STAND STATIC TESTING O7F PREFABRICATED BEAMS USED IN THE EXECUTION OF ROAD BRIDGE SUPERSTRUCTURE

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Rezumat. *Lucrarea tratează încercarea statică pe stand a grinzilor de beton precomprimat utilizate la realizarea suprastructurilor podurilor rutiere. Încercarea a fost efectuată progresiv, prin încărcarea grinzilor cu forțe vertical concentrate, produse cu ajutorul unei instalații hidraulice,. Deformațiile verticale au fost monitorizate cu comparatoare cu fir și rolă, iar cele specifice au fost determinate prin tensometrie electro-rezistivă. Sunt prezentate și analizate rezultatele obținute, evidențiind comportamentul grinzii sub acțiunea sarcinilor verticale.*

Abstract. *The paper addresses the static testing of prestressed concrete beams used in the construction of road bridge superstructures. The test was conducted progressively by applying concentrated vertical forces generated by a hydraulic system. Vertical deformations were monitored using wire and roller comparators, while specific deformations were measured through electro-resistive strain gauging. The obtained results are presented and analyzed, highlighting the beam's behaviour under vertical loads.*

Keywords: Static Testing, Beam Testing, Beam Deformations, Precast Concrete Elements, Road bridges.

1. Introduction

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The development of transportation infrastructure has a significant impact on economic growth, with favorable effects on local or regional economies.

By providing the necessary connection between different economic sectors through the flow of raw materials, goods, and finished products, transportation plays a crucial role in economic and commercial development.

In this context, highways—due to their construction with two separate traffic directions—are high-speed roads that strongly influence traffic flow and enable the traversal of long distances in a time-efficient manner.

In highway construction, bridges, overpasses, and viaducts play a critical role by enabling the crossing of natural obstacles. The main goal that must be achieved by both new and existing bridges is ensuring traffic safety. The load-bearing structure is the main supporting element of a bridge and is generally composed of two main parts: the superstructure and the substructure. The superstructure's role is to directly support the roadway and absorb the loads from road and/or rail traffic.

The load-bearing structure at the level of the bridge superstructure serves to directly support the roadway on the bridge and to transfer loads, via the bearing devices, to the foundation ground [4].

The beams are part of the bridge’s superstructure, whose role is to take over the loads generated by traffic. To ensure optimal operating conditions for bridges, it is necessary to also test the beams in order to confirm their capacity to withstand service loads [4].

This paper presents the results of measurements taken during the bending test of a prestressed concrete beam with a length of 35.75 meters and a height of 1.80 meters (Figure 1).

The test was conducted on a test stand installed on the construction site, in the area where the beams were located, during the period from November 4 to November 8, 2024.

The test consisted of applying four concentrated forces in incremental stages, according to STAS 12313-85 and the test protocol developed by: *WEBUILD S.P.A – Milan,* Romania Branch, Bucharest.

The beam was placed on two foundation blocks and reinforced concrete pads, according to the test design, with metal bearings.

The load application system consisted of:

- Metal frames anchored into the reinforced concrete foundation to absorb the reaction from the hydraulic jacks.

- A system composed of a hydraulic electro-pump for increasing and controlling the pressure in the hydraulic system, and a distributor.
- Four hydraulic jacks, each with a maximum capacity of 2000 kN.

The forces were applied at intervals of 6.00 meters from one another, centered along the span of the beam.

The test stages were carried out in accordance with the test protocol. Deflections were measured using roller-type dial gauges with MF wire, with a precision of 0.05 mm, and strain was measured using the electro-resistive strain gauge method (strain gauges: Hottinger type 1-LY41-50/120) (Figure 2).

Crack formation was monitored in parallel, and a crack microscope was used for measurements.
Dial gauges were placed on the supports, at the quarter span, and at midspan of the beam to measure deflections.

Strain gauges were positioned at midspan on both the top and bottom fibers of the beam to measure specific strains.

Three loading–unloading cycles were performed up to a load of 295 kN (C1, C2, C3 – loading at the serviceability limit state), and two loading–unloading cycles up to a load of 380 kN (C4, C5 – ultimate limit state), followed by one cycle (C6) at 80% of the calculated failure load, i.e., 450 kN, continuing up to the calculated failure load according to the test protocol.

The loading stages are presented in Table 1.

The loading steps are detailed in Tables 2, 3, and 4.

Table 1 Beam Loading Stages

Load Level	*Bending Moment*	*Corresponding Load* *P*
	[kN x m]	*[kN]*
Load from Self-Weight	2803	0
Permanent Load Effects	5524	120
Decompression Load of the Bottom Fiber	8510	255
Serviceability Limit State Load	9505	295
Ultimate Limit State Load	11388	380

Table 2 Test Program for the Serviceability Limit State (C1, C2 and C3)

Cycle	*Stage*	*Stage Type*	*Load Step ΔP [kN]*	*Load P [kN]*	*Pressure [bar]*	*Measurements*
C1	1	**Load from Self-Weight**	0	0	0	
	2	Intermediate	60	60	5	Deflection and Unit Strains
	3	**Load from Permanent Actions**	**60**	**120**	**15**	**Measurement of Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	4	Intermediate	43.75	163.75	5	Deflection and Unit Strains
	5	Intermediate	43.75	207.5	5	Deflection and Unit Strains
	6	Decompression	43.75	251.25	5	Deflection and Unit Strains
	7	**Serviceability Limit State Load**	**43.75**	**295**	**15**	**Measurement of Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	8	Intermediate	-43.75	251.25	5	Deflection and Unit Strains
	9	Intermediate	-43.75	207.5	5	Deflection and Unit Strains
	10	Intermediate	-43.75	163.75	5	Deflection and Unit Strains
	11	**Load from Permanent Actions**	-43.75	120	**15**	**Measurement of Deflection and Unit Strains Visual Inspection of Beam for Crack Closure**
	12	Intermediate	-60	60	5	Deflection and Unit Strains
	13	**Load from Self-Weight**	-60	0	**15**	Deflection and Unit Strains

Table 3 Test Program for the Ultimate Limit State (C4 and C5)

