Evaluation of the Causes of Concrete Kerbs Fast Damage

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Abstract. The paper presents the results of testing double-layered concrete kerbs with surface damage occurred after 3 years of construction. The testing was conducted to determine the causes of the fast destruction. The testing featured a visual inspection of the kerbs’ damage at the location of their construction and then sampling of 7 kerbs with various degrees of damage, which were transported to the laboratory. It was founded that in some kerbs the surface layer was damaged, whereas the concrete’s structural layer in all kerbs was in very good condition, without any damage. The testing program featured determination of properties, such as compressive strength, water absorption, capillary absorption and freeze-thaw durability – resistance to internal cracking and surface scaling. It was founded that the results of structural concrete testing: compressive strength, water absorption, freeze-thaw durability (resistance to internal cracking) and capillary absorption tests were not too useful in determining the kerb surfaces’ resistance to damage. Tests conducted using an optical microscope indicated that the concrete’s texture layer is insufficiently compacted. The test results indicate that the concrete’s water absorption (samples with the thickness of 50 mm, cut out from the kerb’s top surface) is best correlated with the test results the concrete kerb’s surface scaling in the presence of de-icing salts.

1. Introduction

The EN 1340 European standard [1] includes provisions concerning materials, properties, requirements and methods of testing related to prefabricated kerbs. Kerbs can be manufactured from a single type of concrete or from a wear layer and structural layer made from various concretes. If the kerbs are manufactured with a wear layer, the layer should have a minimum thickness of 4 mm on the entire surface declared by the manufacturer as the visible surface. The standard specifies the requirements concerning the flexural strength, wear resistance, slip resistance, shape and dimensions as well as visual aspects. The technical requirements, applicable to concrete kerbs intended for use in conditions of contact with de-icing salts during frost, include the following:

- freezing and de-icing salt resistance – mass loss after 28 freeze-thaw cycles: average value ≤ 1.0 kg/m², whereas no single result can exceed 1.5 kg/m²,
- water absorption ≤ 6.0%.

Preliminary type testing of the kerbs should be conducted to confirm compliance with the standard at the beginning of the manufacturing of a new type of product or family of products or at the launch of a new production line to confirm that the product properties meet the standard’s requirements and the values declared by the manufacturer. In case of changes in raw materials in terms of used ratios or...
manufacturing devices or processes, which can substantially change some or all properties of the ready-to-use product, the type tests must be repeated for the selected property or several properties.

In the case of wear resistance and resistance to atmospheric conditions, the type tests must be repeated annually for each surface family, even if no changes occur. If the type test result (mass loss) is lower than 50% of the required value for a surface family, the testing frequency can be lowered to a single test once per two years. Likewise, if a given surface family is subjected to on-going water absorption testing to confirm compliance with the kerbs subjected to freezing/thawing testing. If both of the aforementioned conditions are met, the test frequency can be lowered to a single test once per four years.

The most frequent type of frost damage occurring in road structures is surface scaling. It is manifested in gradual scaling and chipping of grout or mortar with a thickness of a couple of millimetres. It is often accompanied by revelation of the surface of coarse aggregate grains. Scaling occurs in the case of high absorption in the subsurface layer, especially when the surface is covered by a small layer of water or de-icing salt solution. It is extremely more difficult to protect the concrete against surface scaling than against internal cracking. Concrete surface scaling is a complex phenomenon due to the substantial number of autonomous factors [2-4] and is the subject of many broad studies [5-11].

The paper presents the results of testing double-layered concrete kerbs with surface damage occurred after 3 years of construction. The testing featured 7 kerbs with various degrees of damage. The testing was conducted to determine the causes of the fast destruction.

2. Materials and Methods
The testing was conducted on 7 double-layered concrete kerbs with surface damage occurred after 3 years of construction. The kerbs were manufactured from two types of concretes used in the structural layer and wear layer. In general, it can be stated that the observed damage is concentrated in the wear layer, whereas the structural layer is intact. The collected samples include kerbs with no damage and kerbs with a partially or substantially destroyed surface layer (Figure 1). Table 1 presents the degree of damage of particular kerbs (1-7) subjected to testing.

