Insulating a Precast Concrete Crossing with Elastomeric Rail Enclosure

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The industry is informed of a problem with signal circuit shunting in precast concrete grade crossings. A possible solution, electrical insulation of rail through grade crossings, is provided and a procedure for the electrical testing of grade crossings is suggested. The goal is not to recommend one type of grade crossing system over another or even to suggest that one grade crossing might be better suited over another type of grade crossing for one type of application. These decisions are best made by the engineering managers of each railroad or rail transit system. The goal is more to demonstrate how cooperation between the track engineers and the electrical engineers can provide positive results by using off-the-shelf components. The scope is to present information gained by experience in specifying, procuring, installing, and maintaining grade crossings on both light rail transit and freight tracks.

In the past concrete grade crossings have had problems with signal circuit shunting. This problem has been caused by inadequate electrical insulation of the rail through the crossing. A solution has been to apply an elastomeric rail boot longitudinally and continuously to the rail through a concrete crossing. When designed properly the rail boot electrically isolates the rail, allowing the signal circuit to function correctly. Problems from signal circuit shunting, such as false gate lowerings and crossing flasher operation, false block indications, and a lack of signal protection for broken rails, are virtually eliminated. This method has specific applications to precast tub-type concrete grade crossings and may be useful in other crossings and settings as well.

BACKGROUND

In 1992 the Tri-County Metropolitan Transit Authority (Tri-Met) of Portland, Oregon, engaged several engineering design firms to undertake final design of the Westside Light Rail Transit Project. Parsons Brinckerhoff Quade and Douglas (PB) was assigned general project management and the design of a 4.8-km (3-mi) twin-bore tunnel. BRW, under contract to PB, was given the task of designing the civil structures, roadbed, and trackwork for the remaining 14.5 km (9 mi) of the project. LTK Engineering Services (LTK) was made the systems engineer for the entire project.

The Westside Project is a westward extension of the existing Tri-Met Banfield light rail transit (LRT) system, placed in service in September 1986. Since this LRT is an electrified railway, trackwork design includes consideration for the traction power system. The traction power is supplied to the vehicles by an overhead catenary system delivering a nominal 750 V of direct current (dc), with surges to as much as 900 V of dc. The return current for this system is carried by the two running rails. If the rails are allowed to contact electrically conductive materials, the return current goes to ground. This is called stray current and can result in damage to adjacent utilities and loss of traction power.

Stray currents cause damage to pipelines through the process of electrolysis. As the current passes through the metal pipe walls the metal is corroded. This corrosion process continues until the pipe wall becomes thin, causing failure of the pipeline. Stray currents also result in lost traction power, which must be made up by additional power input to the traction electrification system. Additional power requirements produce an increase in operating expenses.

The Banfield LRT operates by using an electrically powered block signal system. The signal circuit is carried in the two running rails. When the train's steel wheels and axles shunt the circuit, the signal system is energized and the indication for a train in the block is given. Should the signal circuit leak from one rail to the other, a false signal indication is given. This false indication can result in delays to train traffic. Also, the signal circuit is designed such that a broken rail will cause a "stop" indication to be given by the signals. Undesired signal circuit shunting will bypass this built-in safety feature.

At grade crossings protected by gates and flashing lights an additional signal circuit is also carried along the running rails. If this circuit is allowed to leak from one rail to the other, it can cause false gate lowerings, resulting in delays to motor vehicles. Trackwork design that includes consideration of stray currents also pays dividends in the prevention of undesired signal circuit shunting.

DESIGN

Precast tub-type concrete grade crossings are the latest design to become available to the rail and transit industry (Figure 1). Early installations of these crossings, begun in 1967, were in predominantly industrial track settings. Recently, they have become available for use in main line applications. The design eliminates the need for cross-ties, whereas a conventional crossing incorporates concrete panels installed on top of traditional tie-and-ballast track (Figure 2). For both crossing types steel reinforcement is normally incorporated into their designs. Concrete panel crossing designs also frequently include steel angles around the perimeter edges (Figure 2).

In the past concrete crossings have exhibited problems with signal circuit shunting. Often the cause of this failure is a buildup of moisture either at or below the surface of the crossing, which allows an electrical path to develop from one rail to the other (Figure 3). The situation is exacerbated by the application of road salt to aid in the melting of snow on the roadway approaches.