Cycle	*Stage*	*Stage Type*	*Load Step* *ΔP [kN]*	*Load P* *[kN]*	*Pressure* *[bar]*	*Measurements*
C5	66	Intermediate	60	60	5	Deflection and Unit Strains
	67	**Load from Permanent Actions**	**60**	**120**	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	68	Intermediate	43.75	163.75	5	Deflection and Unit Strains
	69	Intermediate	43.75	207.5	5	Deflection and Unit Strains
	70	Decompression	43.75	251.25	5	Deflection and Unit Strains
	71	**Load at the Serviceability Limit State**	**43.75**	**295**	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	72	Intermediate	10.625	305.625	5	Deflection and Unit Strains
	73	Intermediate	10.625	316.25	5	Deflection and Unit Strains
	74	Intermediate	10.625	326.875	5	Deflection and Unit Strains
	75	Intermediate	10.625	337.5	5	Deflection and Unit Strains
	76	Intermediate	10.625	348.125	5	Deflection and Unit Strains
	77	Intermediate	10.625	358.75	5	Deflection and Unit Strains
	78	Intermediate	10.625	369.375	5	Deflection and Unit Strains
	79	**Load at the Ultimate Limit State**	**10.625**	**380**	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	80	Intermediate	-10.625	369.375	5	Deflection and Unit Strains
	81	Intermediate	-10.625	358.75	5	Deflection and Unit Strains
	82	Intermediate	-10.625	348.125	5	Deflection and Unit Strains
	83	Intermediate	-10.625	337.5	5	Deflection and Unit Strains
	84	Intermediate	-10.625	326.875	5	Deflection and Unit Strains
	85	Intermediate	-10.625	316.25	5	Deflection and Unit Strains

Cycle	*Stage*	*Stage Type*	*Load Step ΔP [kN]*	*Load P [kN]*	*Pressure [bar]*	*Measurements*
	86	Decompression	-10.625	305.625	5	Deflection and Unit Strains
	87	**Load at the Serviceability Limit State**	**-43.75**	**295**	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	88	Intermediate	-43.75	251.25	5	Deflection and Unit Strains
	89	Intermediate	-43.75	207.5	5	Deflection and Unit Strains
	90	Intermediate	-43.75	163.75	5	Deflection and Unit Strains
	91	**Load from Permanent Actions**	**-60**	**120**	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	92	Intermediate	-60	60	5	Deflection and Unit Strains
	93	**Load from Self-Weight**	**-60**	**0**	**15**	**Deflection and Unit Strains**

Table 4 Test Program for the Calculated Ultimate Load (C6)

Cycle	*Stage*	*Stage Type*	*Load Step ΔP [kN]*	*Load P [kN]*	*Pressure [bar]*	*Measurements*
C6	94	Intermediate	60	60	5	Deflection and Unit Strains
	95	**Load from Permanent Actions**	**60**	**120**	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	96	Intermediate	43.75	163.75	5	Deflection and Unit Strains
	97	Intermediate	43.75	207.5	5	Deflection and Unit Strains
	98	Decompression	43.75	251.25	5	Deflection and Unit Strains
	99	**Load at the Serviceability Limit State**	**43.75**	**295**	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks**
	100	Intermediate	21.25	316.25	5	Deflection and Unit Strains
	101	Intermediate	21.25	337.5	5	Deflection and Unit Strains
	102	Intermediate	21.25	358.75	5	Deflection and Unit Strains

Cycle	*Stage*	*Stage Type*	*Load Step ΔP [kN]*	*Load P [kN]*	*Pressure [bar]*	*Measurements*
	103	**Load at the Ultimate Limit State**	21.25	380	**15**	**Deflection and Unit Strains** **Visual Inspection of Beam for Cracks**
	104	Intermediate	17.5	397.5	5	Deflection and Unit Strains
	105	Intermediate	17.5	415	5	Deflection and Unit Strains
	106	Intermediate	17.5	432.5	5	Deflection and Unit Strains
	107	**80% of the Calculated Ultimate Load**	17.5	450	**15**	**Deflection and Unit Strains Visual Inspection of Beam for Cracks** **Clearing the beam area of equipment and personnel**
	108	Intermediate	17.25	467.25	5	Deflection and Unit Strains
	109	Intermediate	17.25	484.5	5	Deflection and Unit Strains
	110	Intermediate	17.25	501.75	5	Deflection and Unit Strains
	111	Intermediate	17.25	519	5	Deflection and Unit Strains
	112	Intermediate	17.25	536.25	5	Deflection and Unit Strains
	113	Intermediate	17.25	553.5	5	Deflection and Unit Strains
	114	**Calculated Ultimate Load**	**11.5**	**565**	**5**	**Deflection and visual inspection outside the beam's influence zone**
	115	Intermediate	17.25	582.25	5	Visual inspection
	116	Intermediate	17.25	599.5	5	Visual inspection
	117	Intermediate	17.25	616.75	5	Visual inspection

2. Results

2.1. Beam Loading

For performing the test, a system consisting of a hydraulic electro-pump for increasing and controlling the pressure in the hydraulic installation, a distributor, and four hydraulic jacks each with a maximum capacity of 2000 kN was used.

The loading steps and the pressures applied by the hydraulic system are presented in Tables 2, 3, and 4.

The results obtained during the tests are shown in Table 5.

Three test cycles were carried out: Cycles 1, 2, and 3 up to the serviceability load of 295 kN; Cycles 4 and 5 up to the Ultimate Limit State load of 380 kN; and Cycle 6 up to 80% of the Calculated Ultimate Load, i.e., 450 kN. After this, loading continued up to 565 kN, at which point the force applied by the jacks no longer increased, although the jack stroke continued to increase up to its maximum of 120 mm. This corresponded to an increasing beam deflection without any increase in the applied force from the jacks.

Practically, the observed data indicates that the beam yielded.

Table 5 Table of Applied Load Values

For the Serviceability Limit State Cycles C1, C2 and C3		
Stage According to Design	*Stage Type*	*Load [kN]*
1	Load from Self-Weight	0
3	Load from Permanent Actions	120
6	Decompression	251.25
7	Load at the Serviceability Limit State	295
13	Load from Self-Weight	0

For the Ultimate Limit State Cycles C4 and C5		
Stage According to Design	*Stage Type*	*Load [kN]*
39	Load from Permanent Actions	120
42	Decompression	251.25
43	Load at the Serviceability Limit State	295
51	Load at the Ultimate Limit State	380
65	Load from Self-Weight	0

For the calculated ultimate load Cycle C6		
Stage According to Design	*Stage Type*	*Load [kN]*
95	Load from Permanent Actions	120
98	Decompression	251.25
99	Load at the Serviceability Limit State	295
103	Load at the Ultimate Limit State	380
107	80% of the Calculated Ultimate Load	450
114	Calculated Ultimate Load	565

At 80% of the calculated ultimate load, the value being 450 kN, no cracks appeared on either the south or north face of the beam.

After this stage, the measuring equipment was dismantled, and the beam area was cleared of apparatus and personnel.

