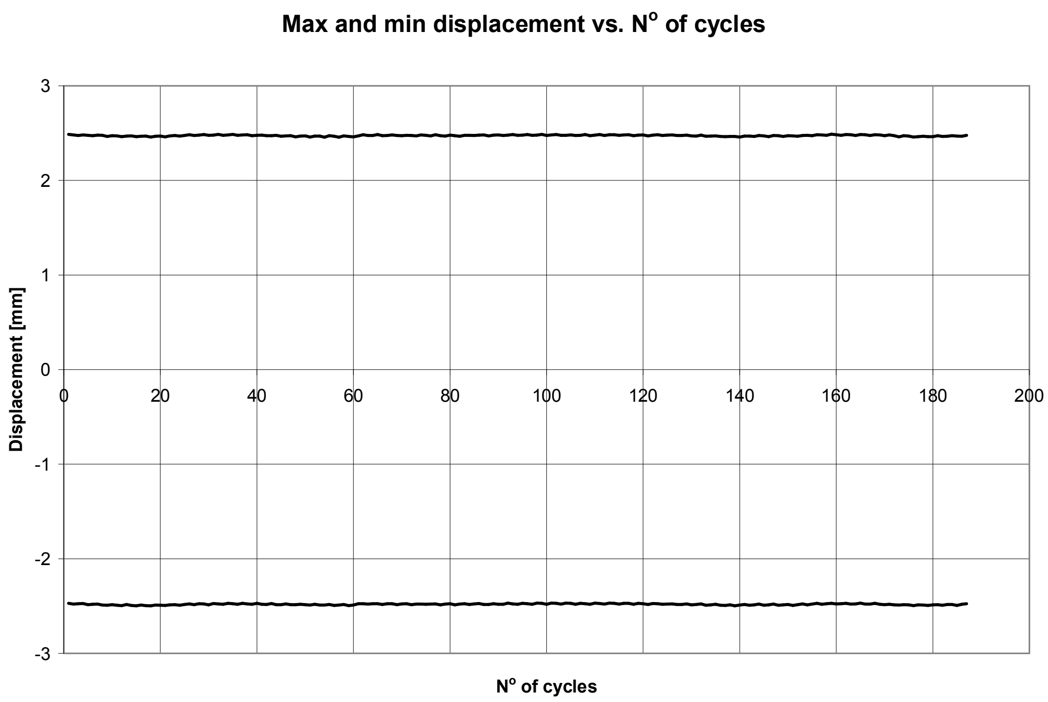
5.2 Sample 3

Sample 3 has been tested with constant amplitude of dilatataion ± 2.5 mm. Pic. 23 shows maximum and minimum deformation Force in tensioning has been practically constant and in pressure it slightly increased – pic. 24 and 26 and then in 37. cycle, a breakage of sample occured. It can be seen on pictures 27 to 28 where hysteresis are shown, in first 37 cycles on picture 27, hysteresis after breakage on picture 28 from 37. to 187. cycle.

