ARCHES

Assessment and Rehabilitation of Central European Highway Structures

Soft, diagnostic and proof load testing in routine bridge assessment

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Objectives (WP2)

- Optimise bridge assessment by using load testing and integration of inspection and monitoring results.
- Do not waste money on unnecessary replacement or strengthening due to innacurate assessment
- To provide Guidelines for more accurate bridge assessment tools in NMS and CEEC

Justification

- In situ tests show that bridges have a reserve strength that is not accounted for in design codes or standard assessment methods
  - Limitation of theoretical models
  - Hidden resisting mechanisms
  - Insufficient information on bridge performance and external loading
  - Absence of documentation for old bridges

Example

- a bridge in Gameljne near Ljubljana:
  - 12.4 m simply supported span
  - "obsolete":
    - low resistance (poor assessment)
    - insufficient serviceability
  - reassessment:
    - 5 layers of reinforcement
    - likely safe

Gameljscica bridge (Slovenia)


2648


2648


M·A·N

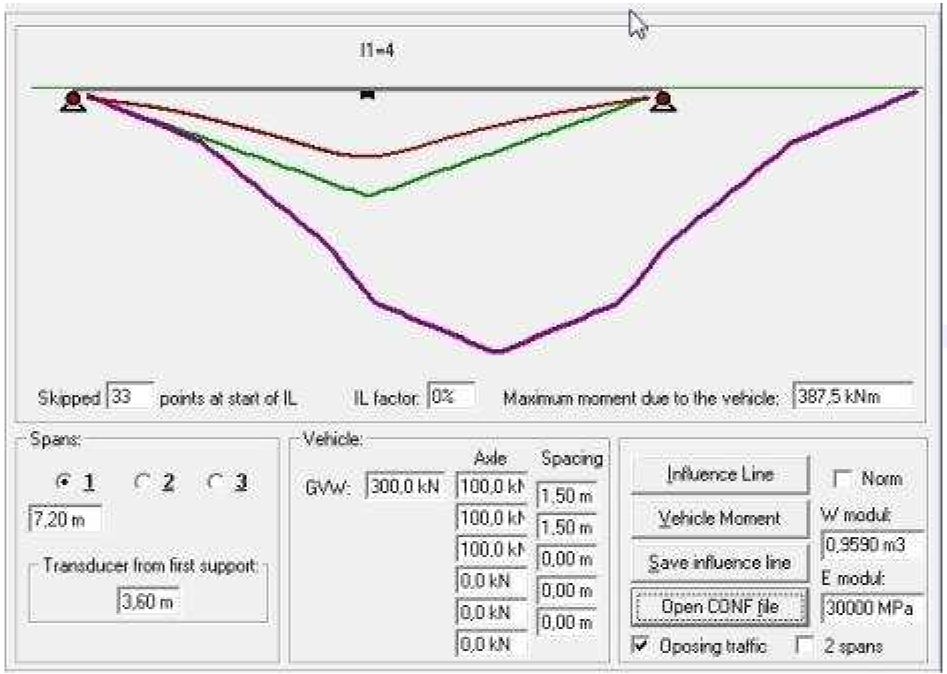
Bridge assessment

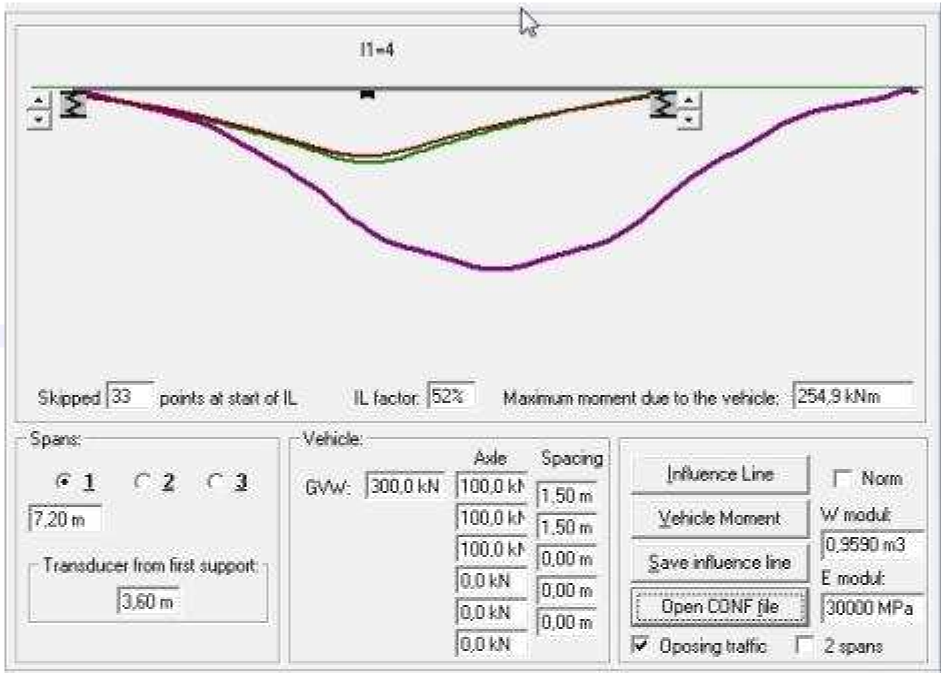
- Realistic structural behaviour:
  - load testing: To improve the limitations of theoretical models
- Realistic traffic loading:
  - static
  - dynamic loading

Soft load testing

- Previous results of SAMARIS
- new, more efficient way of diagnostic load testing
  - based on bridge weigh-in-motion measurements: measures important structural parameters (influence lines, distribution of traffic loads, impact factors) essential for accurate assessment
  - under normal traffic, without pre-weighed vehicles and no road closures
- ARCHES: validate results of soft load testing with more traditional diagnostic and proof load tests
  - Result: Many posted bridges rated as unsafe for normal traffic loads have been rated as safe.

Theoretical (left) and measured influence lines (right): 35% reduction in bending moments at mid-span





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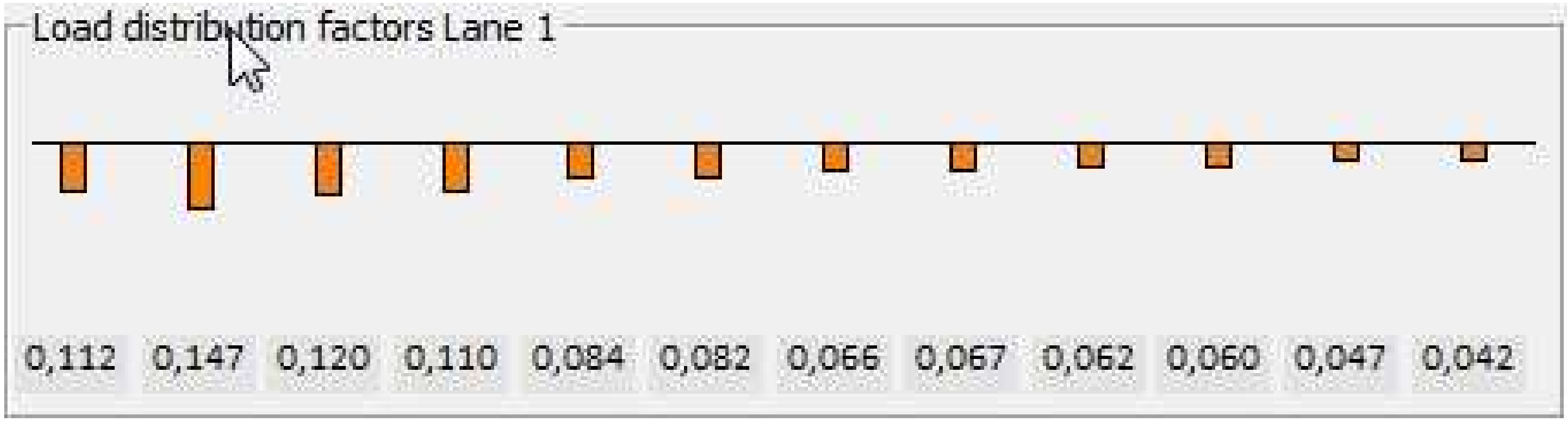
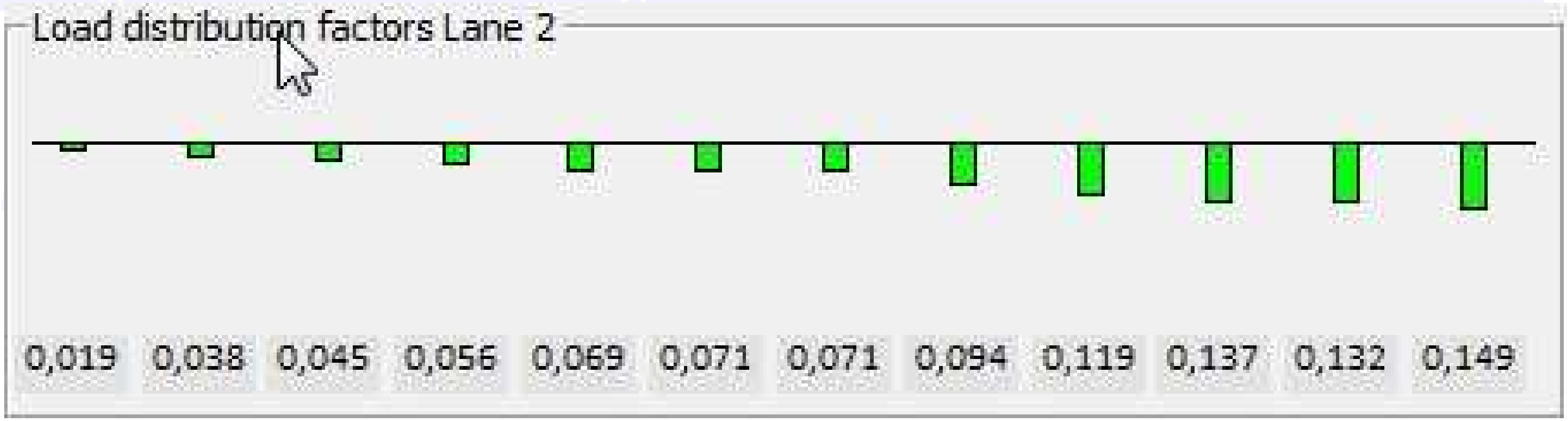
Typical measured load distribution factors obtained with a B-WIM system





