

# Quality control of the concrete of the bridge reg. No. M117 in Pardubice

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**Abstract.** This paper is introducing results of diagnostic survey of bridge reg. No. M117 in Pardubice. Which included the quality control of the concrete used in the construction after more than 40 years of operation. Compressive strength of concrete, identification of content of chlorides in concrete and identification of resistance to CH.R.L. – method C are presented in this paper. This paper come into existence with cooperation with the state-funded organization Road Administration and Maintenance of the Pardubice Region and TOP CON SERVIS s.r.o. company.

## 1. Introduction

The bridge ev. No. M117 bridges over the railway line, street of kpt. Jarose (R36) and several local roads. The bridge has 20 sections and transfers the Kyjevská road.

The load-bearing structure consists, in the cross-section, of 9 pcs pre-stressed prefabricated beams KA 61, which were extended, furthermore, by 0.8 m. The length of the beam is, therefore, 14.4 m. The span is 13.85 m. During the repair of the bridge in the years 1992 – 1993, the exposed and ceiling surfaces of the load-bearing structure were provided with a unifying and protective coat.

Both supports are made of concrete with reinforced-concrete embedded groundsills. The middle supports are of reinforced concrete with cast concrete reinforced-concrete pre-stressed cap sills. During the repair of the bridge in the years 1992 – 1993, the bottom construction was treated with scouted sprayed concrete. The construction-technical investigation was focused only on the bridge fields in the surroundings of the railway line Prague – Ostrava and the highway R36. Shape and characteristics of the structure are in more detail shown below, on Figure 1.





**Figure 1.** Bridge No. M117 in Pardubice.

## 2. Concrete

### 2.1. Compressive strength of concrete – summary

The summary of the results of destructive tests of compressive strength of concrete and thereto corresponding strength classes or, as the case may be, classes of concrete, are identified in the following Tables 1 and 2.

**Table 1.** Summary of the results of the tests of the compressive strengths of concrete.

| Diagnosed construction elements |               | Compressive strength of concrete (MPa) |                | Variation coefficient $v^*$ |
|---------------------------------|---------------|--|----------------|-----------------------------|
|                                 |               | test average                           | characteristic |                             |
| <b>Cap sills of pillars</b>     | destructively | 57.3                                   | 50.3           | 3.4                         |
| <b>Columns of pillars</b>       | destructively | 44.1                                   | 38.1           | 4.4                         |

\* ČSN 73 2011 [1] specifies the limit value of the variation coefficient for the homogenous concrete C30/37 and higher  $v = 12\%$  (homogeneity from the standpoint of strengths).

**Table 2.** Strength class or, as the case may be, class of concrete on the basis of the performed tests.

| Diagnosed structural elements |               | Class of concrete or, as the case may be / strength class of concrete |                              |
|-------------------------------|---------------|---|------------------------------|
|                               |               | ČSN EN 1992   | Requirement of documentation |
| <b>Cap sills of pillars</b>   | destructively | C 45/55   | -                            |
| <b>Columns of pillars</b>     | destructively | C 35/45   | -                            |

The following conclusions can be stated on the basis of the performed tests of the compressive strength of concrete:

- On the basis of destructive tests of compressive strength of concrete within the limited scope, we recommend considering the following classes of concrete for the monitored reinforced-concrete structure of the bridge, according to ČSN EN 1992:
  - Columns of pillars: C 30/37
  - Cap sills of pillars: C 40/45

## 2.2. Identification of content of chlorides in concrete

The content of chloride ions above a certain limit level significantly increases the risk of the corrosion of the reinforcement. That is why a chemical analysis of the concrete was performed within the diagnostic works in order to identify the content of the chloride ions in concrete [4].

Sampling was evenly distributed along the structure of the bridge. Altogether, 20 samples of concrete were taken in 10 places (always two samples from a different depth in one place).