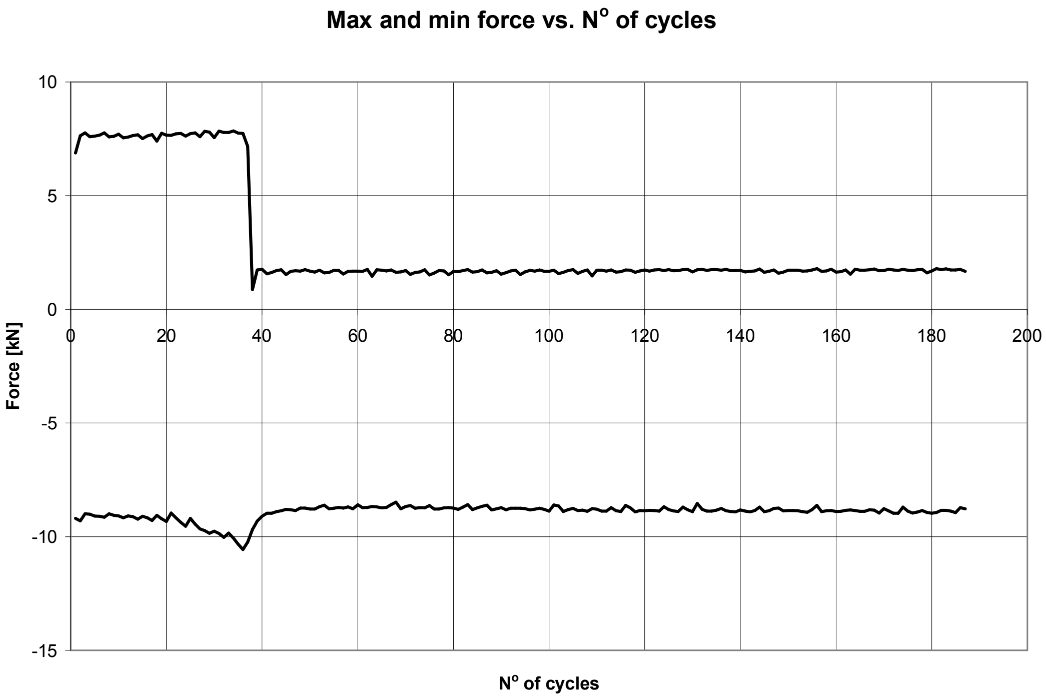
Breakage has practically occured after 37 cycles, which can be seen on a diagram of absorbed energy, pic. 25.

Accumulated dilatation l = 115 mm

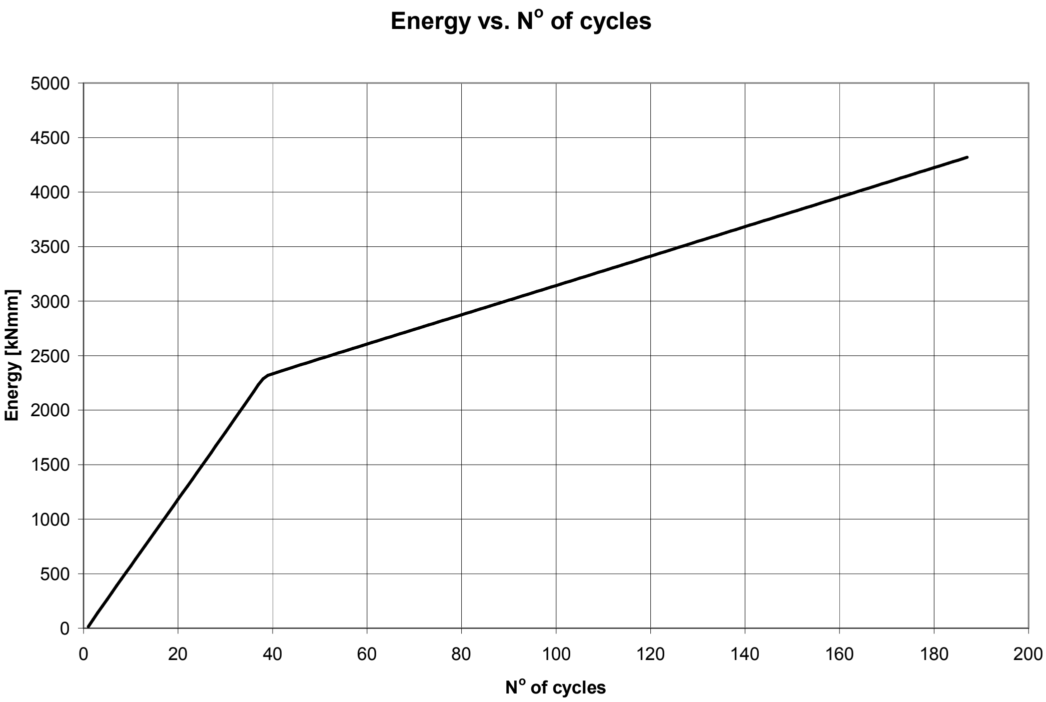
Δl_i	$\lvert\Delta\varepsilon_i\rvert$	n_{cyc}	$\Sigma\lvert\Delta\varepsilon_i\rvert$
mm			
±2.5	0.0217	37	1.61