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No.	Type	Material	Spans	RF for 81 ton low-loader			RF for normal traffic		
				Theor. IL	SLT	SLT vs. Theor.	Theor. IL	SLT	SLT vs. Theor.
1	Beams	ST/WO	5.20	0.90	1.39	1.54	0.78	1.05	1.35
2	Slab	RC	6.00	0.40	1.24	3.10	0.38	1.08	2.84
3	Slab	RC	4.50	1.20	2.10	1.75	0.87	1.33	1.53
4	Beams	RC	19.6	0.73	1.73	2.37	0.66	1.20	1.82
5	Slab	RC	7.95	0.77	1.94	2.52	0.73	1.37	1.88
6	Slab	RC	5.25	0.77	2.23	2.90	0.62	1.52	2.45
7	Slab	RC	6.20	0.76	1.83	2.41	0.65	1.18	1.82
8	Slab	RC	6.20	0.41	0.98	2.39	0.35	0.79	2.26
9	Slab	RC	6.20	0.50	1.28	2.56	0.43	1.03	2.40
10	Slab	RC	6.83	0.67	1.38	2.06	0.66	0.97	1.47
11	Slab	RC	3.89	0.74	1.48	2.00	0.58	1.07	1.84
12	Slab	RC	8.98	0.60	1.90	3.17	0.62	1.34	2.16
13	Beams	RC	8.40	0.57	1.14	2.00	0.54	0.96	1.78
14	Slab	RC	8.60+10.60+8.60	0.42	0.88	2.10	0.40	0.73	1.83
15	Beams	RC	10.00	0.72	1.08	1.50	0.77	1.00	1.30
16	Slab	RC	8.00	0.80	2.06	2.58	0.66	1.40	2.12
17	Beams	RC	10.0+3×11.3+10.0	0.45	1.99	4.42	0.47	1.03	2.19
18	Slab	RC	6.63	0.53	1.44	2.72	0.50	0.96	1.92
19	Slab	RC	8.40	0.57	1.25	2.19	0.58	1.11	1.91
20	Slab	RC	16.2+23.05+16.2	0.80	1.23	1.54	0.69	0.98	1.42