The beam loading continued with intermediate steps towards the calculated ultimate load of 565 kN.

The crack openings at the calculated ultimate load of 565 kN ranged from 0.1 to 0.2 mm on the cantilever of the south face, with a 0.3 mm crack located at 18.4 m on the south face. On the north face, crack openings ranged between 0.1 and 0.2 mm and developed on the cantilever.

2.2. Vertical Displacements of Beam Sections (Deflections)

Vertical displacements were measured at each loading step on the supports, at mid-span, and at the two quarter points of the beam, on both the north and south faces.

Table 6 presents the main strain values for the principal loading stages according to Table 1, for loading cycle 1; Table 7 for loading cycle 2; Table 8 for loading cycle 3; Table 9 for loading cycle 4; Table 10 for loading cycle 5; and Table 11 for loading cycle 6.

Table 6. Main strain values for the principal loading stages (C1)

CYCLE	*STAGE*	*LOAD*	*PRESSURE*	*SUPPORT*			*QUARTER*			*MIDSPAN*			*QUARTER*			*SUPPORT*		
				C1	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C3;C4*	*C5*	*C6*	*Average C5;C6*	*C7*	*C8*	*Average C7;C8*	*C9*	*C10*	*Average C9;C10*
		P [KN]	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
C1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C1	2	60	12	0	0	0	0.76	0.71	0.735	1.06	1.04	1.05	0.77	0.78	0.775	0	0.02	0.01
C1	3	120	24	0	0	0	1.65	1.66	1.655	2.32	2.29	2.305	1.67	1.58	1.625	0.02	0.03	0.025
C1	6	251.25	50.25	0.03	0.03	0.03	4.03	4.03	4.03	5.63	5.58	5.605	4.06	4.04	4.05	0.07	0.07	0.07
C1	7	295	59	0.05	0.05	0.05	5.02	5	5.01	7.02	6.98	7	5.05	5.04	5.045	0.1	0.09	0.095
C1	8	251.25	50.25	0.06	0.06	0.06	5.01	4.98	4.995	6.98	6.94	6.96	5.04	5.01	5.025	0.11	0.09	0.1
C1	11	120	24	0.09	0.07	0.08	3.09	3.07	3.08	4.27	4.21	4.24	3.08	3.05	3.065	0.11	0.09	0.1
C1	12	60	12	0.06	0.08	0.07	1.95	1.94	1.945	2.7	2.65	2.675	1.94	1.94	1.94	0.11	0.09	0.1
C1	13	0	0	-0.03	0.12	0.045	0.43	0.48	0.455	0.61	0.59	0.6	0.48	0.47	0.475	0.09	0.07	0.08

Table 7. Main strain values for the principal loading stages (C2)

CYCLE	STAGE	LOAD	PRESSURE	SUPPORT			QUARTER			MIDSPAN			QUARTER			SUPPORT		
				C1	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C3;C4*	*C5*	*C6*	*Average C5;C6*	*C1*	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C9;C10*
		P [KN]	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
C2	14	60	12	-0.01	0.13	0.06	1.23	1.27	1.25	1.73	1.73	1.73	1.23	1.29	1.26	0.07	0.09	0.08
C2	15	120	24	0.04	0.12	0.08	2.19	2.19	2.19	3.08	3.04	3.06	2.22	2.22	2.22	0.09	0.1	0.095
C2	18	251.25	50.25	0.07	0.08	0.075	4.32	4.31	4.315	6.05	6	6.025	4.37	4.34	4.355	0.15	0.1	0.125
C2	19	295	59	0.07	0.09	0.08	5.22	5.21	5.215	7.32	7.27	7.295	5.22	5.25	5.235	0.15	0.11	0.13
C2	20	251.25	50.25	0.07	0.09	0.08	5.21	5.2	5.205	7.3	7.25	7.275	5.21	5.23	5.22	0.16	0.11	0.135
C2	23	120	24	0.07	0.12	0.095	3.29	3.29	3.29	4.58	4.52	4.55	3.31	3.28	3.295	0.15	0.12	0.135
C2	24	60	12	0.02	0.14	0.08	2.11	2.14	2.125	2.95	2.93	2.94	2.14	2.15	2.145	0.14	0.12	0.13
C2	25	0	0	-0.06	0.16	0.05	0.57	0.66	0.615	0.68	0.7	0.69	0.6	0.67	0.635	0.11	0.1	0.105

Table 8. Main strain values for the principal loading stages (C3)

CYCLE	STAGE	LOAD	PRESSURE	SUPPORT			QUARTER			MIDSPAN			QUARTER			SUPPORT		
				C1	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C3;C4*	*C5*	*C6*	*Average C5;C6*	*C1*	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C9;C10*
		P [KN]	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*P [KN]*	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
C3	26	60	12	-0.02	0.16	0.07	1.33	1.4	1.365	1.87	1.9	1.885	1.38	1.41	1.395	0.12	0.11	0.115
C3	27	120	24	0.04	0.13	0.085	2.28	2.31	2.295	3.19	3.18	3.185	2.3	2.32	2.31	0.13	0.12	0.125
C3	30	251.25	50.25	0.07	0.1	0.085	4.41	4.42	4.415	6.19	6.15	6.17	4.47	4.45	4.46	0.16	0.12	0.14
C3	31	295	59	0.07	0.11	0.09	5.27	5.28	5.275	7.39	7.36	7.375	5.32	5.31	5.315	0.16	0.13	0.145
C3	32	251.25	50.25	0.07	0.11	0.09	5.26	5.27	5.265	7.37	7.34	7.355	5.3	5.29	5.295	0.16	0.13	0.145
C3	35	120	24	0.07	0.13	0.1	3.29	3.32	3.305	4.59	4.55	4.57	3.31	3.3	3.305	0.16	0.13	0.145
C3	36	60	12	0.01	0.12	0.065	2.16	2.21	2.185	3.01	3.03	3.02	2.18	2.21	2.195	0.14	0.13	0.135
C3	37	0	0	-0.07	0.18	0.055	0.57	0.67	0.62	0.69	0.71	0.7	0.65	0.67	0.66	0.11	0.12	0.115

Table 9. Main strain values for the principal loading stages (C4)

