Construction and maintenance of underground railway tracks to safety standard of SANS: 0339

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Synopsis

To date, the construction and maintenance of underground railway tracks in the mining industry in South Africa have been done on an ad hoc basis without proper standards and guidance. The Mine Health and Safety Inspectorate recently issued a requirement to all underground mines to compile a 'Code of Practice (COP) for Underground Railbound and Transport Equipment'.

The paper briefly illustrates the life cycle costing of railway tracks and the importance of defining and measuring the track geometry of an underground railway system. The importance of maintenance on an underground railway track system is illustrated and typical underground railway track maintenance activities are listed.

Underground railway track construction methods and quality have a significant effect on ultimate railway track quality. Many of the underground railway track geometric deficiencies occurring are built into the track during construction. A construction method should be adopted to ensure the best track geometry results. A summary of some of the most important incorrect construction procedures currently used at some of the mines is listed.

Introduction

The design, construction and maintenance of underground railway tracks, to date, in the mining industry in South Africa have been carried out on an ad hoc basis without proper standards and guidance, while existing standards have generally not been complied with. Tracks underground are, therefore, generally in poor condition due to incorrect design and construction procedures and very little maintenance planning.

This is mainly due to the fact that the transportation of freight and/or passengers is not the mining industry's core business, compared to, for example, a railroad company. Spoornet and Metro staff are usually put through various training workshops and courses as part of their employment to appreciate the importance of track design and maintenance. This is not the case in the mining environment. The two most important issues relating to poor underground railway track conditions are that it is a major contributor to railbound transport accidents in the underground mining environment and it leads to speed restrictions and affects main production.

Llife cycle costing of a railway track

The life cycle of a railway track is grouped into four major phases:

- ➤ Planning phase
- ➤ Design phase
- ➤ Construction phase
- ➤ Operational and maintenance phase.

Proper infrastructure maintenance management is important as the maintenance of fixed railway infrastructure typically results in up to 70% of the total cost of the life cycle of infrastructure assets. This is illustrated by a hypothetical situation shown in Figure 1.

Figure 1 shows the level of influence through each phase of decisions on the total cost of the life of an infrastructure asset. The horizontal bar chart portion of Figure 1 indicates a typical time frame for the different phases over the life of the infrastructure asset, while the upper part shows plots of increasing cost (dashed line) and decreasing influence (solid line) over the life of the infrastructure asset.

It can be concluded that expenditures made during the planning, design and construction phases are relatively small compared to the total life cycle cost of the asset. However, the decisions made during these early phases (planning, design and construction) have

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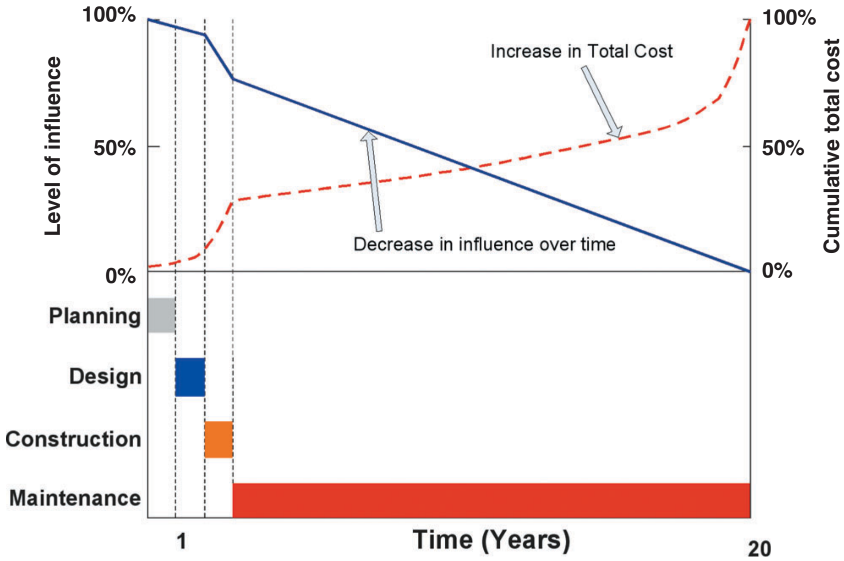

Figure 1—Influence of different phases on the total life cycle cost (adapted from Haas *et al.*)

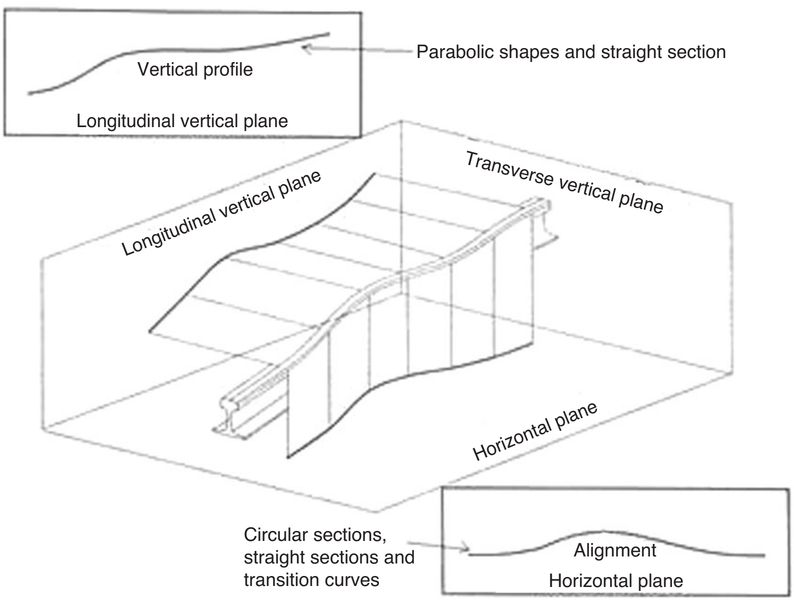

Figure 2:—Track geometry parameters (after Ref. 1)

comprehensive consequences for expenditures later in the life of the asset. In the surface railway environment infrastructure costs typically vary between 20% and 30% of operating cost, depending on the annual capital investment.

