INVESTIGATION OF ENVIRONMENTAL INFLUENCE ON CARBONATION AND CHLORIDE INGRESS IN CONCRETE BRIDGE STRUCTURES

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Summary: The reinforced concrete as the structural material is widely used for bridge structures. It qualities allow to use the concrete for achievement of optimum shapes and configuration of structures. During its lifetime the concrete bridge structures are subjected to various environmental impacts that caused external and internal deterioration factors. Usually deteriorations introduced by carbonation or/and chloride ingress are the result of interaction between the material and the environment. The article focuses on environmental characteristics typical for Latvia, such as content of deicing salt during winter maintenance, CO_2 emission, humidity, freeze-thaw cycles and other potential impacts. For a number of reinforced concrete bridges with various ages have been made investigation on the level of carbonation and chloride penetration level. By using semi-probabilistic deterioration models have been forecasted the residual service life of the structures.

The major and long-term investments of society are devoted to build infrastructure facilities such as roads and bridges. This cause to pay attention on increasing maintenance cost not only for new investments. After explosive increase of construction capability in Latvia in last year's, the considerable increase of maintenance costs will follow in future. Therefore it is very important for new and maintained structures to give enough accurate forecasting for residual service life. Even if the most concrete structures provide satisfactory performance over an acceptably long service life period, deterioration processes in various extents affect all structures and materials in the course of time. The service-life of concrete structure depends on its interaction with surrounding environment. Nearly every type of deterioration mechanism of concrete structures may be modeled by a two phase model with initiation and propagation phase [1]. There are many reasons of deteriorations in reinforced concrete caused by various environmental impacts: freeze-thaw cycles, alkali-aggregate reactions, etc.

The influence of the environment on deterioration of reinforced concrete bridge structures could be estimated by observation of causes and quantity of arisen deteriorations. Concrete during its lifetime is affected by influence of various external and internal factors. Usually the deterioration in concrete proceeds as a result of interaction between environment and concrete where the primary role plays the mechanism of transportation of water, gas and ions. Moisture is one of the most important reasons for beginning of deterioration processes. The moisture level in concrete widely depends on air humidity (RH level), wetness, wind and solar radiation.

The results of regular bridge inspections showed that the major influence on service life of reinforced concrete bridges in Latvia corrosion of reinforcement. Other types of damages, if environment is not aggressive, did not affect the concrete bridge residual service life so much. Reinforcement corrosion is major and more common type of concrete bridge deterioration also in other countries [2][3].

The general way how to describe the environmental actions on concrete structure is to use the surface climate that depends of surface conditions. The climate of Latvia is determined by the geographical location, land surface relief and vegetation as well as by the prevailing air mass transport. These factors create varying weather conditions of Latvia, with well distinguished differences between the coastal and inland areas.

Carbonation of concrete is a process where carbon dioxide, which is in the air, diffuses in concrete and with presence of water reacts with calcium hydroxide to form calcium carbonate and thus reduces pH value of the concrete pore solution. Once this carbonation process reaches reinforcement, corrosion of reinforcement may be initiated. Carbonation is a natural process which mainly is influenced by:

- Amount of CO_2 in surrounding environment.
- Internal relative humidity (RH) of the concrete.
- Wetting periods.
- Concrete carbonation resistance (concrete permeability, $Ca(OH)_2$ amount in concrete).

The average Carbon dioxide content in the surrounding air varies between 350 and 380 ppm. The forecast is that it may increase to about 700 ppm in 2100 [Richardson]. Internal relative humidity of the concrete is related to relative humidity of the air around the structure. Rates of carbonation are highest for relative humidity of 50% to 75%, but the critical relative humidity for corrosion is about 80%. In Latvia the average air relative humidity varies between 65% and 96%. That means that in Latvia there are positive preconditions for carbonation process. Concrete bridge assessment inspections show that carbonation is one of the major deterioration processes in Latvia. Reports show that carbonation is an issue if concrete cover is insufficient.
Calculating residual service life for about 100 concrete bridges in Latvia there are two most common reasons for failure because of carbonation:

- Insufficient concrete cover (75% below 30mm and 90% below 40mm).
- Low strength concrete.

The results show that for current environmental actions in Latvia, bridge structures have sufficient concrete carbonation resistance to assure service life of 100 years, if minimum concrete cover of 40 mm is secured.

To avoid formation of ice on roads, de-icing salts are spread during the winter season. The corrosion of the reinforced concrete by de-icing salts is one of the major issues concerning the durability of reinforced concrete structures. To determine the service life of these structures exposed to de-icing salts it is necessary to know the strategy which is used to prevent slippery driving conditions on Latvia's roads.

In general there are two strategies used for spreading de-icing salts on roads in Latvia. Active method and preventive method [5]. In active method the prevention of slippery condition depends on actual road conditions and meteorological observations. The friction of road is measured by de-icing salt spreading vehicle and de-icing salt is applied if slippery conditions are detected. In preventive method de-icing salt is spread on road based on meteorological observations and temperature reaches certain level regardless whether there are slippery conditions or not. In Latvia the regulation for winter road maintenance is similar to the ones used in Sweden, Finland and neighbor countries – Lithuania and Estonia [4]. For determination of residual service life of concrete structures exposed to de-icing salts on roads it is in a great interest to know what amount of chlorides from de-icing agents gets on the surface of structure. There are several researches in which is presented models to determine the amount of chlorides in environment around roads (Blomqvist 1999 u.a.). The transport mechanism of chlorides from the road where de-icing agents are spread to concrete surfaces of the bridges is very complex, because it depends on changing weather, applying method, traffic intensity and speed, structure position and shape. During summer period some amount of chlorides are washed out of concrete structures. As show bridge assessment inspections, the damage to reinforced concrete caused by chlorides usually appears in small portions of the structure where locally aggressive environment is created or in places where have been poor construction quality. The most damage created by chlorides appears at location of deteriorated expansion joints or deteriorated hydroisolation.

REFERENCES

1. Tuutti, K., Corrosion of steel in concrete, CBI Research Report 4:82, Swedish Cement and Concrete Research Institute, Stockholm, 1982.
2. Zenonas Kamaitis. Deterioration of Bridge Deck Roadway Members. Part I: Site Investigations // The Baltic Journal of Road and Bridge Engineering. Vilnius: Technika, I t., 2006, Vol.1,Nr. 4, p.177-184.
3. Zenonas Kamaitis. Deterioration of Bridge Deck Roadway Members. Part II: Condition Evaluation // The Baltic Journal of Road and Bridge Engineering. Vilnius: Technika, I t., Vol.1, Nr. 4, p.185-191.
4. Lindvall A, Environmental actions and response - reinforced concrete structures exposed in road and marine environment, Chalmers University of Technology, Goteborg, Sweden 2003.
5. Valsts autoceļu ikdienas uzturēšanas darbu tehniskās specifikācijas. VAS "Latvijas Valsts ceļi", 2006.

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