![Figure 1. View of damaged kerbs](image)
The aim of these studies was to evaluate the quality of the wear layer and concrete in their “volume”. The scope of testing was as follows:

- compressive strength testing acc. to PN-EN 12390-3:2011 [12],
- concrete bulk density testing acc. to PN-EN 12390-7:2011 [13],
- water absorption testing acc. to PN-EN 1340:2004 [1],
- capillary absorption testing acc. to PN-EN 13057:2004 [14],
- freezing and de-icing salt resistance (resistance to surface scaling) acc. to PN-EN 1340:2004 [1],
- freeze-thaw durability testing using the standard method (F150 freeze-thaw durability degree) acc. to PN-88/B-06250 [15].

The testing was conducted on core samples and samples cut out from each kerb (Figure 2):

![Scheme of sampling for testing](image)

**Table 1.** Degree of damage of particular kerbs

| No. | Degree of damage |
|-----|------------------|
| 1   | Damaged          |
| 2   | No damage        |
| 3   | Minor damage     |
| 4   | No damage        |
| 5   | Damaged          |
| 6   | No damage        |
| 7   | Damaged          |
• 3 core samples with the diameter of φ=100 mm - for testing the compressive strength and the F150 freeze-thaw durability degree evaluation,
• slab sample with the dimensions of 15x15x5 cm from the kerb’s top part, including a surface with a wear layer - for testing freezing and de-icing salt resistance,
• slab sample with the dimensions of 10x10x5 cm from the kerb’s top part, including a surface with a wear layer - for testing the capillary absorption and absorptivity,
• sample with the thickness of 4 cm, including the kerb’s entire cross-section (two concrete layers) - for testing the concrete’s water absorption and bulk density.

The test for the resistance to internal cracking was performed by direct freezing and thawing of cube specimens, using the normal method in accordance with PN-88/B-06250. The samples were saturated in water for 7 days and then subjected to cyclic freezing at –18±2ºC for 4 hours and thawing at +18±2ºC for 4 hours. A total of 150 freeze-thaw cycles were performed. The reference samples for compressive strength tests were stored in water at a temperature of +18±2ºC throughout the freeze-thaw resistance testing. The tests included visual evaluation of the cubes, measurements of their mass and determination of the relative compressive strength loss dR at the end of the final thawing period. Concrete is regarded as resistant to freezing and thawing if the loss in mass is 5% or less and the loss in compressive strength is 20% or less.

The samples for testing the surface scaling acc. to PN-EN 1340: 2004 were stored in air-dry conditions, and then subjected to 28 freezing-thawing cycles in the presence of a 3% NaCl solution. The test featured determination of the mass of the scaled material.

The control tests are usually conducted after 28-35 days of concrete curing. It is necessary to take into consideration that the substantially longer curing of the concrete in the analysed kerbs (2-3 years) causes additional concrete tightness (further cement hydration, carbonisation), which should reduce water absorption and increase the concrete’s freezing and de-icing salt resistance.

3. Results and discussions
The testing was conducted for the structural layer’s and wear layer’s concrete. Table 2 presents the test results of the properties of the structural concrete. The concrete’s compressive strength, water absorption nw, bulk density gbw and freeze-thaw durability (F150) were determined. The results designated as Rc1 concern cylindrical samples including a wear layer, whereas samples designated as Rc2 concern structural concrete samples. The compressive strength of the wear layer’s concrete for particular kerbs amounts from 32.6 to 50.1 MPa, with an average of 41.8 MPa. The compressive strength of the structural layer’s concrete amounts to 35.8-67.0 MPa, with an average of 49.4 MPa. Table 2 also presents the average strengths Rśr, taking into consideration the wear and structural layer. The averages amount from 34.2 to 55.6 MPa.

The bulk density of concrete in the tested kerbs amounts from 2375 to 2427 kg/m³, with an average of 2403 kg/m³, whereas the water absorption nw - from 4.14 to 4.83 %, with an average of 4.50%. The mass gain dm150 of the samples tested using the standard method acc. to PN-88/B-06250 is minor after 150 freezing-thawing cycles and amounts from 0.5 to 3.0 g for particular kerbs. Substantial differences in the loss of strength dR150, which amounts from 0 to 29.1%, were observed.
Table 2. Results of testing the structural concrete’s properties

