Recent R&D for Maintenance Cost Reduction in Local Railways

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Maintenance of ground facilities account for approximately half the running costs of local railway companies. Moreover, as measures are taken to cut the workforce in these companies, this ratio is rising. There is therefore a general consensus that the cost of the ground facility maintenance is the main factor causing financial difficulties for local railway companies. This paper presents recent RTRI R&D into cutting the cost of local track maintenance, which can contribute to alleviating the financial burden on local railway companies.

Keywords: local railway, cost reduction, maintenance

1. Introduction

The term ‘local railway’ generally refers to railway lines other than Shinkansen lines, main conventional lines and urban lines. Small to medium-sized private railways and third-sector operators are collectively called regional railway operators. As of April 1, 2015, there were a total of 95 such undertakings. Nearly half of all operating costs for these smaller railways come from maintenance of fixed facilities. This ratio is expected to grow as rationalization measures are introduced, such as having one-man train operation and unstaffed stations. As such, maintenance of tracks and installations will continue to be a major burden on the financial health of operators (an urgent issue raised by the Transport Policy Council of MLIT.

Figure 1, which is based on data from the annual report on railway statistics for Fiscal 2011 involving all railway operators, shows the relationship between the proportion of concrete sleeper lines to all lines, operating profit or loss per business kilometer and maintenance cost per business kilometer. The horizontal axis, which is a logarithmic coordinate, represents operating profit or loss. The dots on the right-hand side of the coordinates are profit-making operators while those on the left-hand side are loss-making operators. In this exercise, percentage of concrete sleeper introduced on lines is considered to be a representative measure of how much an operator is investing into its tracks. Figure 1 suggests that railway operators fall roughly into the following five groups based on investment into facilities, operating profit/loss and maintenance cost.

1) Profit-making operators making sufficient investments into tracks and maintenance; primarily consisting of leading operators and operators in metropolitan areas:
2) Profit-making operators making small investments into tracks; primarily consisting of infrastructure belonging to streetcar operators and freight operators:
3) Loss-making operators making sufficient investment into tracks; primarily consisting of operators in local cities:
4) Loss-making operators making medium investments into tracks; primarily consisting of local operators (including Hokkaido Railway Company, Shikoku Railway Company and Kyushu Railway Company): 5) Loss-making operators making insufficient investments into tracks and maintenance; primarily consisting of former JNR operators in the third sector and local operators:

Even though there are differences in the situations faced by each of the loss-making operators in Groups 3 to 5, the following common measures can be taken, targeting tracks, to help improve their financial health.

For Group 3 operators with tracks in relatively good condition, costs can be reduced by using efficient track maintenance software. Operators in Group 4 differ widely in size of operation and characteristics; their costs can be reduced by investing in efficient maintenance equipment, while meeting needs specific to the existing traffic density and route specificities. Operators in Group 5 need to introduce cost-efficient technologies to reduce maintenance costs and improve safety with financial support to achieve those goals.

With the above background in mind, this paper looks at ongoing RTRI R&D programs on track technologies, especially those intended for maintenance cost reduction and safety improvement for local railways.

Fig. 1 Relationship between the percentage of concrete sleepers introduced and operating profit/loss and maintenance costs for all railway operators (Source: Fiscal 2011 statistics)
2. Maintenance of ballast contaminated with fine-grained soil using biodegradable polymers

Generally, over the course of time, ballast grains are crushed under passing train loads and contaminated with an ingress of fine-grained soil. As the proportion of fine grains in the ballast increases, tie tampers become less effective in restoring the original performance of the ballast. This deterioration of ballast advances more quickly at rail joints as shock loading leads to hanging sleepers and mud pumping.

Consequently, ballasted track maintenance is mainly concentrated around rail joints. In order to improve the effectiveness of repairs, ideally, ballast around the most affected rail joints, relative to the rest of the track, should be replaced. However, ballast replacement raises the following difficulties: (1) complexity and cost if it is a minor replacement; (2) trouble of disposing waste ballast; and (3) falling number of quarries that produce high-quality crushed stones. As such, it is becoming increasingly difficult to carry out ballast replacement - not just for local railways struggling to generate profit - but also for major railway operators in sections where they generate small profit margins.

In response to these problems, RTRI developed a technique to stabilize ballast with a polymer [1]. This method improves the effectiveness of maintenance to repair deteriorated ballast using tie tampers. The method uses biodegradable aqueous PVA (polyvinyl alcohol) (hereafter “aqueous polymer”), as a soil improvement material, to minimize the weakening of ballast contaminated with fine soil, especially in wet conditions. The stabilization procedures are shown in Fig. 2, and are basically the same as those in standard ballast maintenance, using tie tampers, except that with the new method, aqueous polymer is added.

More specifically: a granular reaction accelerator, primarily composed of sodium silicate, is first mixed with the ballast using tie tampers as shown in Fig. 3, then the aqueous polymer is mixed with the ballast using tie tampers as shown in Fig. 4. This mixes the aqueous polymer with the reaction accelerator, which then causes the polymer to gel and the ballast to gently solidify with the fine soil.

