NON-DESTRUCTIVE TESTING OF PRESTRESSED CONCRETE BRIDGES – EXPERINCES FROM FIELD TEST

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ABSTRACT

Most of the structures in the transport infrastructure are built of reinforced concrete, and many of our large bridges are built of prestressed concrete. A large part of these were built before 1980, and could theoretically have problems with both corrosion in tension cables, chlorides in injection mills and thin lightly damaged feed pipes. After 1980, the standards were tightened. Whether these theoretical problems are real is not fully mapped as basic investigations of these bridges have not been conducted in Sweden. International attempts have been made with methods of non-destructive testing (NDT) to identify problems in the form of cavities, corrosion or breakage in cables. These investigations have had limited success since no individual measurement technique has been shown to be able to be used to map the condition. However, it has also been shown that a combination of different NDT techniques can overcome some of the challenges and detect defects in ducts in prestressing systems installed in large concrete structures. The methodology described in this paper shows that it is possible to detect damages, but also that the results is very much dependent on the skills of the persons that use the equipment and evaluate the data.

Key words: Non-Destructive Testing, Prestressed Concrete, Bridges, Assessment

1. INTRODUCTION

Civil infrastructure and structures are susceptible to different kinds of deterioration processes and defects once built and used. Examples of damages these defects and deterioration processes might lead to are cracking, bond loss, voids, reduction of cover layer, corrosion, delamination etc. which in the long run, if nothing is done, leads to lowering of the performance level and eventually unsafe structures. This necessitates methods to continuously assess the quality of structures in order to avoid problems that might lead to shorter service life or reduction of structural integrity. During the last two to three decades more and more focus has been placed on the life of our bridge and ongoing deterioration processes. Also, considerably development regarding assessment and strengthening methods has been made during this time span. In addition, today we also have stronger calculation tools and a better understanding of our existing bridges and their behavior – at least for RC bridges where existing assessment and repair/strengthening methods is quite well understood. However, this is not the case with our existing prestressed concrete bridges, despite the fact that these bridges are critical for transportation and communication in our modern society. One large challenge with prestressed bridges is the possibility to assess the inner parts, i.e. ducts, anchorage and tendons, without creating damages. It is then of utmost importance that these bridges are investigated more thoroughly. Most likely they are in good quality, but that has most commonly been verified in visual inspections. For prestressed concrete bridges, defects are not always visible and it is important to start investigation methodically from the bridges with the highest priority rankings for traffic but also for hidden defects. The questions that must be asked are: Is the component critical to the safety of the structure? What are the consequences of failure of the component? Can the component be exposed safely? Will exposing the component result in damage to the structure? Will exposing the component result in damage to it? Will exposing the component lead to long-term durability issues with the structure? It is economic to expose the component? What impact would the investigation have on the operation of the structure?
In addition, a bridge owner might have specific constraints that are not listed here and must be considered at assessment. Hidden defects investigation could either be undertaken as special investigation or worked into the normal inspection regime. The former should be considered where the risk of failure of a hidden component with significant consequences is likely to occur before the next inspection (normal).

2. NON-DESTRUCTIVE TESTING OF PRESTRESSED CONCRETE BRIDGES

It is important to follow a clear assessment structure when investigating existing prestressed concrete bridges. In Figure 1 such a structure is presented where focus has been placed in the prestressing. As always, it is crucial to study and scrutinize the existing documents, drawings and also critical sections. Here also the choice of inspection methods should be chosen. In addition, material testing is recommended including testing of chlorides and carbonisation depth. We suggest that the actions taken are the following; Usage of radar to detect the reinforcement/ducts/cables. Check corrosion in reinforcement with half-cell measurement, defined concrete cover with cover-meter. Mapping of ducts/cables with ultrasound and detail mapping in critical areas and voids with additional ultrasound mapping. Verification of voids by sound waves and finally partly destructive testing of ducts where voids can be expected from the measurement and then inspection with endoscope. In the next section, this procedure is practically shown in a field test.