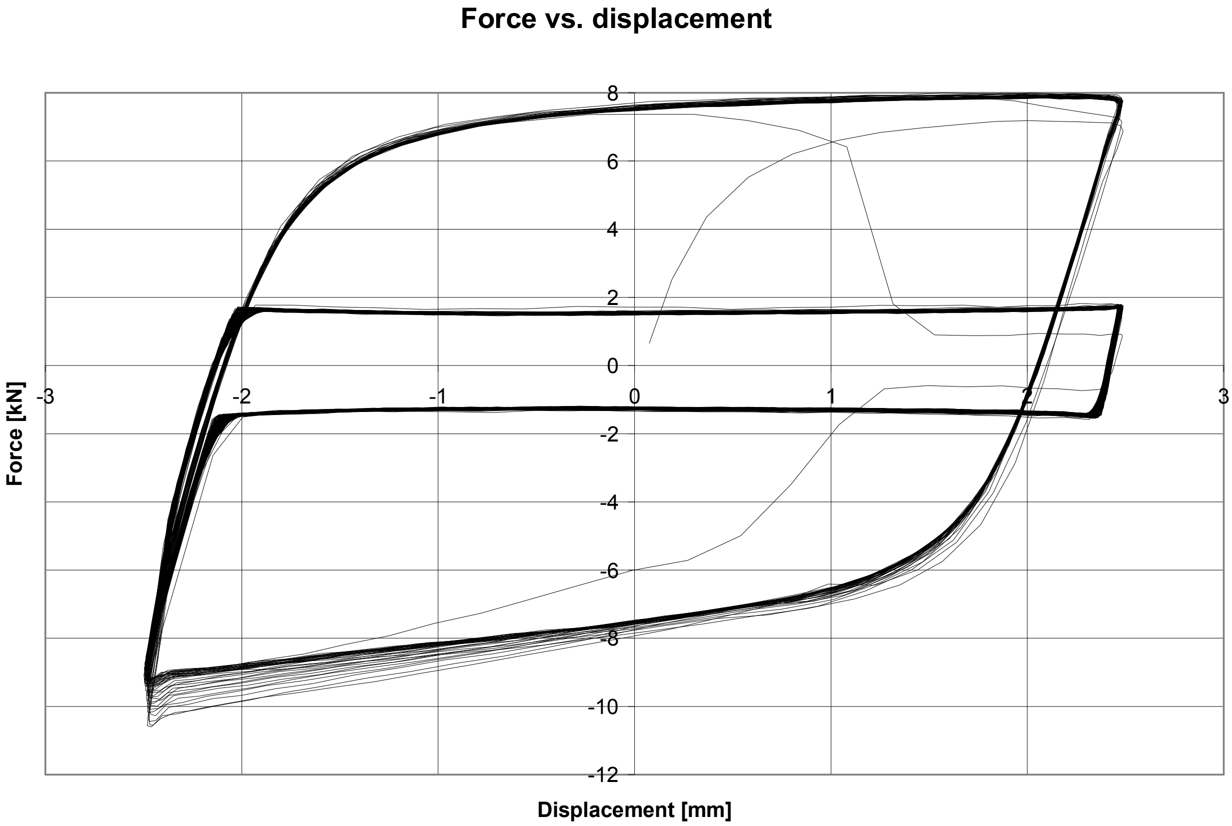
Pic. 23 Maximum/minimum deformation



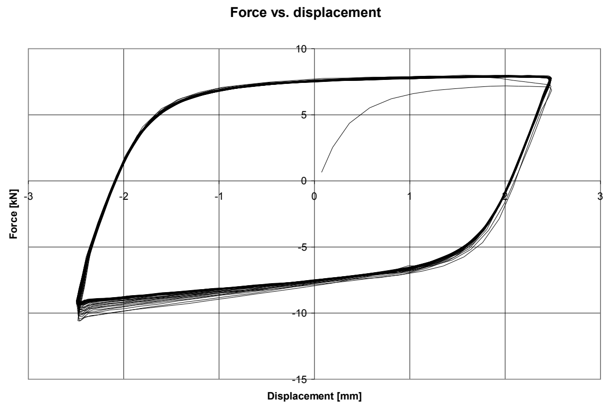
Pic. 24 Maximum/minimum force



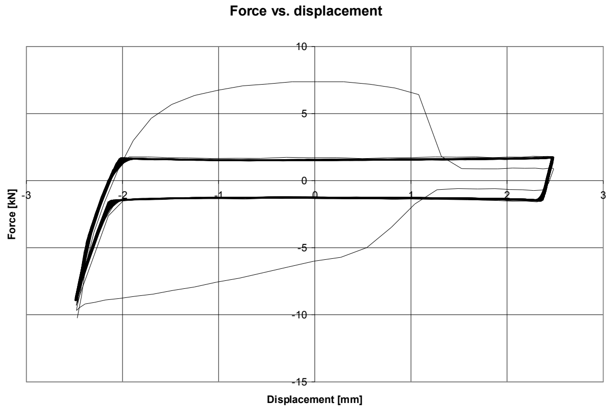
Pic. 25 Absorbed energy



Pic. 26 hysteresis of sample 3



Pic. 27 hysteresis in first 37 cycles



Pic. 28 hysteresis 37.-187. cycles

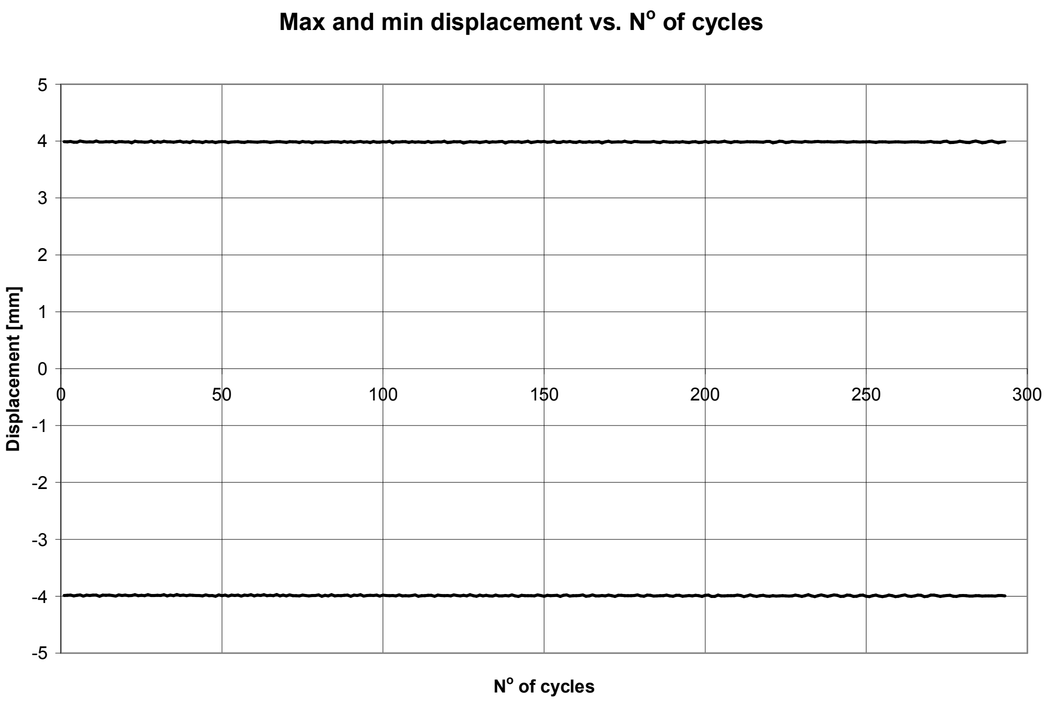
5.3 Sample 4