CYCLE	*STAGE*	*LOAD*	*PRESSURE*	*SUPPORT*			*QUARTER*			*MIDSPAN*			*QUARTER*			*SUPPORT*		
				C1	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C3;C4*	*C5*	*C6*	*Average C5;C6*	*C1*	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C9;C10*
		P [KN]	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*P [KN]*	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
C4	38	60	12	-0.02	0.18	0.08	1.41	1.49	1.45	2	2.03	2.015	1.46	1.5	1.48	0.12	0.13	0.125
C4	39	120	24	0.05	0.16	0.105	2.38	2.43	2.405	3.35	3.34	3.345	2.42	2.43	2.425	0.14	0.13	0.135
C4	42	251.25	50.25	0.08	0.12	0.1	4.42	4.44	4.43	6.21	6.18	6.195	4.48	4.47	4.475	0.15	0.13	0.14
C4	43	295	59	0.08	0.12	0.1	5.2	5.21	5.205	7.3	7.27	7.285	5.25	5.25	5.25	0.16	0.14	0.15
C4	51	380	76	0.1	0.15	0.125	7.45	7.48	7.465	10.44	10.4	10.42	7.44	7.47	7.455	0.15	0.16	0.155
C4	59	295	59	0.12	0.15	0.135	6.73	6.75	6.74	9.43	9.38	9.405	6.72	6.73	6.725	0.15	0.16	0.155
C4	60	251.25	50.25	0.11	0.18	0.145	5.97	6	5.985	8.36	8.32	8.34	5.95	5.99	5.97	0.15	0.16	0.155
C4	64	60	12	-0.03	0.23	0.1	2.53	2.64	2.585	3.57	3.61	3.59	2.56	2.6	2.58	0.12	0.15	0.135
C4	65	0	0	-0.07	0.21	0.07	0.69	0.82	0.755	1.08	1.12	1.1	0.81	0.86	0.835	0.08	0.15	0.115

Table 10. Main strain values for the principal loading stages (C5)

CYCLE	*STAGE*	*LOAD*	*PRESSURE*	*SUPPORT*			*QUARTER*			*MIDSPAN*			*QUARTER*			*SUPPORT*		
				C1	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C3;C4*	*C5*	*C6*	*Average C5;C6*	*C1*	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C9;C10*
		P [KN]	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*P [KN]*	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
C5	66	60	12	-0.02	0.22	0.1	1.47	1.58	1.525	2.12	2.18	2.15	1.53	1.62	1.575	0.1	0.13	0.115
C5	67	120	24	0.05	0.19	0.12	2.49	2.55	2.52	3.5	3.52	3.51	2.52	2.57	2.545	0.13	0.18	0.155
C5	70	251.25	50.25	0.09	0.15	0.12	4.64	4.66	4.65	6.51	6.5	6.505	4.68	4.7	4.69	0.16	0.17	0.165
C5	71	295	59	0.09	0.15	0.12	5.51	5.54	5.525	7.75	7.74	7.745	5.55	5.59	5.57	0.16	0.19	0.175
C5	79	380	76	0.11	0.18	0.145	7.23	7.25	7.24	10.05	10.08	10.065	7.15	7.25	7.2	0.16	0.21	0.185
C5	80	369.38	73.875	0.11	0.18	0.145	7.23	7.25	7.24	10.06	10.08	10.07	7.16	7.25	7.205	0.16	0.21	0.185

C5	86	305.63	61.125	0.12	0.17	0.145	7.03	7.03	7.03	9.89	9.81	9.85	7	7.08	7.04	0.16	0.21	0.185
C5	87	295	59	0.12	0.17	0.145	6.86	6.87	6.865	9.6	9.6	9.6	6.84	6.91	6.875	0.16	0.21	0.185
C5	92	60	12	-0.03	0.25	0.11	2.51	2.62	2.565	3.5	3.61	3.555	2.57	2.62	2.595	0.13	0.21	0.17
C5	93	0	0	-0.03	0.23	0.1	0.83	0.91	0.87	1.17	1.26	1.215	0.87	0.97	0.92	0.13	0.2	0.165

Table 11. Main strain values for the principal loading stages (C6)

CYCLE	*STAGE*	*LOAD*	*PRESSURE*	*SUPPORT*			*QUARTER*			*MIDSPAN*			*QUARTER*			*SUPPORT*		
				C1	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C3;C4*	*C5*	*C6*	*Average C5;C6*	*C1*	*C2*	*Average C1;C2*	*C3*	*C4*	*Average C9;C10*
		P [KN]	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*	*P [KN]*	*[bar]*	*cm*	*cm*	*cm*	*cm*	*cm*	*cm*
C6	94	60	12	0.03	0.23	0.13	1.6	1.67	1.635	2.2	2.32	2.26	1.6	1.72	1.66	0.14	0.21	0.175
C6	95	120	24	0.09	0.19	0.14	2.74	2.77	2.755	3.78	3.85	3.815	2.72	2.83	2.775	0.16	0.21	0.185
C6	98	251.25	50.25	0.1	0.17	0.135	4.82	4.83	4.825	6.68	6.77	6.725	4.8	4.91	4.855	0.17	0.21	0.19
C6	99	295	59	0.1	0.17	0.135	5.64	5.67	5.655	7.83	7.95	7.89	5.61	5.74	5.675	0.16	0.21	0.185
C6	103	380	76	0.1	0.18	0.14	7.31	7.35	7.33	10.1	10.25	10.175	7.19	7.36	7.275	0.14	0.22	0.18
C6	107	450	90	0.12	0.2	0.16	8.91	8.94	8.925	12.34	12.49	12.415	8.75	8.94	8.845	0.12	0.21	0.165
C6	114	565	113															

Tables 12 to 14 present the actual deflections of the beam (the settlements of the support devices and the residual deflections have been eliminated).

Table 12. Measured Deflections -Cycles C1, C2, and C3 (cm)

Load	*C1*					*C2*					*C3*				
	Support	*Quarter*	*Midspan*	*Quarter*	*Support*	*Support*	*Quarter*	*Midspan*	*Quarter*	*Support*	*Support*	*Quarter*	*Midspan*	*Quarter*	*Support*
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
60	0	0.73	1.05	0.77	0	0	1.19	1.66	1.19	0	0	1.28	1.79	1.29	0