An informative recalculation was carried out for the following prerequisites and qualified estimates and conditions:

- Quantity of cement used for the production of 1 m<sup>3</sup> of concrete is 350 kg for the bottom constructions and 420 kg for the concretes of the beams.
- Volume weight of concrete of the beams was estimated on the level of 2350 kg/m<sup>3</sup>, for the cap sills of pillars on the level of 2350 kg/m<sup>3</sup> and 2230 kg/m<sup>3</sup>.

The limit content of Cl<sup>-</sup> [% of weight] related to weight of cement is, according to ČSN EN 206 [2], for common concrete 1 % of volume weight; reinforced-concrete 0.4 % of weight; pre-stressed concrete 0.2 % of weight.

From the performed analysis of the content of the chlorides, the following can be stated:

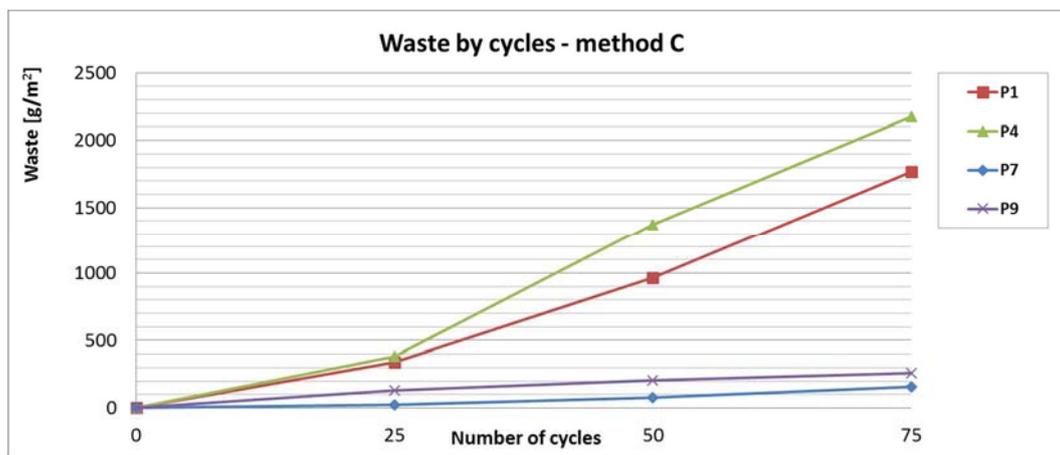
- Average content of Cl<sup>-</sup> [% of weight] identified by means of a laboratory analysis for the concrete of the cap sills is 0.33 % for the depth of sampling of 0-15 and 0.26 % for the depth of sampling of 15-30 mm. The limit content of Cl<sup>-</sup> [% of weight] related to weight of the cement for the pre-strained concrete is, according to ČSN EN 206, 0.2 % of weight
- Average content of Cl<sup>-</sup> [% of weight] identified by means of a laboratory analysis for the concrete of the columns of pillars is 0.19 % for the depth of sampling of 0-15 and 0.13 % for the depth of sampling of 15-30 mm. The limit content of Cl<sup>-</sup> [% of weight] related to weight of the cement for the reinforced-concrete concrete is, according to ČSN EN 206, 0.4 % of weight
- Average content of Cl<sup>-</sup> [% of weight] identified by means of a laboratory analysis for the concrete joints between KA beams is 0.53 % for the depth of sampling of 0-15 and 0.52 % for the depth of sampling of 15-30 mm. The limit content of Cl<sup>-</sup> [% of weight] related to

weight of the cement for the reinforced-concrete is, according to ČSN EN 206, 0.4 % of weight

- Average content of Cl<sup>-</sup> [% of weight] identified by means of a laboratory analysis for the concrete of the KA beams is 0.09 % for the depth of sampling of 0-15 and 0.05 % for the depth of sampling of 15-30 mm. The limit content of Cl<sup>-</sup> [% of weight] related to weight of the cement is, according to ČSN EN 206, for the pre-strained concrete 0.2 % of weight
- In the concrete of the cap sills of pillars and joints between the KA beams, the content of chloride ions within the whole range of the depth of sampling (0 – 30 mm) is high and does not comply with the requirements of ČSN EN 206.
- In the concrete of the pillars and KA beams, the content of chloride ions within the whole range of the depth of the sampling (0 – 30 mm) is low and complies with the requirements ČSN EN 206.