Grade crossings are used where railroad and transit tracks intersect roadways. Frequently, major utilities are located along these roadways. Therefore, it is imperative that when specifying the

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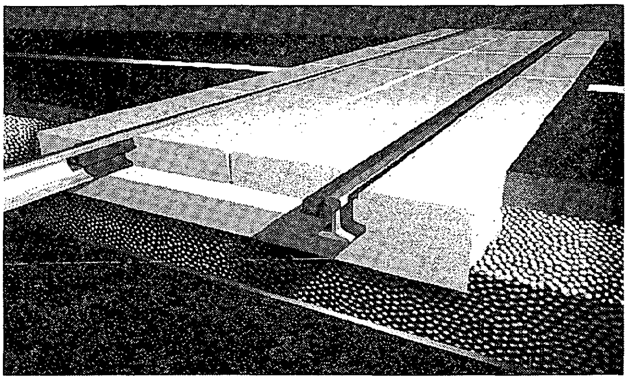

FIGURE 1 Precast tub-type grade crossing.

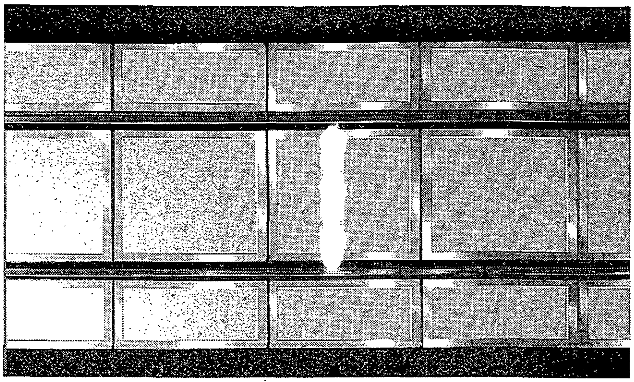

FIGURE 3 Electrical path.

crossing performance, requirements for electrical isolation through the crossing must be provided.

One solution that has been successfully tested is the elastomeric rail enclosure. This separates the rail from other electrically conductive elements and reduces the chances of undesired signal circuit shunting. These rail enclosures are of three types: (a) a preformed rubber strip inserted against the web of the rail and held in place by the concrete crossing panels, (b) a pourable elastomer, such as rubber tire buffings combined with an epoxy binder and poured into the space between the rail and the concrete crossing panel, and (c) a rail boot consisting of a sheet of elastomer formed to fit tightly around the outside of the rail (Figure 4).

The Westside LRT Project incorporated precast tub-type concrete grade crossings because Tri-Met has had several years of successful experience with this crossing type. This crossing design uses a rail boot, the third type described above. BRW developed a procurement specification based on Tri-Met's experience coupled with current information supplied by vendors and the particular requirements of the project.

First, BRW analyzed the crossing structure to determine if it would meet proposed LRT and vehicular load requirements. LTK supplied information about electrical requirements and recommended design changes so that the boot surrounded all rail surfaces within the concrete crossing confines. The project team's goal was to electrically insulate the rail and prevent leakage of signal or return current. To accomplish this goal the boot was designed to prevent any contact between the concrete and the rail. This effort sought to minimize the likelihood that an electrical bridge might be created if debris accumulated between the rail and the concrete. Consequently, the design evolved a rail boot shape that covered all of the rail base and both sides of the web and up to the top of the field side on the rail head but only up to the bottom of the rail head on the gage side. An elastomeric insert in the flangeway aids in holding the boot in place and prevents foreign (possibly conductive) material from working inside the boot below the rail head (Figure 4). Finally, the elastomeric insert allows a minimum-sized flangeway gap, which is becoming a very important issue as a result of the Americans with Disabilities Act. This is possible because of the smaller wheel flange on Tri-Met's light rail vehicle.

Before incorporating the design in new construction the specification mandated that electrical resistance tests be made on a prototype crossing of the production run. To ensure the ability to meet traction power requirements, a high resistance standard was imposed: to meet or exceed 10 MΩ at 750 V of dc. For signal circuits an additional requirement was to meet or exceed 10,000 Ω at 50 V of alternating current (ac) of various frequencies. The electrical testing specification was as follows:

> A single track grade crossing unit shall be placed on the shop floor and completely assembled with two running rails. The grade crossing unit shall be dry on a dry floor. With 750 volts direct current (dc) applied to each rail on either side of the crossing unit for a duration of three