120	0	1.65	2.29	1.61	0	0	2.11	2.97	2.13	0	0	2.20	3.08	2.20	0
163.75	0	2.50	3.48	2.50	0	0	2.90	4.07	2.92	0	0	3.04	4.25	3.04	0
207.5	0	3.20	4.47	3.20	0	0	3.48	4.89	3.51	0	0	3.69	5.19	3.70	0
251.25	0	3.99	5.56	3.99	0	0	4.23	5.93	4.24	0	0	4.32	6.06	4.33	0
295	0	4.95	6.93	4.96	0	0	5.12	7.19	5.12	0	0	5.17	7.26	5.18	0
UNLOADING															
251.25	0	4.93	6.88	4.94	0	0	5.11	7.17	5.10	0	0	5.16	7.24	5.16	0
207.5	0	4.47	6.22	4.44	0	0	4.76	6.63	4.73	0	0	4.78	6.69	4.71	0
163.75	0	3.76	5.24	3.73	0	0	3.95	5.51	3.94	0	0	4.02	5.60	3.99	0
120	0	3.00	4.15	2.97	0	0	3.19	4.44	3.17	0	0	3.19	4.45	3.17	0
60	0	1.87	2.59	1.85	0	0	2.03	2.84	2.03	0	0	2.10	2.92	2.08	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 13. Measured Deflections - Cycles C4 and C5 (cm)

Load	*C4*					*C5*				
	Support	*Quarter*	*Midspan*	*Quarter*	*Support*	*Support*	*Quarter*	*Midspan*	*Quarter*	*Support*
0	0	0	0	0	0	0	0	0	0	0
60	0	1.36	1.91	1.37	0	0	1.42	2.04	1.46	0
120	0	2.29	3.23	2.30	0	0	2.39	3.37	2.40	0
163.75	0	3.14	4.39	3.14	0	0	3.20	4.49	3.30	0
207.5	0	3.59	5.06	3.61	0	0	3.81	5.36	3.81	0
251.25	0	4.32	6.08	4.35	0	0	4.52	6.36	4.54	0
295	0	5.09	7.16	5.11	0	0	5.39	7.60	5.41	0
305.63	0	5.31	7.48	5.31	0	0	5.58	7.87	5.60	0
316.25	0	5.44	7.66	5.47	0	0	5.77	8.14	5.79	0
326.88	0	5.69	8.02	5.72	0	0	6.04	8.47	6.02	0
337.5	0	6.37	8.95	6.35	0	0	6.29	8.80	6.25	0
348.13	0	6.58	9.23	6.56	0	0	6.39	8.95	6.35	0
358.75	0	6.70	9.42	6.70	0	0	6.52	9.14	6.49	0
369.38	0	6.83	9.58	6.82	0	0	6.71	9.36	6.67	0

Load	*C4*					*C5*				
	Support	*Quarter*	*Midspan*	*Quarter*	*Support*	*Support*	*Quarter*	*Midspan*	*Quarter*	*Support*
380	0	7.33	10.28	7.31	0	0	7.09	9.90	7.03	0
UNLOADING										
369.38	0	7.32	10.27	7.30	0	0	7.09	9.91	7.03	0
358.75	0	7.31	10.25	7.30	0	0	7.09	9.90	7.03	0
348.13	0	7.29	10.21	7.27	0	0	7.07	9.88	7.03	0
337.5	0	7.21	10.09	7.18	0	0	7.06	9.87	7.02	0
224.375	0	7.07	9.90	7.05	0	0	7.02	9.83	7.00	0
316.25	0	6.89	9.64	6.87	0	0	6.98	9.78	6.96	0
305.63	0	6.76	9.47	6.75	0	0	6.88	9.69	6.87	0
295	0	6.60	9.26	6.58	0	0	6.71	9.44	6.70	0
251.25	0	5.84	8.19	5.82	0	0	5.92	8.32	5.91	0
207.5	0	5.11	7.16	5.07	0	0	5.11	7.16	5.08	0
163.75	0	4.42	6.19	4.39	0	0	4.34	6.07	4.30	0
120	0	3.50	4.91	3.47	0	0	3.52	4.94	3.48	0
60	0	2.48	3.47	2.45	0	0	2.44	3.42	2.44	0
0	0	0	0	0	0	0	0	0	0	0

Table 14 Measured Deflections - Cycle C6 (cm)

Load	*Support*	*Quarter*	*Midspan*	*Quarter*	*Support*
0	0	0	0	0	0
60	0	1.99	2.36	1.50	0
120	0	2.58	3.65	2.60	0
163.75	0	3.30	4.61	3.30	0
207.5	0	3.86	5.39	3.84	0
251.25	0	4.68	6.56	4.68	0
295	0	5.51	7.73	5.50	0
316.25	0	5.84	8.20	5.82	0
337.5	0	6.37	8.90	6.32	0

358.75	0	6.77	9.45	6.71	0
380	0	7.18	10.02	7.11	0
397.5	0	7.59	10.59	7.40	0
415	0	7.81	10.91	7.72	0
432.5	0	8.17	11.40	8.07	0
450	0	8.76	12.25	8.68	0

For cycle C1 at the total load of P = 295 kN, corresponding to the normal serviceability limit state, a maximum elastic deflection of 69.3 mm was measured at midspan, which is less than 1.1 times the calculated deflection = 1.1 * 83.5 = 91.85 mm.

The residual coefficient, equal to the ratio of residual deflection to total deflection, Kr = 0.6 / 7 = 0.09 < 0.10.

For cycle C2 at the total load of P = 295 kN, corresponding to the normal serviceability limit state, a maximum elastic deflection of 7.19 mm was measured at midspan, which is less than 1.1 times the calculated deflection = 1.1 * 83.5 = 91.85 mm.

The residual coefficient Kr = 0.69 / 7.295 = 0.09 < 0.10.

For cycle C3 at the total load of P = 295 kN, corresponding to the normal serviceability limit state, a maximum elastic deflection of 7.21 mm was measured at midspan, which is less than 1.1 times the calculated deflection = 1.1 * 83.5 = 91.85 mm.

The residual coefficient Kr = 0.70 / 7.375 = 0.09 < 0.10.

No cracks appeared during loading at the normal serviceability limit state (295 kN) for cycles C1, C2, and C3.

No cracks appeared during loading at the ultimate limit state (380 kN) for cycles C4 and C5.

At 80% of the calculated ultimate load, namely 450 kN, no cracks appeared on either the South or North face of the beam.
After this stage, the measuring equipment was dismantled, and the beam area was cleared of apparatus and personnel.

The beam loading continued with intermediate stages up to the calculated ultimate load of 565 kN.

The crack opening at the calculated ultimate load of 565 kN was between 0.1 – 0.2 mm on the South cantilever face, and a crack of 0.3 mm was observed at 18.4 m on the South face. On the North face, cracks with openings between 0.1 – 0.2 mm developed along the cantilever.

To prevent accidents, personnel were evacuated from the beam area after reaching 80% of the ultimate load.

At this load level, only the beam deflection increased, reaching the maximum stroke of the hydraulic press at 120 mm, while the applied load remained constant.

In this situation, the beam yielded, indicating its collapse.