### 2.3. Identification of resistance to CH.R.L. – method C

For this test, a bore with the diameter of 150 mm was taken within the investigation from the structure 4. The bores V1 and V7 from the cap sills of the pillars and the bores V4 and V9 from the columns of pillars.



**Figure 2.** Graphic illustration of wastes from samples V1, V4, V7 and V9.

The following results from the performed measurement:

- Sample V1 (cap sill of the pillar) features the waste of 1769 g/m<sup>2</sup> after 75 cycles, sample V4 (column of the pillar) features the waste of 2176 g/m<sup>2</sup> after 75 cycles, sample V7 (cap sill of the pillar) features the waste of 156 g/m<sup>2</sup> after 75 cycles and sample V9 (column of the pillar) features the waste of 258 g/m<sup>2</sup> after 75 cycles.
- For the CH.R.L. test, the standard ČSN 73 1326 requires a core bore with Ø150 mm and for the reinforced concrete a core bore taken from the structure with Ø100 mm.
- Based on the results of the CH.R.L test, method C, according to ČSN 73 1326 [3], the concrete of the bore V7 and V9 has a high resistance against CH.R.L. and complies with the requirements for concretes of the grade of the environment XF required nowadays for this type of the structure (the highest grade of the impact of the environment XF4 according to TKP 18 (waste < 1000 g/m<sup>2</sup> after 75 cycles of method C).
- With respect to the samples V4, the resistance against the effect of CH.R.L. is incompliant already after 50 cycles and with respect to the sample V1 after 75 cycles; the breakdown occurs along the whole surface of the test specimen.

### 3. Summary

The construction-technical investigation was focused only in the bridge fields in the surroundings of the railway line Prague – Ostrava and the highway R36.

On the basis of the performed works, the following can be stated, therefore:

- On the basis of a limited number of the destructive tests of compressive strength of concrete, it is recommend considering the class of the concrete:
  - Columns of pillars: C 30/37
  - Cap sills of pillars: C 40/45
- In the concrete of the cap sills of pillars and joints between the KA beams, the content of chloride ions within the whole range of depth of the sampling (0 – 30 mm) is high and it does not comply with the requirements of CSN EN 206. In the concrete of the columns of the pillars and the KA beams, the content of chloride ions within the whole range of the depth of the sampling (0 – 30 mm) is low and complies with the requirements of CSN EN 206.
- On the basis of the results of the CH.R.L test, method C, according to CSN 73 1326, the concrete of the bore V7 and V9 has a high resistance to CH.R.L. and complies with the requirements for the concretes of the grade of the environment XF required nowadays for this type of the structure (the highest grade of the impact of the environment XF4 according to TKP 18 (waste < 1000 g/m<sup>2</sup> after 75 cycles, method C). With respect to the samples V4 (column of the pillar No. 14), the resistance against the effect of CH.R.L. is already in compliance after 50 cycles and with respect to the sample V1 (cap sill of the pillar No. 15) after 75 cycles; the breakdown occurs along the whole surface of the test specimen.
- By means of destructive probes into the Columns of pillars, the reinforcement of the type 10 400 (Rs40) was identified. On the reinforcement, there is an apparent surface corrosion of the reinforcement. On the binder bars, there is an apparent surface corrosion of the reinforcement, locally up to deep corrosion of the reinforcement related to peeling-off of the corrosion products in the layers and considerable weakening of the surface of the cross-section of approx. 20 - 30% of the surface of the cross-section, refer to the probe S3, pillar No. 14.
- By means of destructive probes into the prestressed cap sills of pillars, the pre-stressed reinforcement was revealed in the form of cables with individual diameters of the wires of approx. 4 mm. In the place of the probes into the sides of the cap sills (probes S1, S6 and S7), prestressed cables were found in the middle of the span. Individual cables featured signs of surface corrosion of the reinforcement; the protectors were usually not fully filled with the injection mixture.
- With the probe S8 into the face of the cap sill, 11 anchors of the prestressed reinforcement were revealed. Due to the symmetry of the element, it can be considered that the cap sill is reinforced probably by 18 prestressed cables.