Sample 4 has been tested with constant amplitude of dilatataion ± 4 mm. Pic. 29 shows maximum and minimum deformation.

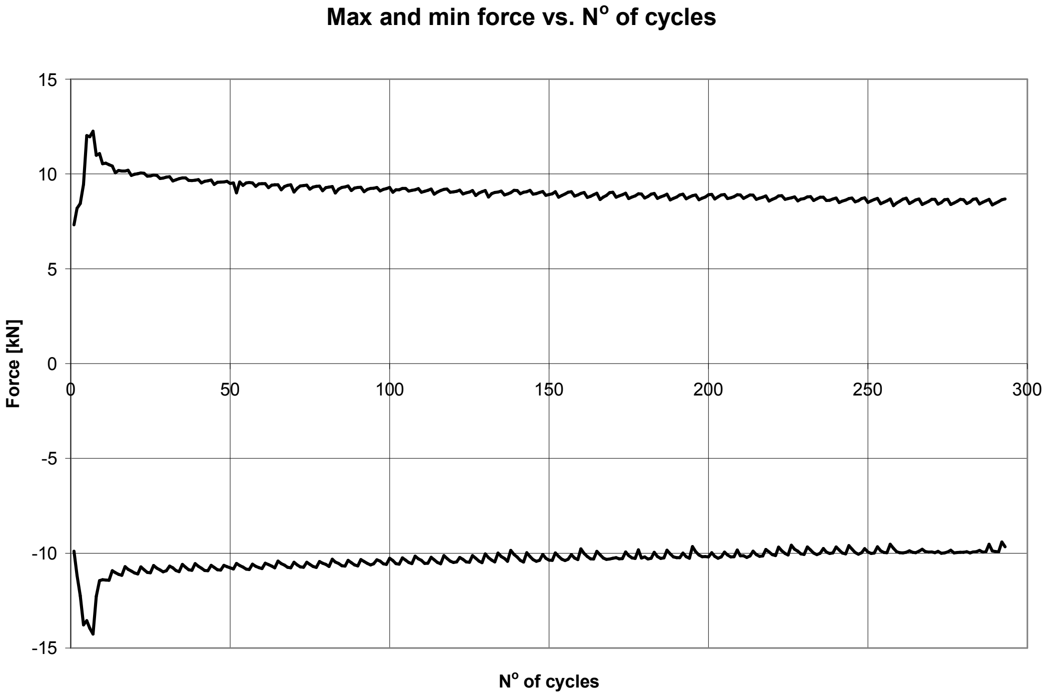
Force has been growing in first 7 cycles and then slightly decreased – pic. 30. However, after 7th cycle, a brakage of sample occured, which can't be seen on the force diagram. It can be seen on pictures 33 to 34 where hysteresis are shown, in first 7 cycles on picture 33, and hysteresis after breakage on picture 34 after brakage from 7. to 293. cycle. Hysteresis of the whole testing on picture 32 clearly shows the difference in behaviour before and after the breakage. Although maximum and minimum force are almost the same, surfaces of the diagram are very different. This confirms the diagram of absorbed energy, pic 31 where decrease of curve gradient is visible.