Diagnostic load testing

- Load the bridge to check validity of theoretical models
- Appraisal of material properties and structural behaviour
- Bridge closed to normal traffic

Proof load testing

- Load the bridge to a certain level of load to assure a minimum capacity versus service loads (actual traffic) with a required safety level

BELFA project (Germany)

BELFA project (Germany)

Michigan State (USA)

Justification

- High reserves of strength in some decomissioned bridges
  - Hidden resisting mechanisms
  - Composite action due to friction
  - Limitation of available analytical models
  - Lack of knowledge on failure mechanisms
  - Absence of documentation for old bridges

Application

- Only exceptional cases
  - Old bridges with lack of documentation
  - Bridge with high level of redundancy (robustness)
  - Bridges that have not passed the standard assessment process

Important issues

- Minimum load level to achieve?: Target proof load
- Risk of damage to the bridge (failure during the test?)
- When should the increment of loading stop?
- How to deal with bridge owner reluctance?

Main characteristic of traffic data used in the calibration

	Netherlands (NL)	Slovakia (SK)	Czech Republic (CZ)	Slovenia (SI)	Poland (PL)
Directions	1	2	1	1	1
Total trucks	646,548	748,338	729,929	147,752	429,680
Time span in weeks	20	83	51	8	22
Number of weekdays with full record	77	290	148	39	87
Trucks per day lane 1	6,545	1,031	4,490	3,158	3,708
Trucks per day lane 2	557	1,168	261	135	314
Trucks per day (both lanes)	7,102	2,199	4,751	3,293	4,022

NMS,CEEC: Proposed proof load factors

Non-documented bridges

Span length (m)	β		
	2.3	**3.6**	**5.0**
10	0.83	1.13	1.57
15	0.89	1.20	1.65
20	1.01	1.36	1.85
25	1.08	1.44	1.97
30	1.11	1.46	2.00
35	1.12	1.48	2.01

- Nominal value from the EC-1

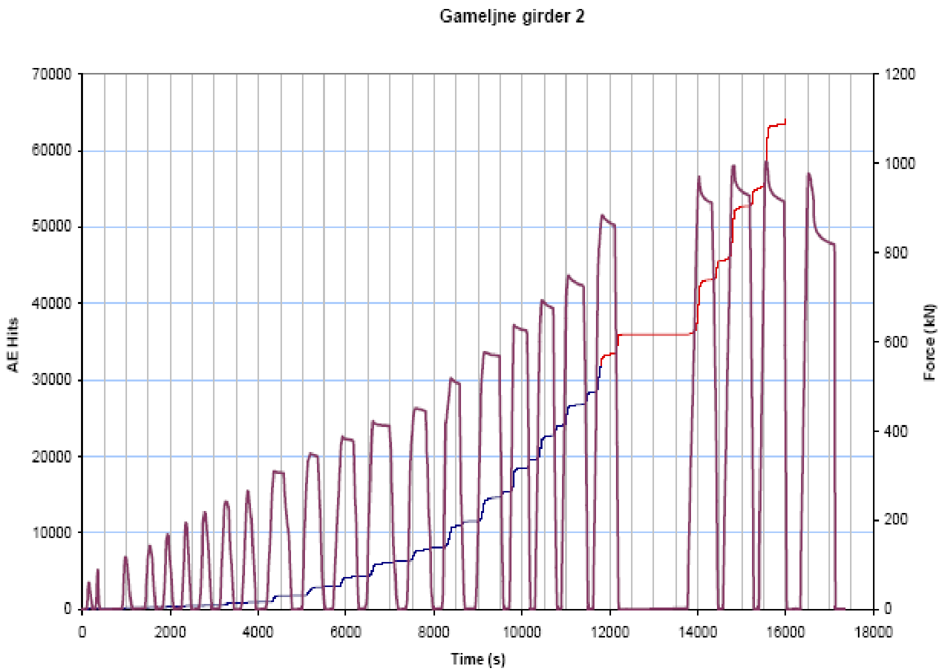
NMS,CEEC: Proposed proof load factors

Documented bridges (BETA= 2.3)

