Tests of Grouting Voids in Post-tensioned Bridges by X-ray Penetration

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Summary

Utilizing the X-ray facilities originally dedicated for nondestructive testing of steel structures, nondestructive tests were carried out to investigate the grouting voids and tendon rupture in post-tensioned prestressing concrete structures. The testing procedure and technical parameters, namely, tube voltage, exposure time, source-to-film distance and sensitivity, for detecting grouting voids in duct are proposed based on the principle of X-ray penetration. The concrete-steel thickness equivalent coefficient is also obtained as about 0.2. Through a systematic study on a large number of radiographs, the approach and procedure to detect the grouting voids in metal or PVC duct (including both round and flat shaped ones) and rupture of tendons are presented. Finally, an investigation of grouting voids by X-ray in a post-tensioned concrete bridge, which is the first time in China, is introduced in this paper.

Keywords: X-ray penetration; grouting voids; exposure amount; radiograph; density; steel tendon.

1. Introduction

Prestressed concrete (PC) structure is the main type of bridges with a span over 20 m in China. Most of the PC bridges were constructed using post-tensioned steel tendons which are bonded to surrounding concrete by grouting material and corrugated duct. It has been found that insufficient grouting is one of the major factors inducing corrosion, and even rupture of tendons. Therefore, detecting voids in duct by nondetective tests(NDT) is extremely important for the safety of tendons and durability of structures. X-ray penetration method is applied in this paper because it is direct and simple in finding the voids. There are different materials, such as, duct (steel/PVC), steel tendons, cement paste and voids, in concretes, therefore in order to detect voids in grouting paste, penetration parameters and method for steel or plain concretes has to be calibrated before any real application.

2. Penetration parameters

Utilizing the X-ray facilities originally dedicated for nondestructive testing of steel structures, the following technical parameters of penetration, namely tube voltage, exposure amount, source-to-film distance and sensitivity, for detecting grouting voids in ducts are proposed and used in this paper based on our trials and literatures.

1. A maximum tube voltage of 300 KV and a fix tube current of 5 mA were used. The maximum available thickness of concrete for penetration is 400 mm under 300 KV for 40 min.

2. To reduce the geometric unsharpness to the minimum, a source-to-film distance of 600-1000 mm is suggested for concrete with thickness of 100-400mm.

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3. Image sensibility is described by absolute sensibility, which is determined by the image quality needles with a minimum diameter of 2.5 mm located at the edge of effective penetration area. The density of radiograph of the concrete itself is controlled between 1.0 and 3.0.

4. Industrial X-ray film (100FW) was used with lead intensifying screens. The films were developed automatically.

Apart from the above technical parameters, penetration direction affects the image quality as well. The size and location of voids perpendicular to the direction of X-ray can be judged by eyes, but not for those parallel to X-ray.

3. Indoor tests

Concrete specimens with various thickness and different concrete grades were tested by X-ray. The results of penetration reveals that a rapid increase in the tube voltage and exposure amount with the increase of concrete thickness. However, with the same penetration parameters, the density of radiograph is almost independent on the concrete strength. The radiograph density of high strength concrete is a bit weaker than low strength concrete because of better quality and higher density of high strength concrete.The concrete-steel thickness equivalent coefficient of around 0.2 is found by penetrating a steel-step block simultaneously with concrete specimen. It means that the radiograph density of concrete with a thickness of 100 mm is the same as that of steel with a thickness of about 20 mm under the same exposure parameters. The concrete-steel thickness equivalent coefficient is useful for obtaining exposure parameters of concrete from those of steel.

Penetration tests were carried out on steel and PVC ducts with different degrees of the grouting in concrete specimens. The contour of PVC duct looks as half-moon black block which is unlike that of steel duct in a white spiral shape. Un-grouted areas show higher density than grouted areas which have the same density as that of concrete itself outside the duct. Ruptured steel tendons inside duct can be clearly identified as remarkable difference in density between steel and concrete.

Fig. 1 Radiograph of A2 with n voids inside duct

Fig. 2 Radiograph of A3 with voids at the bottom of duct

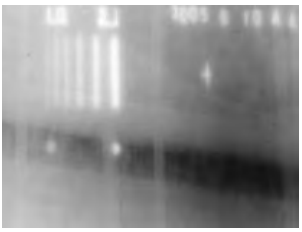

Fig. 3 Radiograph of A4 with voids along

4. Field tests of a post-tensioned prestressing bridge

Before the approach of Xi Cheng Canal bridge at WuXi was demolished in June 2005, a NDT by X-ray was carried out for detecting grouting voids and tendon rupture in ducts. The approach is a simply supported structure with post-tensioned T girders. A seriously deteriorated beam was selected for testing after inspection of all the girders. Because grouting voids commonly appear at inlet and outlet of the duct, Six X-ray films (A1-A6) with size of 400 mm×300 mm were placed in sequence from diaphragm at 1/4 span to the bearing. Radiographs A2-A4 of tendon No.2 are shown in Figs.1-3 as examples. All of the reinforced steels, steel tendons and duct contours can be clearly identified. No grouting voids exist in Fig.1 because the density inside and outside duct is the same. Distinguishable density inside the duct can be recognized (Fig.2), which means voids begin to appear on the left side under the tendons. Going towards the bearing, Fig.3 shows completely un-grouted areas under the tendons as much higher density is shown below tendons than that outside duct. Autopsy was executed after testing and verified the results of X-ray tests.