Study of track tamping effectiveness, in Iranian railway

Mohammad Mehdi Movahedi, Azad Islamic University
Firozkoh branch
Reza Hatami, Head, Track machinery Dept., Iranian Railway Research Center

Abstract:
The main philosophy of carrying out the track maintenance, is "Improving the track condition and geometry"
After the tamping (lining and leveling) which is one of the main types of maintenance, the main parameters are expected to be in a better condition, The continues tests and measurements along the tracks of Iranian Railways, indicates that the track quality, immediately after the tamping is higher, and, in case of using the track stabilizer, the track will be more stable, at the desired position, but after passing the trains, track will have a the different behavior, in some sections, in the Semi-stable condition (after 1000000 tons traffic) the quality is higher than the condition before the tamping, but in some sections, the quality will be lower than the condition before the tamping, only after passing 2 or 3 trains. In the other hand the tamping has reduced the track quality in these sections.
In this article the experiences and studies of an engineering team from Iranian Railway Research Center, in the following points has been discussed:
1- The different defects
the vertical, lateral, horizontal defects
2- The different needed mechanized maintenances for all types of the defects,
3- The field test results in Iranian railway, (measuring the tamping effectiveness in different conditions)
4- Discussing the main reasons and factors (including the tamping period, track components condition, tamping quality, (frequency, depths),..) that are effective on track quality after tamping.
Introduction

While performing track maintenance operation, every single work of maintenance has got a special task. It may depend on type of activities of a railway (passenger or freight), geographical situation, … . In Europe and North America, being so rainy, drainage is of great concern, other than common maintenance operations such as periodical tamping. Whereas shoulder cleaning machines are applied in North America and Australia in addition to other types of maintenance. In England and some other American railways, ballast screening machines have been replaced by stone blowers. Most countries make use of the sand removal equipments in deserts. However what is considered as general maintenance of track in most railways of the world can be regarded as: 1. modification of track profile, longitudinal and cross level; 2. ballast optimization; 3. rail grinding; 4. sleepers and track drainage replacement; 5. track drainage adjustment; 6. rehabilitation

From a different point of view, types of maintenance can be attributed to such situations as track possession, benefit/loss analysis of track maintenance and/or operation costs. In North American railways, gana working or a team work is common by which a part of track shall be blocked for 12 to 72 hours and different working teams perform maintenance work. But in Europe, maintenance is generally made during the night, i.e. the track is blocked from 24:00 to 6:00 o'clock. Therefore with regard to the trains traffic and the impossibility of changing track possession time, they mostly use quicker machinery, such as MDZ sets.
Common failures of tracks and their development due to traffic

Experiments made by ERRI shows that a failure emerged in the track shall grow rapidly after the overhaul after the critical load of 2 million tons passed over it, then its growth shall be slowed down. In other words, before reaching to the critical load of 2 million tons, the track is not completely stabilized and this rapid growth shows track instability.

However, the results of related tests show a gradual stabilization in the tracks due to the imposed traffic load and the decrease in the amplitude of changes. But of course, this may change according to the variables of superstructure and other track situations.

1. Settlement of track

Average settlement of track can be calculated through the following formula:

\[ me(T) = a_i + a_o \log \frac{T}{T_r} \]

\[ T_r = 2MT \quad 9MT = 10^6 \text{ tons} \]

where:

T: bulk tonnage after overhaul

\( a_i \): track average settlement for Tv load (which is 5 to 15 mm)

\( a_o \): 2 to 6 mm increase in the rate of settlement within 10 years depending on track bed quality

\( \frac{a_o}{a_i} \): rate shows the failure's slow growth after passage of about two million tons of freight and it is usually between 0.25 to 0.7.
2. longitudinal failure

For high and average speed tracks, trivial amounts of longitudinal failures is specifically considered. Therefore standard deviation, $Sd_{ld}(T)$ plays an important part. Statistical studies made by ERRI has been concluded to the following formula:

$$Sd_{ld}(T) = C_1 + C_0 \log \frac{T}{T_r}$$

$C_1$: standard deviation of longitudinal failures for a load of $2 \times 10$ tons with an average amount of 1 to 1.35 mm.

$C_0$: rate of increase in the standard deviation of longitudinal failures like a function of traffic load with an average amount of 0.1 to 0.2 millimeters in 10 years.