3. FIELD TEST

To locate voids in the duct we use several different methods, each one of them with their own unique advantage. The cover meter is first used to locate the rebars and measure the cover. This is necessary to calibrate the GPR and make sure that the settings are correct.

The GPR is used to locate the tendon ducts and mark them in the construction to facilitate the use of ultrasonic testing, in Figure 2a data from the GPR measurement is shown. The arrows are pointing at ducts. When the depth and location of the tendon ducts is confirmed, we know precisely where to use the ultrasonic method, see Figure 2b.

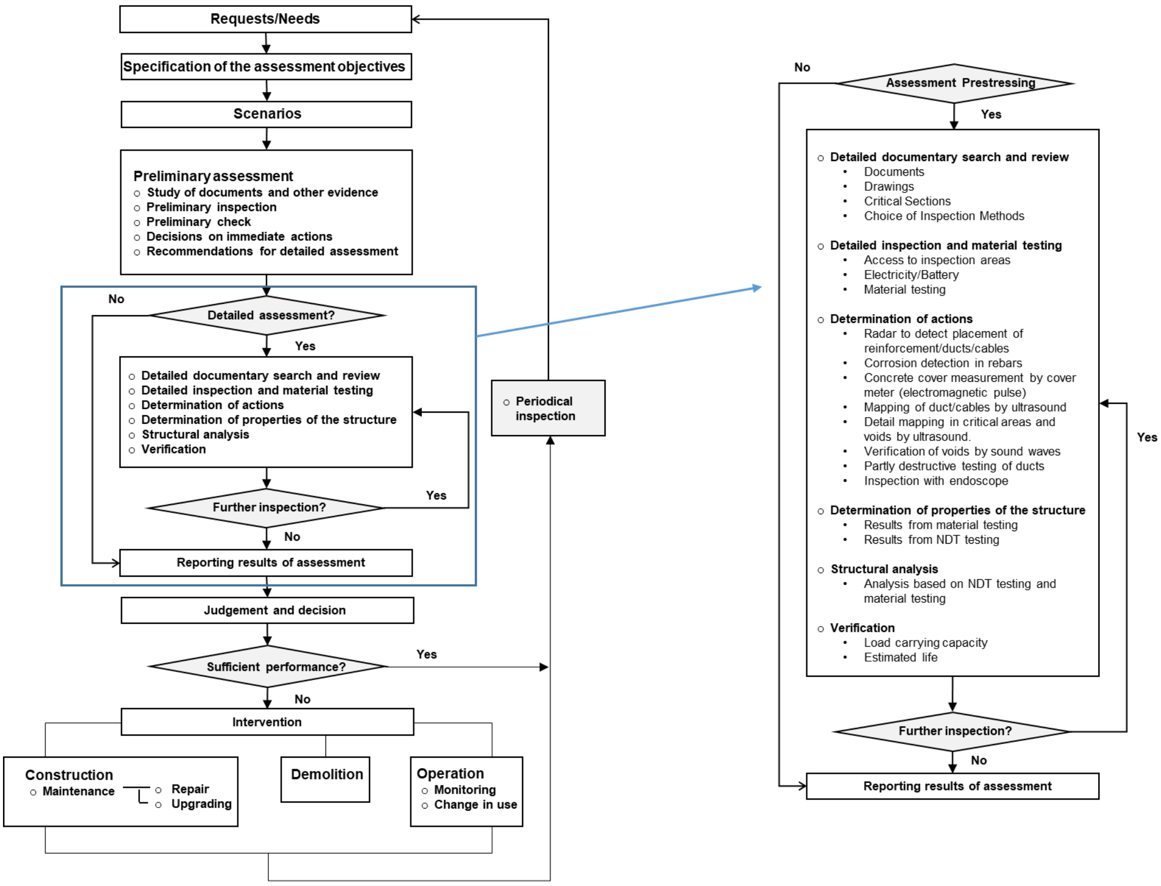

Figure 1 – General procedure for investigation defects in a prestressed concrete bridge.