Figure 5 shows the results of a ballast stabilization trial in the field using the proposed method. It was found that contrary to ordinary ballast maintenance, which would only be able to prevent recurrence of joint settlement for about three months, the polymer method prevented recurrence for over 10 months. The aqueous polymer and reaction accelerator of the method do not solidify ballast too much.
much and, as such, can simply be poured in again without requiring additional intervention. The polymer method is expected to be finalized to allow application of the ballast stabilization method, by the end of FY2016.

3. Turning existing tracks into cost-efficient low maintenance tracks in tunnel sections

In parts of old mountain tunnels constructed in the early days of railway development, the top surface of the roadbed rock was poorly finished, causing the ballast depth to become uneven, with the result that these sections have continuously experienced track irregularity. In addition, many old tunnels have less clearance between the train top and tunnel crown as a result of the track being raised after many years of ballast maintenance, and can therefore no longer be maintained using MTT. One effective solution would be to make these sections into ballast-less track, using filling material to solidify the ballast. However, this normally involves replacing the existing ballast with new ballast to ensure the filling material is correctly incorporated, and existing sleepers have to be replaced with new ones that are compatible with the fastening system used for realigning the ballast-less track. Material costs for such work will easily add up. Furthermore, removal of and introduction of new materials into a tunnel is not efficient; therefore, the track length that can be worked on per available hours short, further adding to the cost of modifying the track.

Given this situation, RTRI developed a low-cost ballast-less track that uses ultrafine cement grout and does not require the replacement of the existing ballast or sleepers [2]. The method uses ultrafine cement grout that is widely used as ground grouting material in anti-liquefaction of sand ground as filling material and can be used on existing ballast contaminated with fine soil (See Fig. 6). Using this method, in order to use the existing sleepers, the top surface of the grouted ballast layer comes directly into contact with the bottom face of the sleeper as shown in Fig. 7. This enables the track to be realigned as required, and the track panel raised and grout added when longitudinal level realignment becomes necessary due to bearing ground subsidence.

Figure 8 shows a situation of ultrafine cement grout being poured onto the ballast of a life-size model track that has a rate of fine soil contamination typically found on the existing tracks. Figure 9 shows the cross section of the grouted ballast layer after a loading test. The filling trial found that a grout layer measuring around 100 to 150 mm in thickness was formed in the ballast with a rate of fine soil contamination representative of the existing tracks. In addition, a subsequent loading test produced good results. With these favorable outcomes, the low-cost method was applied to a long length tunnel on a commercial line. Ongoing monitoring of the trial has found that the track has so far developed almost no irregularity.

4. Sleeper conversion planning support system — from timber to concrete

The number of sections on local railways still using timber sleepers today, is not negligible. The rails on tracks laid on timber sleepers tend to loosen easily due to the rotting of the timber, faulty spikes, etc., especially in sharp curves where there are higher risks of derailment due to gauge widening etc. For these reasons, it is recommended that timber sleepers should be replaced with concrete sleepers. However, as with the ballast replacement mentioned earlier, replacing all of the existing timber sleepers with concrete sleepers in a single operation is financially
difficult for sections operating on small profit margins. As the best possible alternative, many railway operators have been adopting a compromise where only one in every two to four timber sleepers is replaced with a concrete sleeper (See Fig. 10). However, this interim method is only designed to prevent the worsening of current track conditions, and there are no clearly established criteria for when this replacement method should be used.

RTRI therefore developed a sleeper conversion planning support system to help determine when timber sleepers need to be replaced with concrete ones [3] (See Fig. 11) to ensure partial conversion to concrete sleepers is as effective as possible, based on a quantitative analysis of the expected improvement in safety. The system, which is based on the performance-based design of ballasted tracks, uses input from track-related data such as alignment specifications, track structural conditions, vehicle and operational conditions and track irregularity, to calculate wheel load and lateral force and, based on the calculations, evaluates curve-specific safety performance and calculates implementation priorities (See Fig. 12). It has been found that the system offers the same level of safety at 10 to 20% less cost than when replacement is prioritized simply in order of smaller to larger curve radius.

5. Other research and development projects underway for local railways

The following are some of the major R&D projects being carried out to help reduce maintenance costs for local railways.

1) On low-specification, continuous welded rail tracks for local railways: an R&D project aiming to realize low-specification, continuous welded rail tracks for local railways (See Fig. 13) through a full review of the current track requirements.

2) On low-cost devices for gauge and twist monitoring: an R&D project aiming to develop low-cost track inspection devices dedicated to monitoring track gauge and twist, critical parameters for derailment prevention, that are capable of dynamic inspection (of tracks under train loads), to help improve safety for railway operators who do not own track inspection cars; or safety of passing tracks and sidings.

6. Conclusion

It is difficult to dramatically cut the cost of maintaining local railway facilities only by reducing track maintenance costs. Nevertheless, RTRI continues to promote the practical application of track technology which can help reduce costs and improve safety, in order to improve the sustainability of local railways.

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