R/Rn	Span-length (m)					
	10	15	20	25	30	35
1.0						0.31
0.9	0.15	0.28	0.45	0.55	0.59	0.61
0.8	0.51	0.58	0.69	0.78	0.82	0.84
0.7	0.63	0.69	0.82	0.94	0.96	0.98
0.6	0.72	0.78	0.92	1.00	1.04	1.05
0.5	0.78	0.84	0.96	1.04	1.07	1.09

- Nominal value from the EC-1

Acoustic emission



Proof load test: Barcza bridge

- **The bridge** - should be removed in the next future
- **The lateral span** - to not interact with the railway traffic
- **The end girder** - load possibility (short span)

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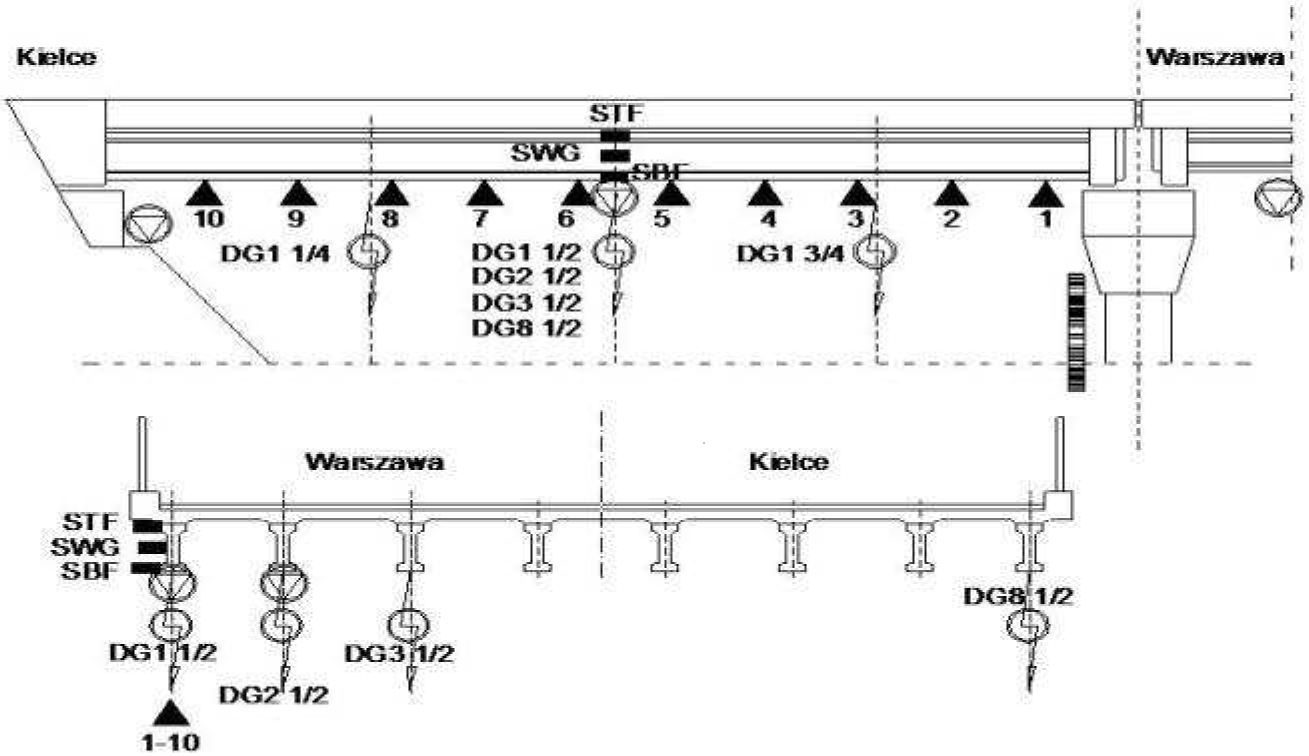
Diagnostic **and proof load testing - Measuring equipment**



