NON-DESTRUCTIVE INSPECTION OF TENDON GROUTING IN PRESTRESSED CONCRETE BEAMS

Elastic Wave Velocity Method

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1・ Background

Electromagnetic waves (X-ray method) and elastic waves (ultrasonic method and impact elastic wave method) have been studied as non-destructive methods to evaluate the grout used in PC members. Of these, elastic wave methods, and in particular the impact elastic wave method, are widely used because there are few restrictions on inspection conditions and the work can be performed efficiently. Elastic wave methods can be categorized into those in which elastic waves are propagated in the axial direction of PC steel members (Fig. 1) and those in which elastic waves are propagated in the direction perpendicular to the PC steel components (Fig. 2). With the former, the velocity of elastic wave propagation as deduced from impact-induced elastic waves to roughly evaluate the average grout condition inside the sheath. The latter approach relies on frequency characteristics (impact echo method) and has the potential to be a detailed inspection method that can identify unfilled areas.

This paper provides an overview of impact elastic wave methods based on the velocity of elastic wave propagation, which is mainly developed in Japan, as used for broad-based inspections to evaluate PC grout condition.

2・ Outline of Elastic Wave Velocity Method

In this method, a hammer, steel ball or similar is used to cause a mechanical impact on the concrete surface. The resulting elastic waves are detected with a suitable sensor. The state of the concrete interior can be evaluated from the velocity of wave propagation. The elastic waves input when using this method have much greater energy than those used for ultrasonic testing and they include a low-frequency component. This method is therefore less affected by attenuation and scattering and is capable of measuring large areas of PC members.

Figure 3 shows the principle by which PC grout condition is evaluated. If the sheath is not filled with grout, the elastic waves propagate most rapidly through the steel bar. Therefore, the apparent elastic wave velocity is close to the propagation velocity in a steel bar. On the other hand, if the sheath is filled with grout, the elastic waves propagate through the composite member consisting of the steel bar and grout; the propagation velocity is then lower than that in the unfilled case.

3・ Inspection of Actual PC Bridge Girders

The results of evaluating PC grout condition of the transverse prestressing steel bars in the girders of an in-service PC bridge (shown in Fig. 4) are outlined in this section. This bridge has separate girders for outbound and inbound lanes, each consisting of four main beams, filler members and extension members. These members are integrated into one unit with transverse prestressing steel bars.

The device shown in Fig. 5 was used to generate the elastic waves. The impact was applied to the ends of the steel bars where they protrude from the extension member. To record the time of elastic wave input, a sensor was installed near the point of impact. The propagated elastic waves were detected with sensors fitted to the concrete side face between the inbound and outbound lanes. The velocity of elastic wave propagation was obtained by dividing the distance between the sensors by the difference in time of wave arrival between the sensors.

Figure 6 shows an example of the results obtained. In the steel bars whose propagation velocity exceeded 4,800m/s (shown in red in the figure), areas without grout were found by drilling. In the steel bars where the propagation velocity was less than 4,300m/s (shown in blue in the figure), drilling confirmed that filling with grout was good. Steel bars with intermediate propagation velocity (shown in yellow in the figure) had mixed filled and unfilled areas.

On the basis of the results of the drilling tests, grout was reintroduced to the steel bars whose propagation velocity exceeded 4,800m/s. The velocity of wave propagation was then measured again. Figure 7 compares the propagation velocity before and after re-grouting. In all cases, propagation velocity was lower after re-grouting. This indicates that the effectiveness of re-grouting can be evaluated by comparing propagation velocity before and after re-grouting.

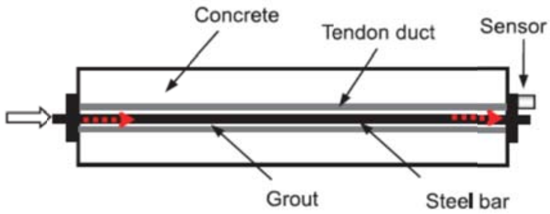

Fig. 1 Method for propagating elastic wave in axial direction of PC steel bar

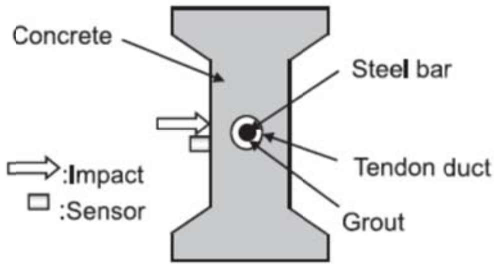

Fig. 2 Method for propagating elastic wave

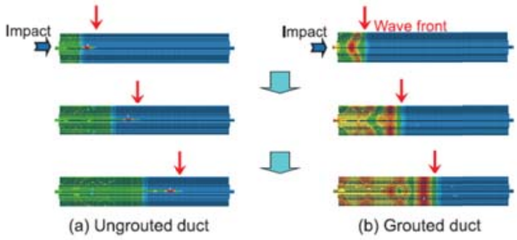

Fig. 3 Principle for evaluation of PC grouting condition according to propagation velocity


Fig. 4 Inspected PC girders


Fig. 5 Impact device