Accumulated dilatation l = 115 mm

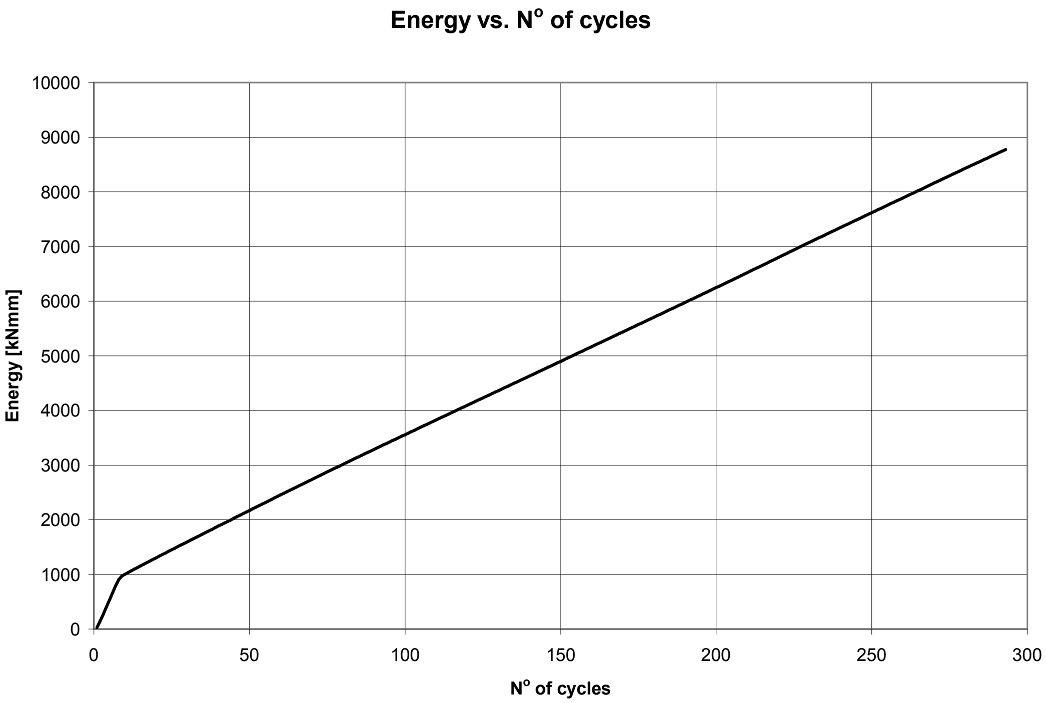
Δl_i	$\lvert\Delta\varepsilon_i\rvert$	n_{cyc}	$\Sigma\lvert\Delta\varepsilon_i\rvert$
mm			
±4	0.0348	8	0.56



