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Compressive Strength Assessment of 60–70-Year-Old Bridge Concrete in Eastern Slovakia: Compliance with Historical Standards vs. Current Eurocode Requirements

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Abstract

This article focuses on the evaluation of concrete substructures of 10 road bridges in eastern Slovakia, built between 1960 and 1970, based on core sampling and compressive strength testing performed in accordance with current European procedures for in-situ strength assessment. The results confirm that the concrete was predominantly site-batched, characterized by a large aggregate size and significant strength variability. Although all tested specimens meet the design requirements valid at the time of construction, only about half of the bridges achieve the prescribed characteristic strength when assessed according to present-day European standards. Despite their age of 60–70 years, the substructures (abutments and piers) remain in very good condition. In contrast, the superstructures show extensive deterioration, dominated by reinforcement corrosion and alkali–silica reaction, which will require costly rehabilitation or replacement in the near future.

Keywords: in situ testing, concrete, bridges, site-mixed concrete, ageing concrete bridges

1 Introduction

In recent years, the Center of Research and Innovation in Construction at the Faculty of Civil Engineering, Technical University of Košice, has carried out numerous diagnostic surveys of bridge structures in eastern Slovakia. From this broader set, ten road bridges constructed in the 1960s and 1970s as cast-in-place concrete structures were selected for detailed investigation. The diagnostic work focused primarily on the substructures – abutments and piers.
Core specimens 110 mm in diameter were drilled from these elements with a minimum quantity of 3 pieces (Figure 1). After extraction, the cores were prepared by cutting and grinding the end surfaces and subsequently subjected to compressive strength testing in a laboratory (Figure 3), In addition to compressive strength, the bulk density of the concrete and the maximum aggregate size were determined for each specimen. The following sections of this paper present the results of the laboratory tests, a comparison of the measured strengths with the requirements of the standards valid at the time of construction [1,2], an

evaluation against current European standards [3,4], an analysis of the occurrence of concrete with large aggregate sizes (Figure 2), and an assessment of the density of the concrete.

Figure 1: The process of core drilling the and a view of the holes after the drill bits have been removed

Figure 2: The Core drills with different aggregate sizes, from left: large, medium and small grains

2 Methods

Core samples were subsequently tested in the laboratory. The procedure for extraction, preparation, and testing followed the current European standard [5]. The cores were cut and end surfaces ground to produce cylindrical test specimens. Each prepared specimen was weighed and measured to determine its bulk density. Following the compressive strength test in a laboratory testing machine (Figure 3), the maximum aggregate size was visually determined on the fractured surfaces. A summary of the measured compressive strength values, bulk densities, and maximum aggregate sizes is presented in Table 1.

Table 1: Basic results of pressure tests, and sample parameters (density and size of aggregates)

designation of bridge	**[1)] district of SR**	**core drill number**	**density (kg/m^3)**	**max. grain size (mm)**	**[2)] compressive strength (MPa)**
B1	Gelnica	CD1	2446	16	36.9
		CD2	2398	36	36.4
		CD3	2450	26	38.5
B2	Lučenec	CD1	2298	32	31.4
		CD2	2306	22	32.2
		CD3	2293	72	33.9
B3	Košice 1	CD1	2311	16	37.3
		CD2	2299	20	34.1
		CD3	2320	16	43.3
B4	Košice-okolie	CD1	2340	25	25.7
		CD2	2323	35	21.6
		CD3	2334	35	31.3
B5	Košice 3	CD1	2380	20	37.8
		CD2	2398	16	40.3
		CD3	2347	24	38.8
B6	Košice 2	CD1	2341	35	29.3
		CD2	2459	34	21.4
		CD3	2309	22	25.6
B7	Spišská Nová Ves	CD1	2329	22	32.1
		CD2	2496	22	29.3
		CD3	2246	22	33.6
B8	Michalovce	CD1	2488	32	31.0
		CD2	2231	32	25.3
		CD3	2215	32	28.6
B9	Michalovce	CD1	2267	28	29.8
		CD2	2179	16	22.6
		CD3	2242	24	18.4
B10	Michalovce	CD1	2274	22	22.2
		CD2	2326	32	31.8
		CD3	2335	32	35.8

[1)] - District in eastern Slovakia where the bridge is located

[2)] - Compressive strength determined on core drills according to STN EN 13791/A20

Figure 3: Left - prepared samples, middle - Matest press machine, right - damaged sample after testing

3 Results and discussion

At the time of construction (1960s and 1970s), the bridges were designed according to the Czechoslovak standard ČSN 73 6202 [2], the strength classes of concrete were defined according to the Czechoslovak standard ČSN 73 1201 [1]. For the investigated monolithic structures, grade B300 was most commonly specified, corresponding approximately to the current strength class C25/30. Today, bridge structures are designed in accordance with the Eurocode suite (primarily EN 1992-2 in conjunction with EN 1992-1-1) [3], while the specification of concrete, its strength classes and other properties are governed by STN EN 206 [4] together with the respective national annex. In addition to the fundamental compressive strength requirement, the present analysis also addresses the influence of maximum aggregate size and concrete bulk density on the resulting material properties. The measurement results and their evaluation with respect to the above parameters are detailed in the following sections.