2.2. Specific strains:

The specific strains were determined by the electrical resistance strain gauge method using Hottinger 1-LY41-50/120 strain gauges and an MX840B measuring bridge (see Figure 1) from Hottinger Brüel & Kjær.

Fig. 1. MX840B Data Acquisition System

Specifications of the MX840B Data Acquisition System are:

- Measurement channels: 8 channels
- Sampling frequency: 40 kS/s per channel
- A/D converter: 24-bit per channel
- Parameterized channels (TEDS)
- CANbus I/O
- Transducer connector: D-SUB-15HD
- Power supply for active transducers (DC): 5 to 24 V
- Software: catmanAP, catmanEasy, and catmanPostProcess

Tables 15 to 23 present the measured specific strain values for each loading step. The values determined along the beam axis were obtained by averaging the measurements from the North and South faces for both the upper plate and the lower bulb.

Table 15. Measured specific strains - ε (μm/m) - Cycle 1

Load	*Upper plate*			*Lower bulb*		
KN	*South*	*North*	*Average*	*South*	*North*	*Average*
0	-4	-8	-6	-2	-8	-5
60	-64	-79	-71	56	16	36
120	-154	-169	-161	117	65	91
163.75	-227	-244	-236	191	128	159
207.5	-289	-303	-296	249	181	215
251.25	-368	-382	-375	306	232	269
295	-464	-481	-472	377	290	333
UNLOADING						
251.5	-458	-479	-469	377	287	332
207.5	-412	-432	-422	337	257	297
163.75	-342	-369	-356	284	210	247
120	-270	-296	-283	224	154	189
60	-167	-187	-177	138	80	109
0	-44	-80	-62	-8	-38	-23

Table 16. Measured specific strains - ε (μm/m)-Cycle 2

Load	*Upper plate*			*Lower bulb*		
KN	*South*	*North*	*Average*	*South*	*North*	*Average*
60	-91	-86	-89	34	19	26
120	-187	-185	-186	100	73	86
163.75	-302	-303	-302	124	88	106
207.5	-338	-340	-339	189	151	170
251.25	-400	-405	-402	258	214	236
295	-465	-472	-468	344	297	321

UNLOADING						
251.5	-461	-466	-463	346	300	323
207.5	-420	-425	-423	319	275	297
163.75	-339	-334	-337	265	233	249
120	-257	-253	-255	209	180	194
60	-147	-135	-141	121	109	115
0	6	32	19	22	51	36

Table 17. Measured specific strains - ε (μm/m) - Cycle 3

Load KN	*Upper plate*			*Lower bulb*		
	South	*North*	*Average*	*South*	*North*	*Average*
60	-81	-67	-74	64	63	63
120	-160	-144	-152	144	132	138
163.75	-243	-234	-238	207	185	196
207.5	-348	-344	-346	276	247	261
251.25	-375	-372	-373	300	269	285
295	-460	-461	-460	363	326	344
UNLOADING						
251.5	-464	-464	-464	356	319	337
207.5	-417	-415	-416	334	300	317
163.75	-350	-342	-346	265	239	252
120	-258	-248	-253	214	194	204
60	-155	-137	-146	126	123	124
0	-19	19	0	0	48	24

Table 18. Measured specific strains - ε (μm/m) - Cycle 4

Load	*Upper plate*			*Lower bulb*		
KN	*South*	*North*	*Average*	*South*	*North*	*Average*
60	-68	-42	-55	91	111	101
120	-168	-144	-156	154	160	157
163.75	-245	-228	-237	222	217	220
207.5	-277	-261	-269	272	264	268
251.25	-356	-347	-352	320	301	311
295	-429	-422	-426	380	357	369
305.625	-456	-447	-451	393	371	382
316.25	-453	-447	-450	419	393	406
326.875	-464	-451	-457	395	376	386
337.5	-476	-463	-469	553	529	541
348.125	-484	-469	-477	578	556	567
358.75	-506	-489	-497	577	559	568
369.375	-536	-523	-529	569	545	557
380	-579	-565	-572	595	575	585
UNLOADING						
369.375	-568	-550	-559	606	594	600
358.75	-573	-553	-563	598	587	593
348.125	-572	-550	-561	594	585	589
337.5	-560	-544	-552	591	575	583
326.875	-549	-531	-540	577	564	570
316.25	-543	-529	-536	550	534	542
305.625	-526	-506	-516	546	535	540
295	-503	-480	-491	542	534	538
251.25	-428	-402	-415	483	480	481
207.5	-377	-373	-375	416	381	399
163.75	-314	-305	-309	357	331	344
120	-217	-204	-210	297	281	289
60	-123	-105	-114	216	214	215
0	-11	11	0	41	70	55

Table 19. Measured specific strains - ε (μm/m) - Cycle 5

Load	*Upper plate*			*Lower bulb*		
KN	*South*	*North*	*Average*	*South*	*North*	*Average*
60	-3	3	0	116	106	111
120	-81	-78	-80	206	182	194
163.75	-169	-167	-168	262	233	248
207.5	-238	-236	-237	295	267	281
251.25	-315	-313	-314	343	311	327
295	-415	-417	-416	396	356	376
305.625	-452	-453	-453	391	351	371
316.25	-465	-466	-465	412	371	391
326.875	-398	-385	-391	524	491	507
337.5	-433	-417	-425	532	499	515
348.125	-445	-429	-437	539	505	522
358.75	-473	-454	-463	534	503	518
369.375	-502	-483	-493	537	504	520
380	-537	-520	-528	564	527	545
UNLOADING						
369.375	-543	-528	-535	560	520	540
358.75	-550	-538	-544	547	508	527
348.125	-574	-564	-569	519	481	500
337.5	-604	-594	-599	486	450	468
326.875	-594	-588	-591	494	452	473
316.25	-605	-596	-600	480	439	460
305.625	-613	-605	-609	454	414	434
295	-604	-593	-598	436	400	418
251.25	-537	-519	-528	365	337	351
207.5	-405	-380	-393	361	336	348
163.75	-335	-306	-320	296	279	287
120	-310	-272	-291	179	173	176
60	-215	-172	-194	85	94	89
0	-23	23	0	-2	26	12

Table 20. Measured specific strains - ε (μm/m) - Cycle 6

Load	*Upper plate*			*Lower bulb*		
KN	*South*	*North*	*Average*	*South*	*North*	*Average*
60	-104	-66	-85	54	56	55
120	-234	-201	-218	114	99	106
163.75	-317	-287	-302	151	128	139
207.5	-379	-352	-366	183	158	170
251.25	-463	-439	-451	244	212	228
295	-569	-553	-561	280	237	258
316.25	-612	-595	-604	292	248	270
337.5	-647	-654	-650	339	271	305
358.75	-707	-717	-712	343	271	307
380	-783	-796	-790	330	258	294
397.5	-812	-829	-821	369	292	331
415	-845	-865	-855	373	294	334
432.5	-905	-930	-918	372	286	329
450	-957	-992	-974	469	329	399
467.25	-994	-1032	-1013	470	320	395
484.5	-1036	-1082	-1059	437	323	380
501.75	-1067	-1127	-1097	434	345	389
519	-1115	-1186	-1150	411	336	373
536.25	-1207	-1296	-1251	641	346	494
553.5	-1234	-1329	-1282	764	378	571
565	-1293	-1392	-1343	920	825	872
582.25						
599.5						
616.75						

The values at the lower fiber and upper fiber were determined by extrapolating the measured values.