| No. | Degree of damage | Rc1 MPa | Rc2 MPa | Rśr MPa | gsw kg/m³ | nw % | dm150 g | dR150 % |
|-----|------------------|---------|---------|---------|-----------|------|---------|---------|
| 1   | Damaged          | 45.6    | 55.4    | 50.5    | 2392      | 4.52 | 3.0     | 12.8    |
| 2   | No damage        | 32.6    | 35.8    | 34.2    | 2385      | 4.47 | 1.0     | -5.6    |
| 3   | Minor damage     | 44.2    | 67.0    | 55.6    | 2427      | 4.51 | 2.0     | 29.1    |
| 4   | No damage        | 41.5    | 42.9    | 42.2    | 2418      | 4.71 | 3.0     | 7.0     |
| 5   | Damaged          | 41.5    | 51.8    | 46.7    | 2405      | 4.33 | 2.5     | 1.0     |
| 6   | No damage        | 50.1    | 52.3    | 51.2    | 2418      | 4.14 | 0.5     | 10.2    |
| 7   | Damaged          | 36.8    | 40.8    | 38.8    | 2378      | 4.83 | 2.0     | 10.8    |
|     | Average          | 41.8    | 49.4    | 45.6    | 2403      | 4.50 | 2.0     | 9.3     |

Table 3 presents the test results of the properties of the concrete’s wear layer. The absorptivity nw1, capillary absorption and resistance to surface scaling m28 in the presence of 3% de-icing salt solution were determined. The water absorption nw1 of the wear layer’s concrete in the tested kerbs amounts from 4.42 to 6.57 %, with an average of 5.42 %. The capillary absorption (Figure 3) is deemed as an important parameter in evaluating the concrete’s quality, but in the case of the tested kerbs, small correlation with the damaged surfaces was observed. Substantial differences occurred in the testing of resistance to surface scaling m28. After 28 freezing-thawing cycles in a 3% NaCl solution, the scaled material’s mass m28 for the 7 tested kerbs amounted from 0.218 to 3.235 kg/m².

Table 3. Results of testing the properties of the wear layer’s concrete

| No. | Degree of damage | nw1 % | m28 kg/m² |
|-----|------------------|-------|-----------|
| 1   | Damaged          | 5.56  | 1.292     |
| 2   | No damage        | 4.42  | 0.218     |
| 3   | Minor damage     | 5.78  | 2.276     |
| 4   | No damage        | 5.75  | 1.622     |
| 5   | Damaged          | 5.00  | 1.033     |
| 6   | No damage        | 4.90  | 0.455     |
| 7   | Damaged          | 6.57  | 3.235     |
|     | Average          | 5.42  | 1.447     |

Figure 3. Results of testing the capillary absorption of 7 kerb samples (no. 1-7)
The analysis of the test results demonstrates that the results of resistance to surface scaling $m_{28}$ are well correlated with the results of water absorption $n_{w1}$ (Figure 4). The smaller mass losses $m_{28}$ amounting to 0.218 and 0.455 kg/m² and the lowest water absorption $n_{w1} = 4.42$ and 4.90 % were demonstrated by the wear layer’s concretes of kerbs no. 6 and 2. Only the above two kerbs met the condition of freezing and de-icing salt resistance: mass loss after 28 freezing-thawing cycles $m_{28} \leq 1.0$ kg/m².

Figure 4. Relation between the concrete’s absorptivity $n_w$ and the resistance to surface scaling $m_{28}$ in the presence of 3% NaCl

Figure 5 presents the view of the concrete’s cross-section in kerb no. 1. It is visible that the concrete’s texture layer is insufficiently compacted. The high porosity of the layer caused increased water absorption and lack of resistance to surface scaling.

Figure 5. View of the sample of the wear layer’s concrete in kerb no. 1

4. Conclusions
The following conclusions were formulated based on the analysis of the tests of double-layered concrete kerbs with surface damage occurred after 3 years of construction:
1. The results of testing the concrete’s water absorption are best correlated with the results of surface scaling of the concrete kerbs. The kerbs that met the condition $n_w < 5.0\%$ demonstrated no damage.

2. The results of structural concrete testing: compressive strength, water absorption, freeze-thaw resistance (resistance to internal cracking) and capillary absorption tests do not correlate well with the results of resistance to kerb surface damage.

3. Only two out of the seven tested kerbs met the condition of freezing and de-icing salt resistance: mass loss after 28 freezing-thawing cycles $m_{28} \leq 1.0$ kg/m$^2$. These are kerbs with no damage.

4. It was founded that the tested kerb’s concrete texture layer is insufficiently compacted. The high porosity of the layer caused increased water absorption and lack of resistance to surface scaling.

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