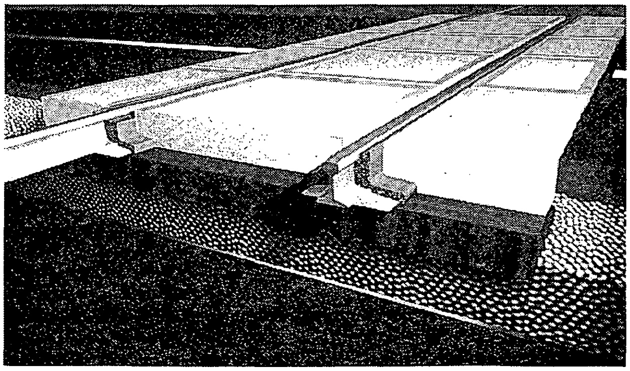

FIGURE 2 Concrete panel crossings.

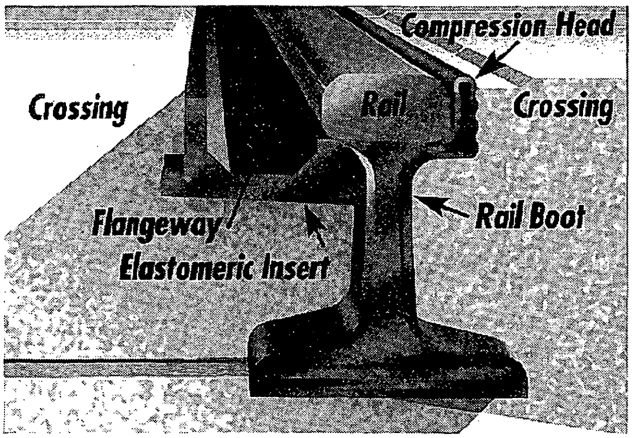

FIGURE 4 Tri-Met rail boot cross section.

> minutes, the actual current flow measured between the rails and from each rail to the ground shall be measured to the nearest 0.1 microampere and recorded. In addition, a potential of 50 volts alternating current (ac) shall be applied to each rail on either side of the unit for a duration of three minutes for each increment of measurement for frequencies from 20 Hertz (Hz) to 10 kHz, in increments of 2,000 Hz. The impedance measured between the rails after three minutes shall be measured with an accuracy of ± 2% and recorded for each frequency. The acceptance criterion for the 750 volts dc shall be 10 megohms. The minimum impedance for any frequency between 20 Hz and 10 kHz with 50 volts ac shall be 10 kilohms.

During the development of this paper several suggestions for the enhancement of the electrical test have been received. A water soak test was suggested. That test is performed as follows:

> Immerse the concrete crossing complete with rails in water for twelve hours. Immediately after removal from the water apply a 10 volt ac 60 Hz current between the two rails for a minimum of 15 minutes. The minimum impedance shall be 10 kilohms.

Another suggestion was made to perform the electrical testing while the concrete crossing panel is partly submerged in water. This would ensure a complete ground. The procedure is as follows:

> Place the concrete crossing assembly complete with rails in a bare (uncoated) metal trough with a minimum clearance of four inches between the panel and the trough walls. The trough shall be leveled and water poured into the trough taking care to ensure the water does not rise any higher than two inches below the base of the rail. The water shall be maintained at this level for the duration of the tests The water may be regular tap water with resistivity of 3,000 to 5,000 ohm-cm.

It was suggested that current flow measurement to the nearest 0.1 μA was a bit excessive and that measurement to the nearest 1.0 μA would suffice. Also, it was believed that 750 V of dc is needlessly high. The actual traction voltage in the current return rails is only about 90 V of dc. Therefore, reducing 750 V of dc in the test to 90 V of dc was believed to be more appropriate. The size of the rail does not make an appreciable difference in the performance of these tests. The portion of the electrical test should use the same frequencies as those expected to be encountered by the crossing panels.

Another crucial specification requirement was to bond rail boot ends together throughout the crossing. Some vendors supply rail boots in discrete lengths or sections. The project teams's specifications required that if the boot was supplied in sections it would be bonded together and that this bonding would exceed the strength of the parent material. For Tri-Met's project the supply of continuous lengths of rail boot was also allowed, which would preclude the need for joints or joint bonding.

The procurement contract for the supply of the Westside Project grade crossings award went to the low-bid vendor. This vendor has begun to supply grade crossings to the project. To date two of the supplied crossings have been installed, one at 114th Street and another at Schottky Avenue. The vendor chose to use a continuous (nonsegmented) rail boot to achieve the required rail insulation and resiliency.