Tabel 21. Calculated specific strains - ε (μm/m) - Cycles C1, C2 and C3

Load KN	*Upper plate*		*Lower bulb*		*Load KN*	
	South	*North*	*Upper fiber*	*South*	*North*	*Lower fiber*
0	-6	-5				
60	-74	39	-92	30	-78	67
120	-169	98	-194	94	-161	147
163.75	-247	171	-314	118	-251	209
207.5	-311	230	-354	185	-364	279
251.25	-394	288	-421	254	-393	304
295	-496	357	-492	344	-484	368
UNLOADING						
251.5	-492	356	-486	346	-488	361
207.5	-443	318	-444	318	-438	339
163.75	-374	265	-354	266	-364	270
120	-297	203	-268	208	-266	218
60	-186	118	-149	122	-154	132
0	-63	-22	18	37	-1	25

Tabel 22. Calculated specific strains - ε (μm/m) - Cycles C4 and C5

Load KN	*C4*		*C5*	
	Upper fiber	*Lower fiber*	*Upper fiber*	*Lower fiber*
60	-60	106	-3	115
120	-165	166	-88	202
163.75	-250	233	-180	260
207.5	-285	284	-253	296
251.25	-371	330	-333	346
295	-449	392	-439	399
305.625	-476	407	-477	395
316.25	-475	431	-490	416
326.875	-482	410	-418	534
337.5	-499	570	-453	543

Load KN	*C4*		*C5*	
	Upper fiber	*Lower fiber*	*Upper fiber*	*Lower fiber*
348.125	-507	598	-465	550
358.75	-529	599	-492	547
369.375	-561	589	-522	550
380	-606	619	-560	577
UNLOADING				
369.375	-593	634	-567	572
358.75	-597	627	-576	559
348.125	-595	623	-600	531
337.5	-585	616	-630	500
326.875	-573	603	-623	504
316.25	-567	574	-631	491
305.625	-547	571	-640	465
295	-522	568	-628	448
251.25	-442	508	-554	377
207.5	-397	421	-414	370
163.75	-328	363	-338	305
120	-225	304	-305	190
60	-124	225	-202	98
0	-2	57	0	12

Tabel 23. Measured specific strains - ε (μm/m) - Cycle 6

Load KN	*Upper fiber*	*Lower fiber*
60	-89	59
120	-227	116
163.75	-315	152
207.5	-381	186
251.25	-471	248
295	-585	282

316.25	-629	296
337.5	-679	333
358.75	-742	337
380	-822	326
397.5	-855	365
415	-890	368
432.5	-954	366
450	-1015	439
467.25	-1054	437
484.5	-1102	423
501.75	-1140	433
519	-1195	418
536.25	-1302	545
553.5	-1336	626
565	-1408	938

Maximum specific strain values at the load P = 565 kN are ε = 938 μm/m at the bottom fiber and ε = -1408 μm/m at the top fiber.

3. Conclusions

From the analysis and interpretation of the data, the following observations can be made:

1. At loads corresponding to the serviceability limit state and the ultimate limit state, beam G4 showed no signs of failure or loss of stability. No defects affecting the beam's functionality were observed.

   While loading cycles C1, C2, and C3 at the Serviceability Limit State load of 295 kN, no cracks appeared.

   At the Ultimate Limit State load of 380 kN during cycles C4 and C5, no cracks were detected.

   At 80% of the calculated ultimate load, i.e., 450 kN, no cracks appeared on either the South or North face of the beam.

   After this stage, measuring equipment was dismantled and the beam area was cleared of personnel and apparatus.

Loading continued through intermediate stages up to the calculated ultimate load of 565 kN.

At the calculated ultimate load of 565 kN, crack openings ranged between 0.1–0.2 mm on the South cantilever face and a crack of 0.3 mm at 18.4 m along the South face. On the North face, cracks varied between 0.1–0.2 mm and developed on the cantilever.

To prevent accidents, personnel were removed from the beam area after reaching 80% of the ultimate load.

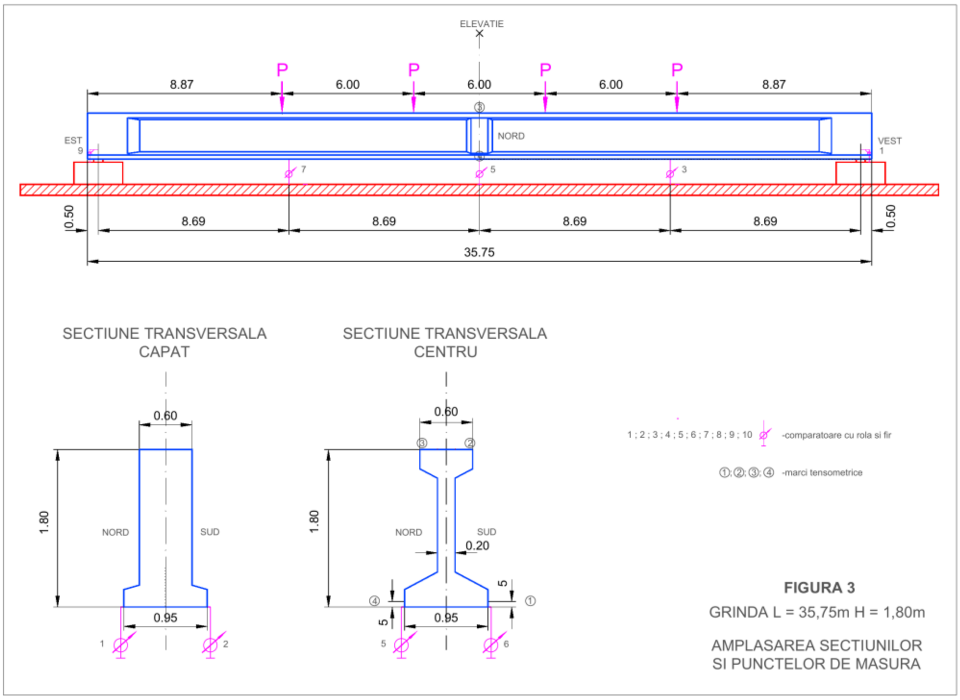
At this force level, only the beam's deflection increased, reaching the maximum press stroke of 120 mm, while the force applied by the presses remained constant.