Deflections - inductive transducers

Deflection/Support displacement – Total Station

Strain/stress - electric resistance wire strain gauges

Acoustic emission - sensors

Support displacement – leveling staff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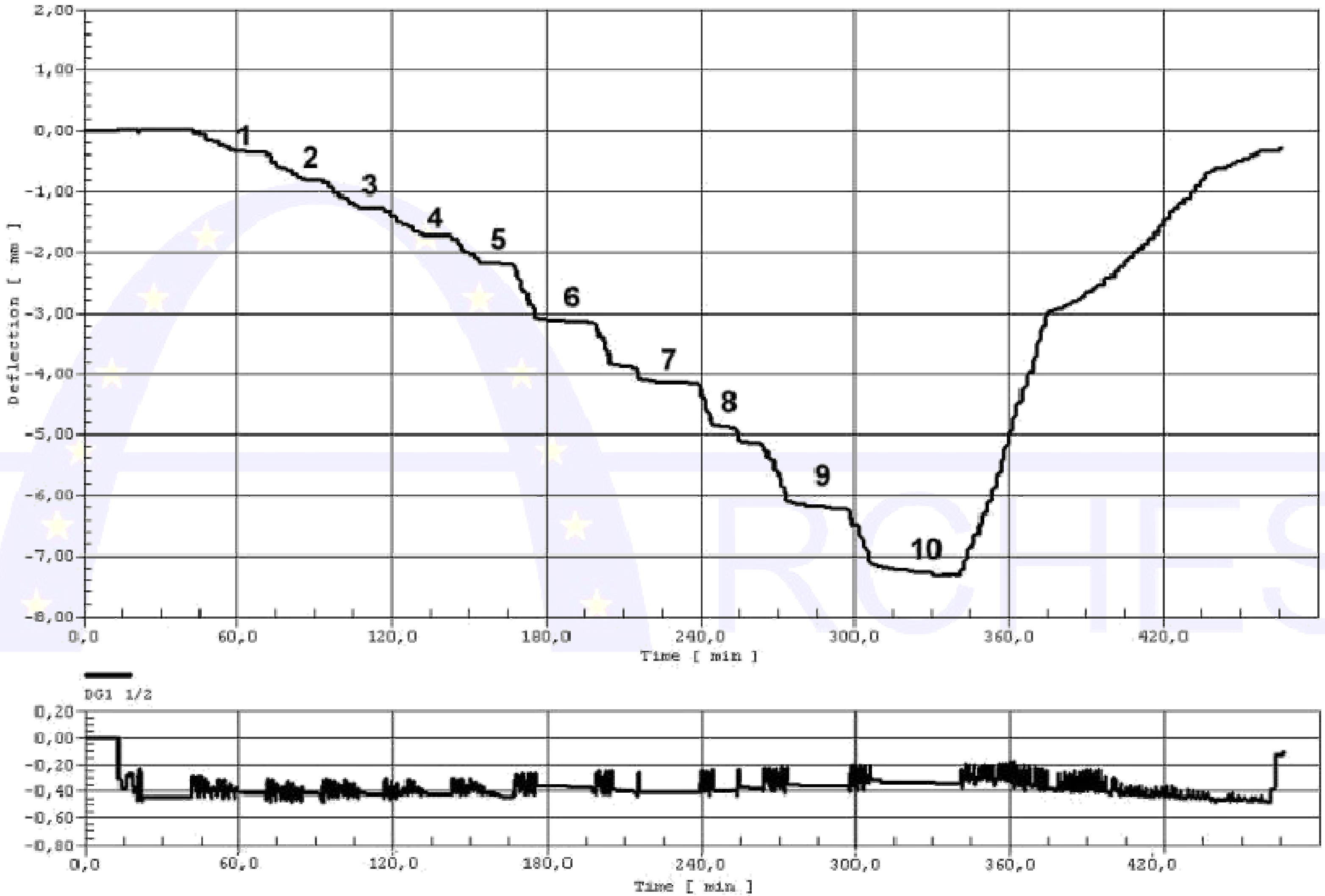
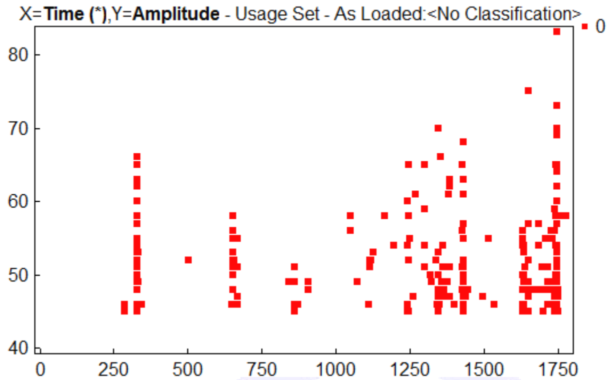
Proof load testing - Test results - Deflections/Time