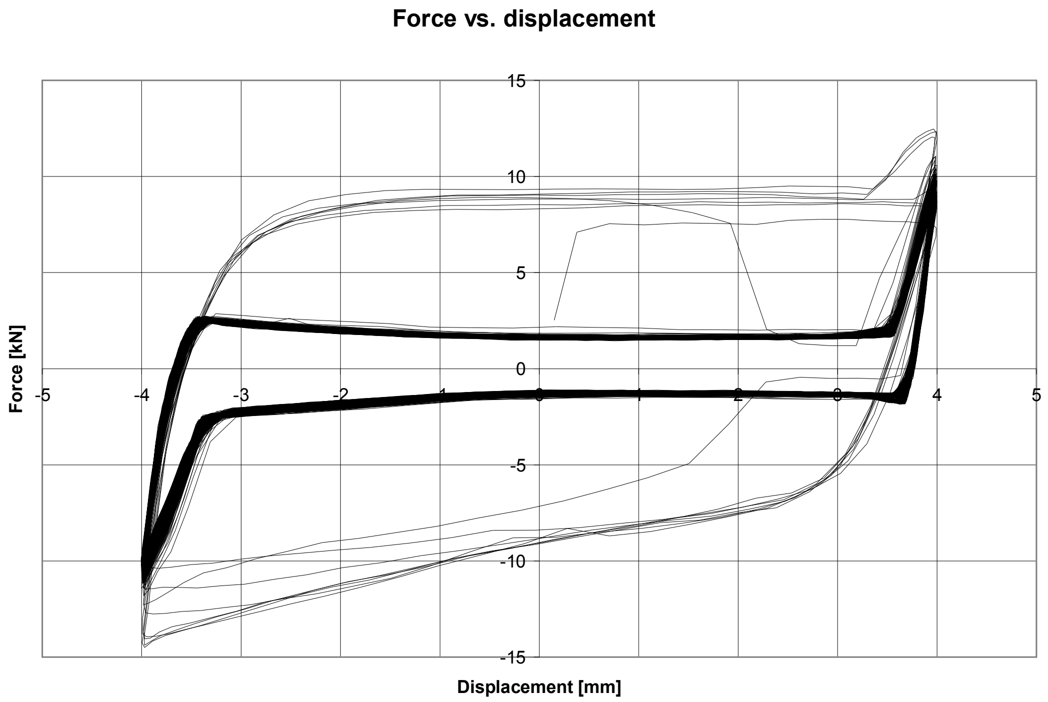
Pic. 29 Maximum/minimum deformation



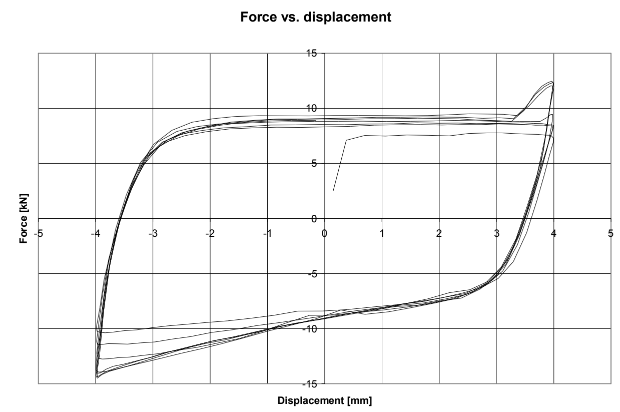
Pic. 30 Maximum/minimum force



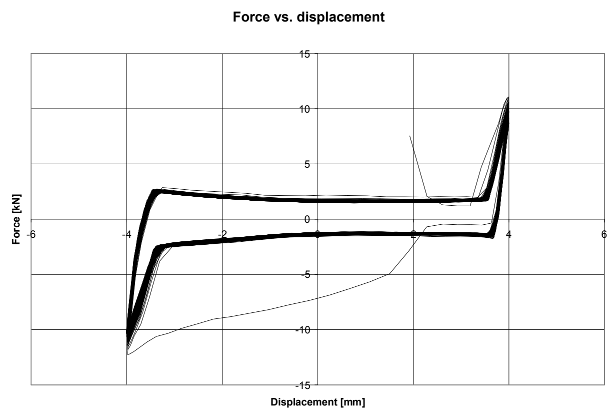
Pic. 31 Absorbed energy



Pic. 32 hysteresis of sample 4



Pic. 33 hysteresis in first 7 cycles



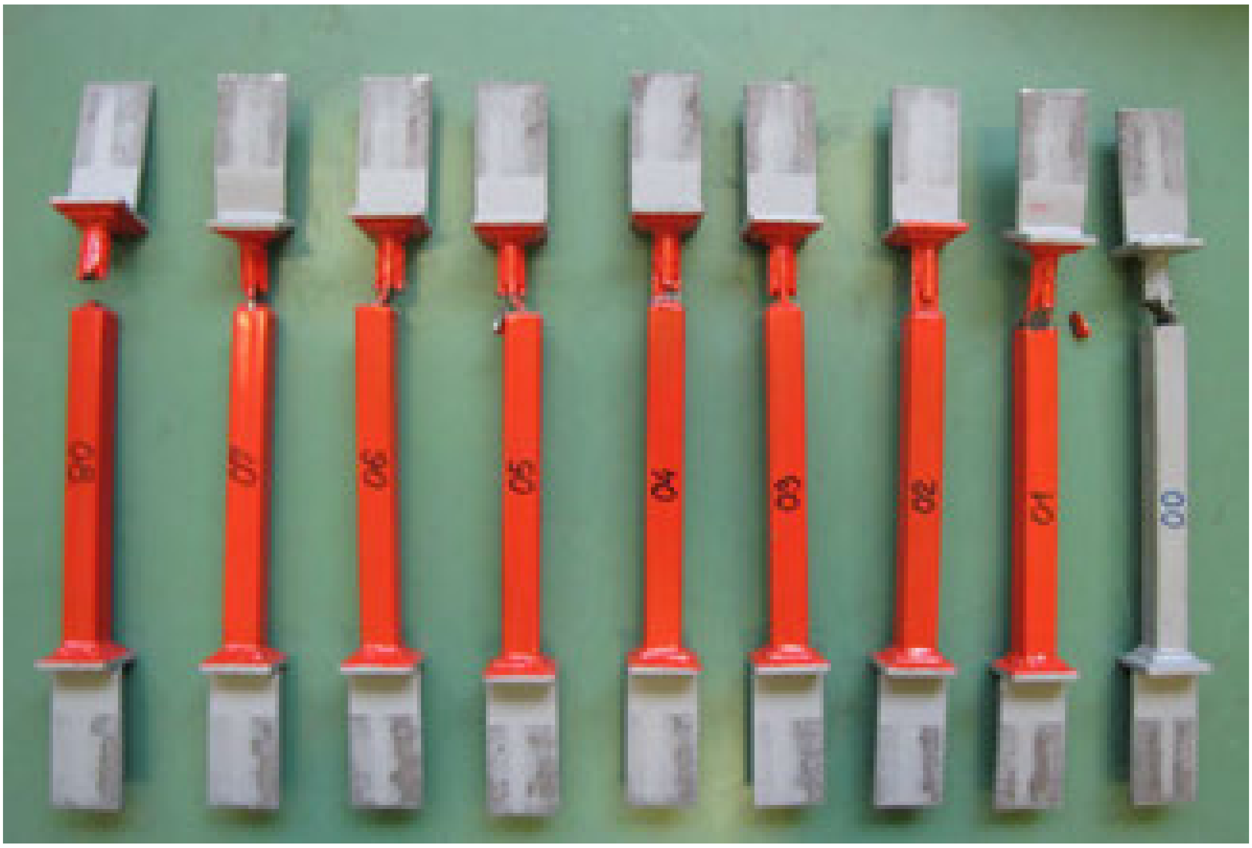
Pic. 34 Hysteresis 7.-293. cycle

5.4 Comparison of results of second sample group

With increase of deformation, lasting and accumulated dilatation is getting shorter, and disregarding the force increase, absorbtion of energy has been decreased.

Damper no.	Deformation	No. of cycles prior to collapse	Force F	$\Sigma\lvert\Delta\varepsilon_i\rvert$	Absorbed energy
	mm		kN		kNmm
2	± 1	740	+6/-6	12.87	11000
3	± 2.5	37	+8/-9	1.61	2300
4	± 4	8	+12/-14	0.56	1000

These data can be used as direction for quality design of real dampers of this type by varying the parameters of deformation and force for real objects.



Pic. 35. View of broken samples after the testing

8 CONCLUSION ABOUT DAMPER HQM

The goal of this research was to give a quality appreciation of the HQM damper from aspect of energy amortization and to check the calculation field of use of this damper.

By research of these samples a good repeatability of series behavior has been shown.

The research results can be used as direction for quality design of real dampers of this type by varying the parameters of deformation and force for real objects.

It is also significant, that this damper type has a large reserve of material plasticity (post collapse capacity) even after the structure degradation, when it doesn't accept tensioning load.