3. Transverse failure

Similar to longitudinal failure, transverse failure can be calculated through an equation as following:

$$Sd_{td}(T) = U_1 + U_0 \log \frac{T}{T_r}$$

$U_1$ (with the average amount of 1.2 mm) and $U_0$ (with 0.1 to 0.4 mm in 10 years) have been similar to $C_1$ and $C_0$. 
4. **Horizontal failure**

Horizontal track loading is different from vertical loading in two fundamental aspects:

1. The effect of its results is quite irregular and discontinuous
2. the imposed stresses shall remain within elastic limits for safety reasons. Like other failures, horizontal failure shall have a rapid growth under the initial load of $T_r$ which is around $M_t^2$, and after that it slows down.

Under horizontal failure equation $M_{d_1}(T) = d_1 + d_0 \log \frac{T}{T_r}$ the $d_0$ and $d_1$ coefficients are the same as $a_2$ and $a_1$. Within a 10 year span, the mean value of $d_1$ is fixed at 0.6 to 1 mm and $d_0$ equals 0.15 to 0.3 mm. The rate of $\frac{d_0}{d_1}$ equaling 0.2 to 0.3 indicates the failure progress after $T_r$ load.

5. **Track gauge failure**

The track gauge failure depends both on the track bed and the components. Therefore it is a difficult thing to specify the revolutionary trend in terms of various factors.

6. **Partial settlement**

The partial settlement equation is quasi-logarithm.

$$sd_{d_1}(T) = g_1 + g_0 \log \frac{T}{T_r}$$

The coefficient of $g_1$ is set as 1 to 2 mm and $g_0$ as 0.2 times to 1 mm in a 10 year span, the same as $C^1$ and 0.
Analysis of tracks failure causes

Causes to track transverse failure
- tangible ballast settlement under sleeper (due to improper tamping)
- asymmetric settlement or washing out of the embankment
- protruding of the sleeper at one end due to freezing of ballast
- protruding of the sleeper at one end due to the cutting earth pressing against the track side
- lack of proper fastening
- fastenings wear and damage
- sleepers wear
- rail head lateral wear
- sleeper twist
- contraction

Causes to track longitudinal failures
- rail displacement in longitudinal route due to trains speed
- wheels stroke while passing over the rails
- horizontal and vertical twists
- changes in the length of rails due to temperature changes
- trains sudden brakes and hence imposing a great deal of pressure over the track
- track longitudinal settlement

Methods for modification of track failure
The basis for recognizing track failures and consequently proposing a suitable strategy is usually the analysis of graphs made by track recording. There are different softwares to enable such analysis. However the basis for the operation of them all in identifying the type of required maintenance can be summarized as below:
<table>
<thead>
<tr>
<th>Type of failure</th>
<th>Modification method</th>
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<tbody>
<tr>
<td>Longitudinal and transverse unevenness</td>
<td>Tamping together with lining and leveling</td>
</tr>
<tr>
<td>Transverse failure (gauge)</td>
<td>Damaged sleepers replacement - replacement or fixing fastenings</td>
</tr>
<tr>
<td>Horizontal and vertical abrasion of rail more than permitted limit</td>
<td>Rail replacement</td>
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<tr>
<td>Rail exfoliation; noise</td>
<td>Rail grinding</td>
</tr>
<tr>
<td>Fouling of ballast, increasing fragility, ballast life cycle</td>
<td>Ballast optimization</td>
</tr>
</tbody>
</table>

Of course failure or irregularity in figures related to a parameter is not sometimes sufficient for decision making and it is better to analyze two or more parameters simultaneously. It should be noted that track recording machine usually measures gauge - transverse leveling - longitudinal leveling and versine.

The main theme in this article is to study the amount of track maintenance effectiveness in improvement of the parameters. Otherwise in the analysis of the method of identifying suitable maintenance for every part of track, switches planning and maintenance can also be of importance.
In the tests made by the involved research team, the amount of effectiveness of track maintenance and indeed the amount of stability of the improved parameters after passing trains have been studied. There is no doubt that Railways of Iran expects an improvement in the track condition and increasing in the speed and safety of the movement after performing such track maintenance. But if the maintenance lacks necessary efficiency, safety is the first thing in danger.
Later in the article the performance of a tamping machine and stabilizer shall be analyzed.