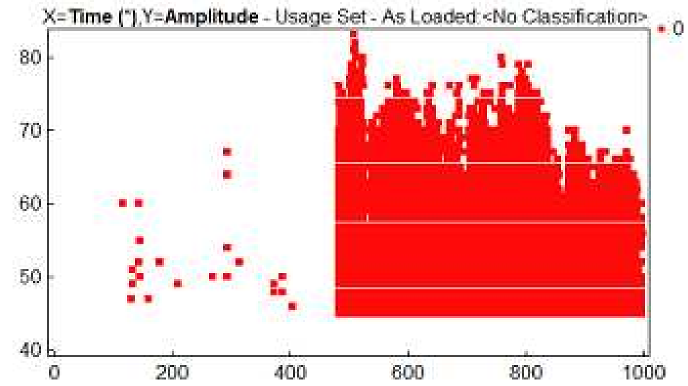


Proof load testing - Test results - Acoustic emission



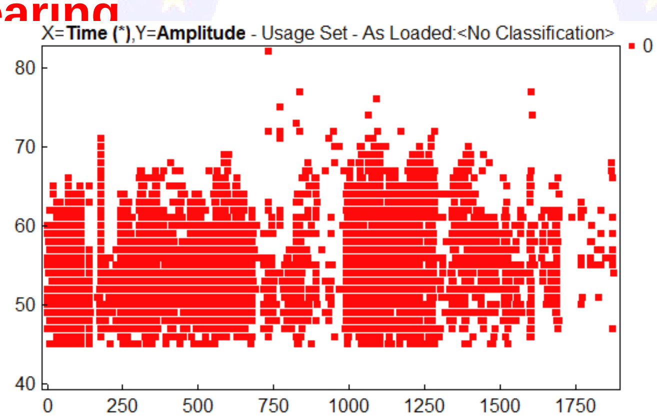
Phase No. 6: five concrete slab layers + one steel weights layer

Cracking in concrete under bearing



Phase No. 7: five concrete slab layers + two steel weights layers

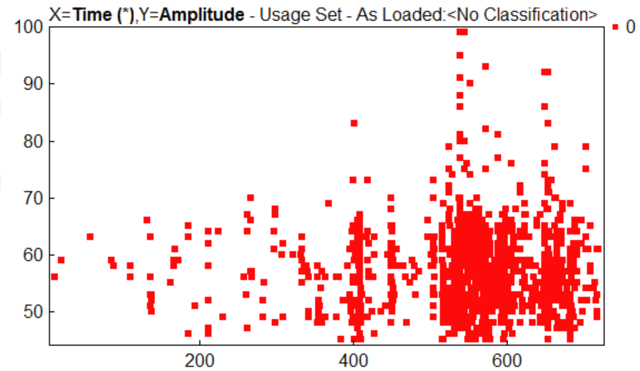
Cracking in concrete under bearing and in transverse beam