The vendor supplied a thermoplastic elastomer (TPE) rail boot. TPE is an "alloy" of cured ethylene-propylene diene monomer rubber microencapsulated in polypropylene. This results in a resin with both rubberlike properties (resilience) and plasticlike properties (high electrical and chemical resistance), and it is processed as a thermoplastic.

FIELD EXPERIENCE

As part of the Westside Project the adjacent freight railroad company [Burlington Northern (BN)] relocated its tracks to provide room to construct the LRT tracks. In relocating its tracks Burlington Northern (BN) installed a new 28-m (92-ft) single-track grade crossing at SW 153rd Street in January 1994. It chose a precast tub-type concrete crossing by the same vendor supplying Tri-Met grade crossings. However, the rail boot supplied and installed at this crossing was of an older type typically supplied in the past to freight railroads. It consisted of natural rubber covering up to the bottom of the rail head (Figure 5).

During the subsequent construction of track for the LRT (next to the freight railroad) the gates and flashers operated frequently despite a lack of train activity. When BN's signal supervisor investigated, he found that the errant operation of the gates and flashers corresponded with water spraying (to keep down dust) on the adjacent LRT roadway construction. The warning devices also operated during rain showers. BN conducted electrical tests to identify how the rail circuit was being shunted. The obvious assumption was that something metallic had punched through the rail boot and had completed an electrical path between the rails through the concrete crossing. BN was preparing to remove the center gage panels of the crossing to find this electrical bridge when they decided to test the rail boot material. When tested the rail boot was found to have a resistivity of less than 300 Ω.

The BN rail boot had been supplied and installed in discrete 2.44-m (8-ft) sections that were not bonded together. It was formed from natural rubber, with carbon black added to enhance extrudability. Conventional wisdom dictated that rubber was a good insulator; however, after the addition of carbon black, its resistivity was markedly decreased. The conclusion reached by BN field supervision was that the water spray combined with the lack of continuous rail coverage and weak rail boot resistivity enabled the crossing circuit to shunt.

The BN field supervision asked the vendor of the concrete crossing for its advice in solving the problem of electrical conductivity. The vendor suggested that the Tri-Met rail boot might be the solution. When BN field supervision conducted a resistance test, the Tri-Met boot tested at an almost infinite resistivity. The vendor requested BN's permission to replace the existing rail boot at SW 153rd Street with the Tri-Met boot. BN agreed that the Tri-Met boot was promising. BN's permission was granted, and the SW 153rd

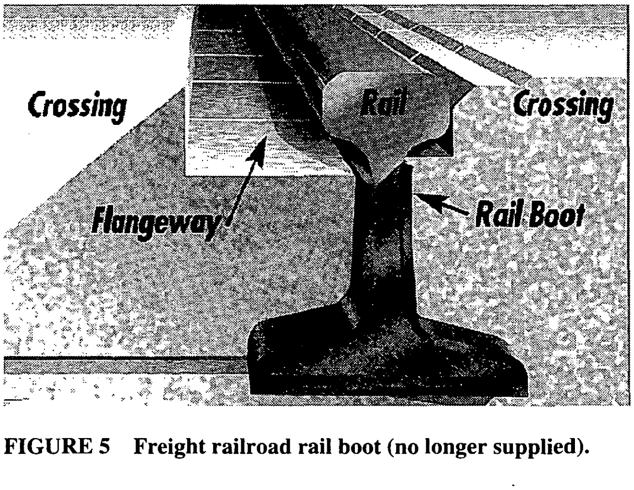

FIGURE 5 Freight railroad rail boot (no longer supplied).

Street crossing was retrofitted with the Tri-Met rail boot and the associated elastomeric insert. The consequence of this retrofit is that BN has minimized false gate lowerings. Water truck spraying no longer activates the gates.

The vendor now supplies rubber boot and elastomeric insert meeting the Tri-Met specification as standard equipment on all its crossings.

CONCLUSION

Because of the design process for Tri-Met's Westside LRT Project, a superior form of rail insulation has been identified and applied to precast tub-type concrete grade crossings. This insulator is a continuous rail boot comprising TPE, which isolates the rail from contact with the concrete crossing structure.

Cooperation between the electrical engineers and the track engineers resulted in a solution to a persistent problem. Electrical testing of the grade crossing track structure at the procurement stage resulted in a superior product. Actual field experience will determine how well the track engineers have performed their job.

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