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Case study

Alkali-silica reaction in Southern-Finland's bridges

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ABSTRACT

In Central Europe and Scandinavia, alkali-aggregate reaction (AAR) typically occurs in massive concrete structures such as bridges and dams. Despite of having similar bedrock with Sweden, Finland has been considered as an AAR free country. The scope of this study was to find out the existence of alkali-silica reaction (ASR) in Finnish bridges. It was also studied how the age of the bridge as well as the aggregate type has affected the occurrence of ASR. The research material consists of 97 condition assessment reports from concrete bridges constructed between 1912 and 1999. The condition assessments were carried out during 2001–2014. All studied bridges are situated in southern or south-western Finland. Alkali-silica reaction was detected by petrographic analysis in 27 bridges, which is 27.8% of all studied bridges. Of the bridges built in the 1970s (38 bridges in the sample) 42.1% was affected by ASR. In the 1960s bridges (33 bridges in the sample) 17.6% was affected. The bridges showing ASR were 31–44 and 43–52 years old, respectively. Thus, there is a potential risk for having ASR damage in concrete bridges also in the Finnish construction and climate. The study shows, however, that the reaction has taken a considerable amount of time to be detected.

1. Introduction

The Finnish Road Administration has approximately 15100 road bridges to its upkeep in Finland [1]. In addition, about the same amount of similar bridges belong to the management of the cities and towns making together approximately 30 000 road bridges in Finland. Finnish bridges are generally quite young – over 95% has been built after 1950. The largest number of bridges were built in the 1960s and '70s. Over time, several different materials have been used to construct bridges including stone, wood, steel and concrete. The most prevalent building material, however, has been concrete. Reinforced and pre-stressed concrete bridges account for 68% of the bridge stock [1]. Moreover, the decks and substructures of steel bridges as well as the substructures of wooden bridges are also primarily of concrete making its share of the structures of the bridge stock even larger.

The bridge stock in Finland is under regular inspection system. Each bridge is inspected visually every five years. Based on this visual inspection systematic condition assessment will be ordered to the bridge before any repair activities. The inspection system provides up-to-date data on the condition of bridges, which allows determining the technical repair needs of various structural members of bridges in the future and the required financing. The inspection and assessment data on material and structural properties, durability and technical condition of the bridges is compiled in a nationally administrated Bridge Register along with road-specific road and traffic volume data, data on the structure and dimensions of bridges, and data on bridge fixtures and equipment. [2].

In Central Europe and Scandinavia, alkali-aggregate reaction (AAR) typically occurs in massive concrete structures like bridges and dams [3]. Despite of having similar bedrock with Sweden, Finland has been considered as an AAR free country due to its climate

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and the common aggregates used [4]. During the last few years, some dozens of ASR cases have been reported (Pyy et al., 2012; Lahdensivu & Aromaa 2015). The scope of this study was to find out existence of alkali-silica reaction (ASR) in Finnish bridges and to study how the age of the bridge as well as the aggregate type of concrete has affected the occurrence of ASR.

2. Alkali aggregate reactions

The alkali-aggregate reaction is an expansion reaction of the aggregate of concrete caused by the alkalinity of hydrated cement, which may disintegrate concrete. The existence of AAR was first discovered in USA in the 1940's, and it is generally divided into three types according to the reacting aggregate: alkali-silicate reaction, alkali-carbonate reaction and alkali-silica reaction [5]. All AARs require reactive aggregate, a sufficient amount of alkali ions in the hydrated cement, and a minimum relative humidity of concrete of 80% [3].

The alkali-silica reaction (ASR) is the most general form of AAR. For the alkali-silica reaction to take place, the pore water must contain dissolved sodium (Na_2O) and potassium (K_2O) alkalis, and the aggregate must contain minerals that have low resistance to alkalinity. The gel produced by the reaction absorbs much water from its surroundings, which causes its volume to grow leading to internal pressure within the pore system. As the building pressure exceeds the tensile strength of concrete, cracks form in the concrete structure allowing the relatively soft gel to extrude through them [6].

The alkali-silicate reaction is similar to ASR: the reaction mechanism is similar, but there are some differences in the physical and chemical form of gel and other reaction products. Disintegration process of concrete is remarkable slower than in ASR, so the reaction is usually called also slow or delayed alkali-silica reaction [7].

The alkali-carbonate reaction is effected by the alkalinity of some limestones and cement and produces a swelling clay-like substance. The gel that forms at high humidity swells about 4% by volume creating pressure within the pore system of the concrete. The cracking of concrete generates a cracking pattern and leads to a loss of bonds between the aggregate and the cement paste [6].

AAR generally means slow deterioration of concrete. Degradation rate is influenced by prevailing conditions as well as the quality of aggregate and cement. In the case of silicon-containing rocks, AAR develops sooner, in 2–5 years, whereas with slower reacting rocks like sandstone and limestone the reaction may take 10–20 years to develop. AAR has been reported to occur also with highly stable rocks such as granite, quartzite and sandstone [5]. With blended cements like blast furnace slag (BFS) and pulverised fuel ash (PFA), AAR is less common since fewer reacting alkalis are generally involved than with OPC [3].

A concrete structure suffering from AAR typically exhibits discolouration due to surface moisture, irregular pattern cracking, swelling and oozing of a gel-like reaction product from the cracks [6]. The damage from AAR resembles the cracking caused by frost attack and often coincides with it [3]. The most significant difference between AAR and frost damage is the pattern of cracking, which in the case of frost damage is the most intensive close to the outer surface and loses intensiveness with depth. AAR cracking begins deeper inside the concrete and produces a more regular cracking pattern across the entire concrete structure [8].

3. Research material

The research material consists of 97 condition assessment reports from concrete bridges completed between 1912 and 1999, see Fig. 1. The condition assessments were carried out during 2001–2014. All studied bridges are situated in southern or south-western Finland.

The basic aim of the condition assessment is to produce information about the factors affecting on the condition and the performance of the structure and consequently about the need and the options for repair for the owner of the building or structure. Damage to structures, its degree and extent, due to various degradation phenomena can be determined by a comprehensive systematic condition assessment [2,9].

In this study the most important information from the condition assessment reports was:

- the geographical location of the bridge
- age of the bridge when ASR was detected

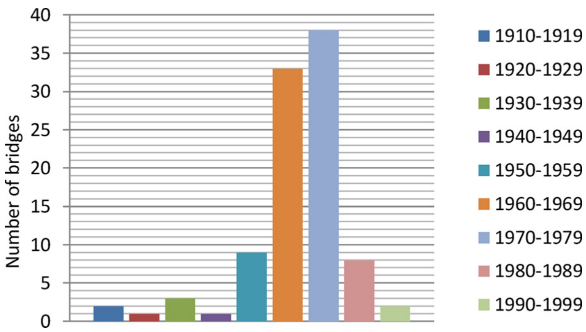

Fig. 1. Age distribution of the studied bridges.