In this situation, the beam yielded, representing its collapse.

2. The measured deflections comply with the admissibility criteria from STAS 12313-85, point 2.6.2.4.
3. The variation of the measured specific strains shows a linear behavior corresponding to the measured deflections on the beam.

Fig 2. Location of the Beam and Hydraulic Presses on the Test Stand

Fig 3. Detail of the Hydraulic Press



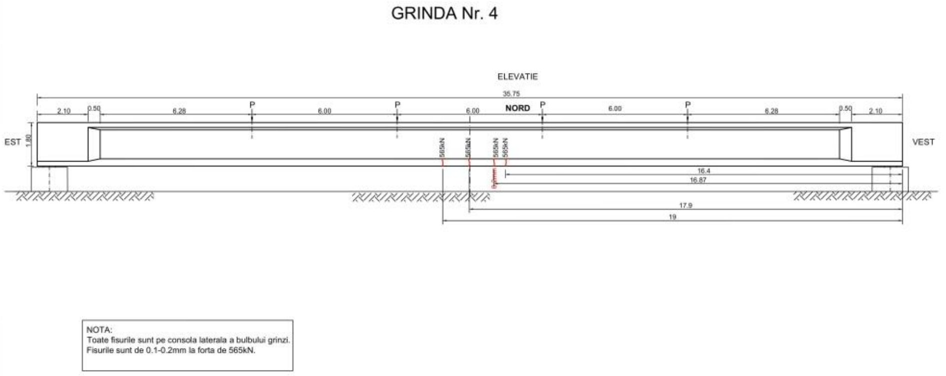


Figura 4.1
RELEVEU FISURI FATA NORD
GRINDA Nr. 4
L=35.75m; H= 1.80m

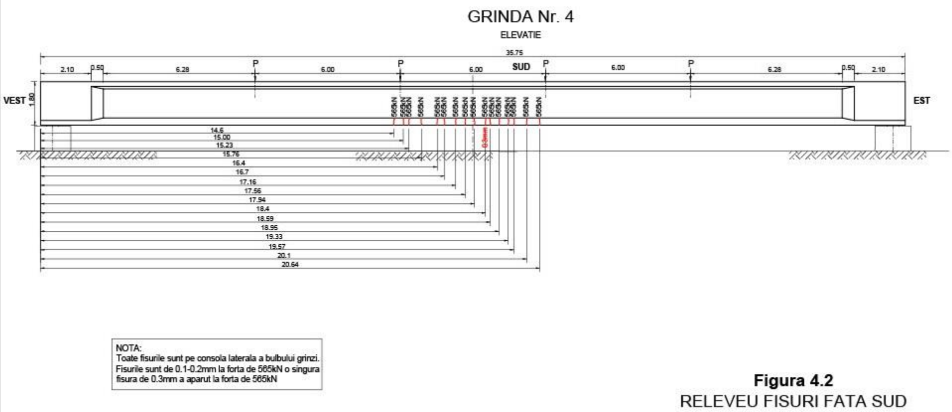
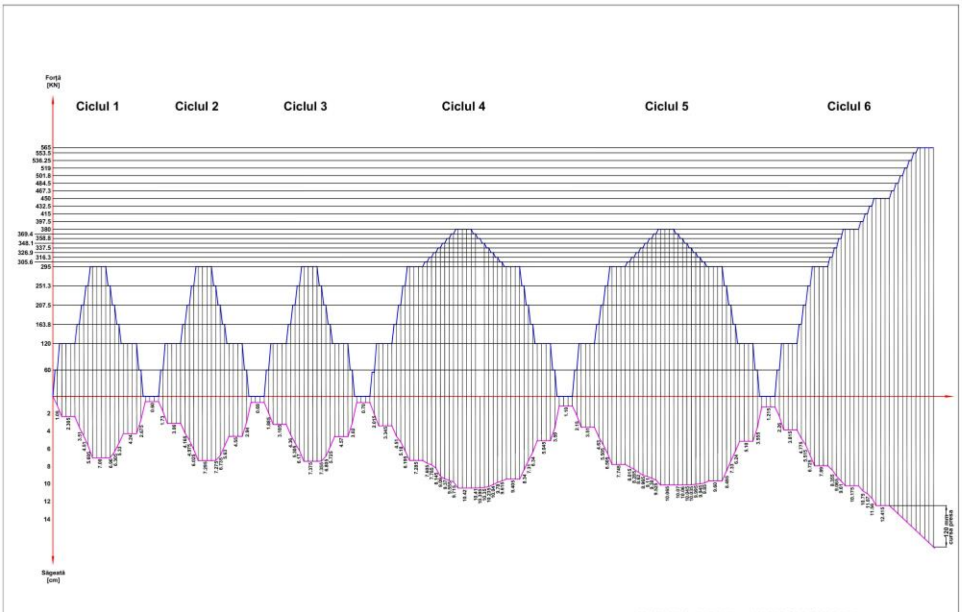


Figura 4.2
RELEVEU FISURI FATA SUD
GRINDA Nr. 4
L=35.75m; H= 1.80m



INCERCAREA LA INCOVOIERE
Grinda cu lungimea L = 35.75m si inaltimea H = 1.80m

FIGURA 5 - Diagrama deformatii - incarcare - timp

R E F E R E N C E S

[1] Proiect de Incercare Grinzi Prefabricate Precompritate elaborat de: WEBUILD S.P.A - Milano Sucursala Romania Bucuresti, 2025.

[2] STAS 12313/85 -Incercarea pe stand a elementelor prefabricate din beton.beton armat si beton precomprimat.

[3] Costel GHEORGHE, Cătălin DIMA, Nicoleta Mariana ENE, Încercarea în regim static și dinamic a suprastructurilor podurilor rutiere, Conference Proceedings of the Academy of Romanian Scientists PRODUCTICA Scientific Session, 2018.

[4] COMISU Cristian, JANTEA Constantin, VARLAM Florin - Alcătuirea şi calculul podurilor, Vol.1, 1996, ISBN 973-97904-5-3.