According to the main bridge inspection of the bridge [6] of 05/2013, the situation of the load-bearing structure and the bottom of the construction is assessed as satisfactory (construction state IV according to CSN 73 6221 [5]). The usability is assessed as conditionally usable (state II according to CSN 73 6221).

With respect to the fact that the whole actual concrete surface of the structures is hidden, be that under the unifying coat (load-bearing structure) or sprayed concrete (bottom construction), it is very difficult to assess the actual structure as a whole on the basis of inspections.

For further use of the bridge structure in the following medium-term horizon (decade), the following must be performed unconditionally:

- A complete renewal of the hydro insulation of the load-bearing structure and, thereby, preventing from water entering the chambers of the KA beams, and also the cap sills and stems of the pillars. It must include a suitable modification of the dilatation areas above

individual cap sills so as to avoid the follow-up damage to the insulation in such places due to the effect of dilatations of the individual fields.

- Elimination of cornice prefabricates and their replacement with others. The client of the diagnostics did not require the verification of the conditions of the attachment of the cornice prefabricates. However, as the fall of the prefabricate in autumn 2017 demonstrated, there has been a real risk of a strong corrosion violation of the anchoring of the cornice elements. However, a real inspection of each anchoring for that particular structural arrangement and without a drastic limitation of the operation in the surroundings of the bridge is not possible.
- Plan and, depending on the possibilities (e.g. at the moment of the replacement of the cornice elements or another uncovering of the bridge), perform detailed diagnostics of the cap sills. Depending on the result, propose intervals and methods of the control monitoring of the prestressed reinforcement of the cap sills of the pillars or, as the case may be, a maintenance intervention (strengthening, replacement). A localized diagnostic investigation of a small range revealed that the steel protectors of the prestressed reinforcement might not be fully filled with the injection material and on individual wires of the cables, surface corrosion of the reinforcement could already be seen. At this moment, the range of the finding is, however, only indicative and informative.

All aforesaid points are only necessary for a temporary fixation and preservation of the current conditions of the structure so as to avoid a significant deterioration of the conditions.

As it has been demonstrated by both stages of the diagnostic investigation, parts of the structures are strongly contaminated by chloride ions and they do not comply with the requirements of CSN EN 206.

The same applies in case of tests of resistance against frost and spreading salts. A considerable part of the samples does not comply with the requirements for concretes of the grade of the environment XF nowdays required for this type of the structure (the highest grade of the effect of the environment XF4 according to TKP 18 (waste < 1000 g/m<sup>2</sup> after 75 cycles, method C). Without the realization of the recommended measures, especially the renewal of the hydro insulation, the degradation processes will escalate in time and the conditions of the structure will deteriorate progressively.

Prestressed cap sills are a sensitive structure with respect to corrosion and possibly potential failures. In case of a replacement of the cornice prefabricates and/or at the moment of the renewal (replacement) of the hydro insulation, we recommend performing detailed diagnostics of all revealed and available parts of the cap sills (anchoring areas and adjacent parts, conditions of cable channels and prestressing). On the basis of the result, propose the following procedure of monitoring and possible steps of repairs (e.g. strengthening) of the cap sills.

### Acknowledgements

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### References

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- [2] CSN EN 206+A1: 2017 *Concrete - Specifications, properties, production and compliance*
- [3] CSN 73 1326: 1985 *Identification of resistance of cement concrete surface to water and defrosting chemicals*
- [4] CSN EN ISO 10304-1: 2009 *Water quality – Determination of dissolved anions by liquid chromatography of ions – Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulphate*
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