**Practical experiment**
A comprehensive and effective method has been applied in order to perform this experiment. The area understudy is situated in the kilometers 164 to 164 500 in the Northwest region, Siyah Cheshme-Takistan block. The way these experiments were made has been as below:
In this experiment, the track quality (gauge, twist and cross level) has been measured prior to the tamping operation.
The track recording machine, SGMT5D applied has been a light digital unit manufacture by Giesmar, France, which is a hand push set many railways make use of to study different sections of a track.
Figure 1: Track parameters before tamping

Measurement after tamping operation
Measured parameters indicate a +7 mm deviation in cross level, +6 mm deviation in twist (with 3 meters) and -4 mm deviation in the gauge.

Measurement after tamping operation
Track measurement after tamping shows the related parameters deviations. The cross level, twist and gauge amounts shall be respectively decreased about $\frac{1}{5}$, $\frac{-3}{3}$ and $\frac{-4}{2}$. 
As it was expected, after stabilizing operation, DGS 62N machine could improve gauge, cross level and twist parameters about 20%. In other words, after the tamping was made, the range of each of the above parameters were came 20% nearer to the baseline. However the interesting point is the improved quality of track after it is cleared and trains passed over it.
8. Track quality after passage of 2500 tons of freight

After three passenger trains totally weighing 2500 tons passed over the track, a very strange and uncommon situation was observed. In less than a 1.5 hours, gauge, cross level and twist parameters were similar to when the tamping was not performed yet. The deviations in the gauge, twist and cross level was respectively $-\frac{6}{3}$, $-\frac{4}{4}$ and $-\frac{2}{6}$.

Undoubtedly, as it was previously mentioned the rhythm of changes in the track geometrical parameters is quite rapid after tamping and stabilizing by means of a stabilizer. However, it does not mean that after a while the geometrical parameters of track may improve, and its deviations may decrease.

Fig 3. Track quality after passing a 2500 tons load

**Categorization of track quality**

Track quality can be calculated after gauge, twist and cross level are measured. Here similar to Indian and American Railways, CTR method is applied to determine the track quality amount. Therefore a
parameter entitled TQI\textsuperscript{1} is defined. By means of the software developed by the RAI Research Center, the number of damages out of 80% of standard domain for each of the above parameters have been added together.

**Analysis of the cause**

As it was seen previously, repairs made by tamping machine and stabilizer was not of expected and necessary effectiveness. Various causes can be attributed to this, such as:

- Insufficient ballast
- Failure in the substructure
- Loose fastenings
- Carelessness in performing tamping operation (improper frequency, bad lifting, …)

After observing the results, every detail was reviewed again; the quality of tamping operation was somehow acceptable; there was neither any sign of failure in the substructure of the route, nor any water leakage in the track bed nor inadequate ballast. However there was obviously a broad range failure in the wooden sleepers in the route.

**Conclusion**

Track mechanized operation aims at improving track geometrical quality and decreasing the parameters deviation from the allowed limit. In many cases, lack of necessary conditions to perform maintenance may lead to the low effectiveness or even abortiveness of the mechanized maintenance. In the studies block in this article, sleeper failure is deemed as the most important failures which can

\textsuperscript{1} Track Quality Index
thwart the performance of mechanized machinery. This problem is not specific to Siyah Cheshme-Takistan block, since the studies made by the experts of this article show that 3.6 million out of 12 million sleepers in the network needs to be replaced, whereas there is not any rail replacer machine in RAI, although many expensive equipment are in stock for ballast maintenance. Therefore sleeper replacement is made either manually or via crane motor trolley with a cost 4 to 5 times more than the actual costs and moreover with lower speed than a rail replacer machine can do. The above figures are all the results of a documentary research, based on true statistics, analysis of the status quo and its distance with the ideal situation. In many areas, sleeper failure has been shown to be the most important problem of the track, but it's significance is not comprehend and sleeper replacement is performed in the worst and most inaccurate way. Therefore while the situation of different sleepers specially wooden ones are so, increasing the speed and traffic after performing mechanized operation shall be quite illogical and hazardous.

References:
1. years experiences of ECO track
2. the article presented in WCRR 2001
3. www.zetatech.com- 2004
4. Thesis of Mr. Alireza Vafadar, "track maintenance management, 2000"
5. Track maintenance planning, David Bwns - 2002
6. Catalogues of Geismar and Loram (manufacturers of track mechanized machinery