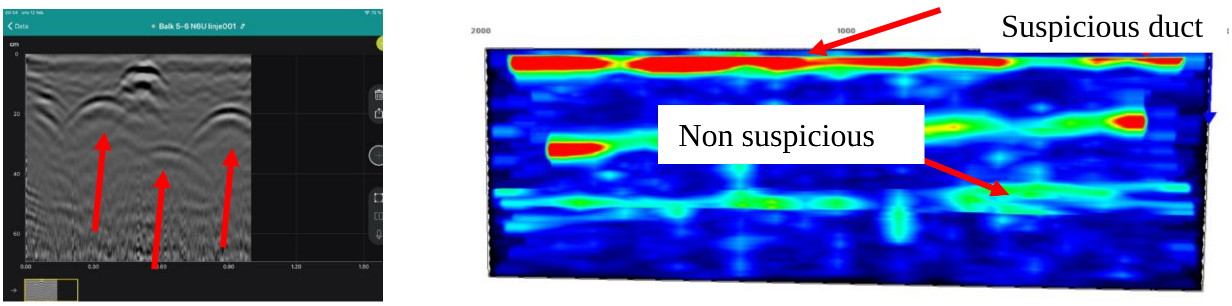

Figure 2 – Deep-embedded ducts into the concrete member: a) Ducts located using GPR and b) Tendon ducts located with the ultrasonic method, and processed in the software.

This method is used to find suspicious areas inside the tendon ducts, The results need to be processed in a software and therefore it’s important to make the measurements at the right spot at once to avoid unnecessary and time-consuming scans. After ultrasonic scanning the suspicious and non-suspicious areas are located in the ducts. To further investigate the suspicious areas, Impact Echo is used to confirm the results, see Figure 3. With this procedure we can, with a very high accuracy, point out the locations of the voids.

a)

b)

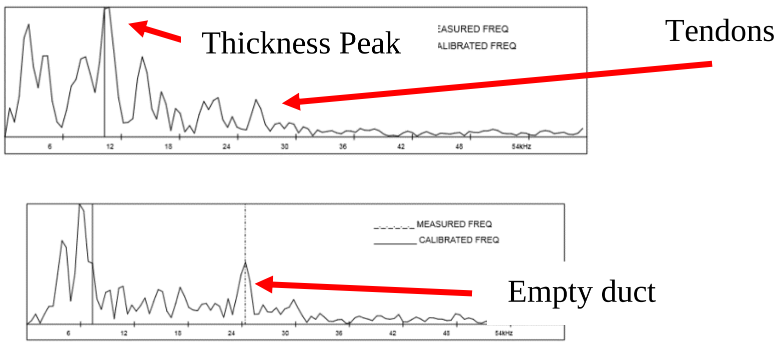

Figure 3 – Frequency peak in: a) a grouted duct; and b) in an empty duct

4. RESULTS AND ANALYSIS

Missing grout in the ducts increases the risk of corrosion in the tendons. Therefore, it important to determine the corrosion rate once a void is located. To do this we made a partial destructive evaluation by drilling into the ducts, see Figure 4.

a) b) c)

Figure 4 – Grouting and tendon status: a) Missing grout and three of the tendons are broken, b) An injected duct and c) Missing grout and the tendons are corroded.

5. CONCLUSIONS AND FUTURE WORK

A successful project needs planning. It is not only the access to the structure that is important but also other practical details such as lightning and electricity. In addition to this, it is of utmost importance that documents are studied before arriving to the site and those areas to be investigated are decided beforehand. In this paper we present a successful assessment of a prestressed concrete bridge where it was possible to detect voids and even corrosion and tendon breakage with a combination of different NDT equipment. The post-processing of the data is essential to obtain good results. It is suggested that the developed methodology is implemented in more projects to gain experiences. Furthermore, the post-processing can be further developed with machine learning algorithms which first can be trained on mock-ups in the lab before implemented on site.

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