Phase No. 8: five concrete slab layers + three steel weights layer

The most increase of AE signal in the girder midpoint

The visual inspection – no cracks near the girder midpoint

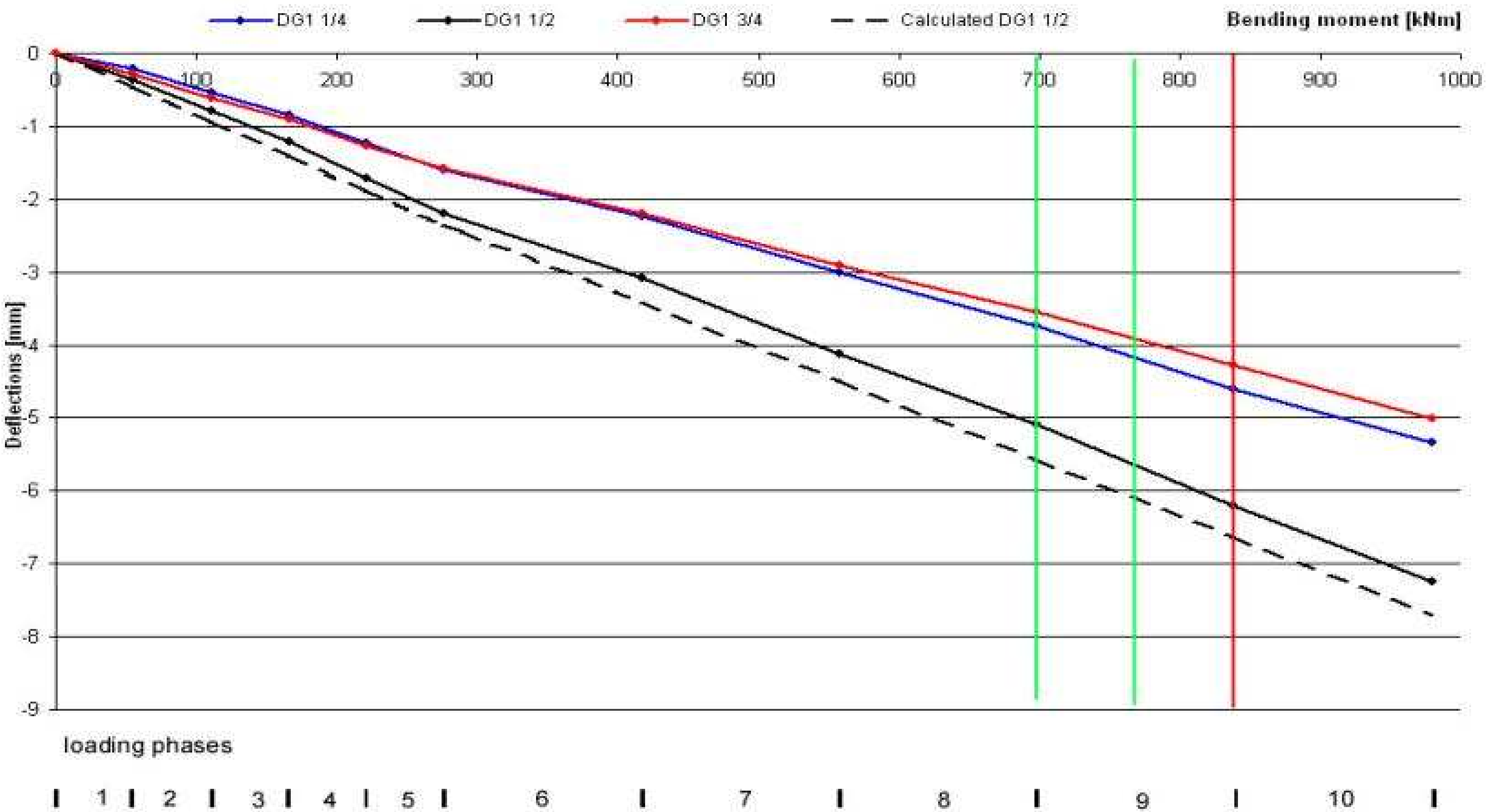


Phase No. 9: five concrete slab layers + four steel weights layer

The fast increase of AE signal in the girder midpoint - development of existing cracking processes

The visual inspection –the crack near the girder midpoint

Proof load testing - Test results – Deflections/Bending moment



Green lines - loading level where load testing should have been stopped on the base of AE signals

The red line - loading level where the cracking was detected by visual inspection

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CONCLUSIONS

- LOAD TESTING
  - Soft
  - Diagnostic
  - Proof

- NEW POSSIBILITIES IN ACTUAL LOADING CAPACITY OF EXISTING BRIDGES

- MORE INFORMATION: DELIVERABLE D16