3.1 The fundamental compressive strength requirement

The following tables (Table 2,3) assign the compressive strengths obtained from laboratory tests to the corresponding strength classes and compare them with the requirements of the standards applicable both at the time of construction and today.

Table 2 - when evaluated according to the historical ČSN 73 1201 [1] the measured strengths corresponded to grades B300 to B450. All specimens satisfied the requirement of the then-valid standard ČSN 73 6202 [2], which specified a minimum grade of B300 for monolithic bridge structures – this requirement was met in 100 % of cases.

Table 3 - when reassessed using current standards STN EN 206 [4], the measured strengths corresponded to classes from C20/25 to C35/45. The current bridge design requirement (STN EN 1992-2 + national annex) [3] of a minimum strength class C30/37 for concrete bridge elements was satisfied in only approximately 20 % of the investigated structures.

Table 2: Verification of strength parameters according to standards at the time of bridge construction

designation of bridge	max. grain size	1) compressive strength (MPa) (average value)	2) grade based on ČSN 73 1201	3) grade required by ČSN 73 6202	fulfillment of requirements
B1	36	37.27	B450	B300	YES
B2	72	32.50	B400	B300	YES
B3	20	38.23	B450	B300	YES
B4	35	26.20	B350	B300	YES
B5	24	38.97	B450	B300	YES
B6	35	25.43	B300	B300	YES
B7	22	31.67	B400	B300	YES
B8	32	28.30	B350	B300	YES
B9	28	23.60	B300	B300	YES
B10	32	29.93	B350	B300	YES
1) - Compressive strength of concrete determined on core drills according to STN EN 13791/A20					
2) - Concrete strength class defined according to ČSN 73 1201 determined from tests 1)					
3) - Required strength class of concrete for bridge construction according to ČSN 73 6202					

Table 3: Verification of strength parameters according to current standards

designation of bridge	max. grain size (mm)	1) compressive strength (MPa) (average value)-reduction based on [6]	2) grade based on STN EN 206	3) grade required by STN EN 1992-2	fulfillment of requirements
B1	36	37.27-8=29.27	C25/30	C30/37	NO
B2	72	32.50-8=24.5	C20/25	C30/37	NO
B3	20	38.23-8=30.23	C30/37	C30/37	YES
B4	35	26.20-8=18.2	C16/20	C30/37	NO
B5	24	38.97-8=30.97	C30/37	C30/37	YES
B6	35	25.43-8=17.43	C16/20	C30/37	NO
B7	22	31.67-8=23.67	C20/25	C30/37	NO
B8	32	28.30-8=20.30	C20/25	C30/37	NO
B9	28	23.60-8=15.60	C12/15	C30/37	NO
B10	32	29.93-8=21.93	C20/25	C30/37	NO
1) - Compressive strength of concrete determined on core drills according to [5] and [6]					
2) - Concrete strength class defined according to STN EN 206 [4] determined from tests 1)					
3) - Required strength class of concrete for bridge construction according to STN EN 1992-2 [3]					

3.2 Use of large aggregate fractions

The maximum aggregate size determined from the cores ranged from 20 to 72 mm (Tables 1–3). Such values clearly indicate that the concrete was predominantly site-batched. Aggregate sizes exceeding 32 mm are considered high by today’s standards, and when pumpability is required, current European recommendations [3,4] limit the maximum size to 40 mm. Nevertheless, with an appropriate grading curve and well-designed mix, large aggregate can still yield the required compressive strength, as confirmed by the test results. From a practical perspective, however, placing such mixes was extremely demanding. Interestingly, significantly larger aggregate particles were more frequently observed in bridges located farther from Košice. In those regions distant from ready-mix concrete facilities, local quarry stone was favoured, and concrete was generally made on site.

3.3 Impact of concrete density on achieved in-situ strength

A moderately strong positive correlation (r = 0.68) was found between bulk density and in-situ compressive strength. Specimens with bulk density above 2350 kg/m³ consistently exhibited compressive strengths exceeding 31 MPa, whereas cores below 2250 kg/m³ generally fell below 30 MPa. Approximately 46 % of the variability in compressive strength can be explained by differences in bulk density, indicating that compaction quality and porosity played a significant role in the final performance of these 60–70-year-old site-batched concretes.

4 Conclusion

Laboratory tests of core samples from 60–70-year-old bridges in eastern Slovakia showed that concrete was mostly batched on site, evidenced by large aggregate sizes and high dispersion in compressive strengths. Despite limited quality control of the era, measured strengths met the standards valid at the time. However, only about a quarter now satisfy current characteristic strength requirements. Substructures (abutments and piers) remain acceptable and, with proper maintenance, can serve reliably for decades. In contrast, upper horizontal elements (beams and plates) show serious to critical damage from reinforcement corrosion, cracking, and occasional alkali-silica reaction. Their rehabilitation or replacement will demand substantial funds in coming years, affecting hundreds of similar bridges across Slovakia [7].

References

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