Track geometry

The railway tracks, and more specifically the rails, are used to guide the train wheels evenly and continuously along a profile. This track geometry refers to the track profile in 'space'. The track profile is defined in space by a vertical profile, horizontal plane, and by a transverse vertical profile as shown in Figure 2.

Track geometry measurements on surface railroads are usually made through a self-propelled track geometry track-recording car. Various railroads have different standards for the various measurements and the frequency of running these track-recording cars. The primary purpose of track geometry measurements on existing track is to do a condition measurement of the track and to ensure that the safe geometry tolerances of the track classifications are met. Hence, workplaces are identified along the track that require realignment by tamping.

Geometry measurements in the underground mining environment are currently limited to survey points on the rail and ad hoc gauge measurements. In SANS 0339:2000 various maximum permissible deviations from the track design values are listed. Track geometry measurements help to ensure that the following are achieved:

- The safe geometry tolerances of the track classifications are met (defined in SANS 0339:2000) and therefore reduce the risk of derailments
- Identify work places for the maintenance crew
- Allows for cost-effective maintenance of the track since areas that do not require geometrical alteration are not worked in.

Various handheld push devices are also available for measuring various parameters of track geometry. Of these the track quality measurement (TQM) is the most sophisticated and advanced (see Figure 3). Handheld push devices measure unloaded track profile whereas a heavy self-propelled geometry car measures the loaded profile. The TQM is ideal for underground geometry measurements since it can easily be assembled/disassembled underground. The TQM collects the following parameters every 10 cm along the track at a rate of 5 km/h:

- Distance (km)
- Horizontal versine (mm)
- Vertical versine (mm)
- Gauge (mm)
- Twist (mm)
- Super elevation (mm)
- Longitudinal level (mm).

Maintenance

Due to repeated loading from traffic, the track progressively moves vertically and laterally from the desired geometry. This deviation is irregular, and riding quality decreases as dynamic loads increase. Figure 4 shows two track deterioration trends for a typical problem section of track. The solid line plot shows the track roughness increase with managed maintenance input and the dotted line without maintenance input. The following conclusions can be made about the track performance:

- The original as-built functional condition cannot be regained by typical maintenance input.
- The best possible condition that can be obtained at a given time declines with traffic and maintenance cycles.
- Time between maintenance cycles decreases with increased traffic and maintenance cycles.

If the track is allowed to deteriorate without input to reduce the functional deterioration rate, the weakest component will determine the life of the track. The full potential of the various components will not be utilized because most of the components will start to deteriorate at an accelerated rate due to bad performance of weak components. The track will deteriorate to the minimum acceptable condition and reconstruction of the track will be required at an early stage. The maintenance intervention levels thus assist maintainers to prolong the life of the assets and ensure that optimum levels of safety, availability and performance are achieved.

Varies maintenance tactics can be applied in maintaining a track. Some of these include:

- Run to failure
- Ad hoc maintenance
- Schedule component replacement
- Preventative maintenance
- Condition based maintenance.

The primary purpose of a track maintenance management system is to help a condition-based maintenance tactic or a preventative maintenance tactic to be employed. A track maintenance management system needs to be tailored based on specific needs. Depending on the length and type/class of track to be maintained, the maintenance management system can entail a simple Microsoft Access database with a few linked queries or can be an involved system linked to the company's central financial system.

A viewer capable of interrelating and displaying the data in the database in linear format is an essential element in the maintenance management system. The viewer acts as an analysing tool for various maintenance engineering tasks. Data that can/should be displayed in the viewer includes:

- Asset inventory (track layout)
- Traffic data

Figure 3—Track quality measurements (TQM)

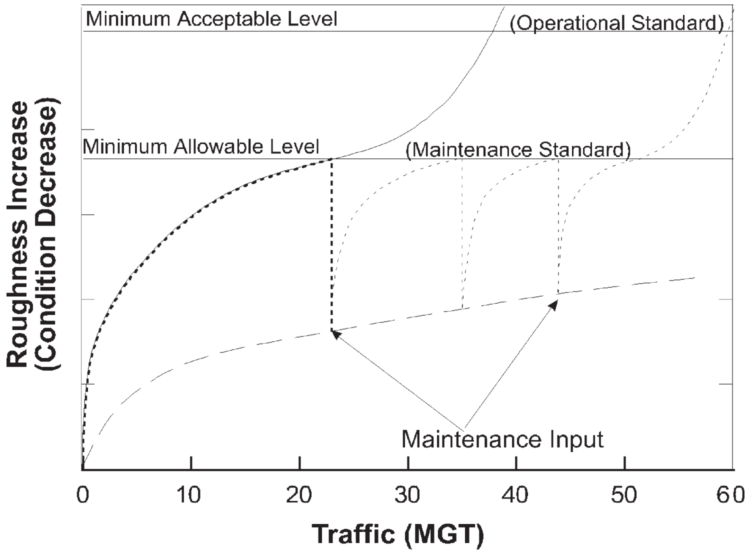

Figure 4—Hypothetical track deterioration rates with and without maintenance input

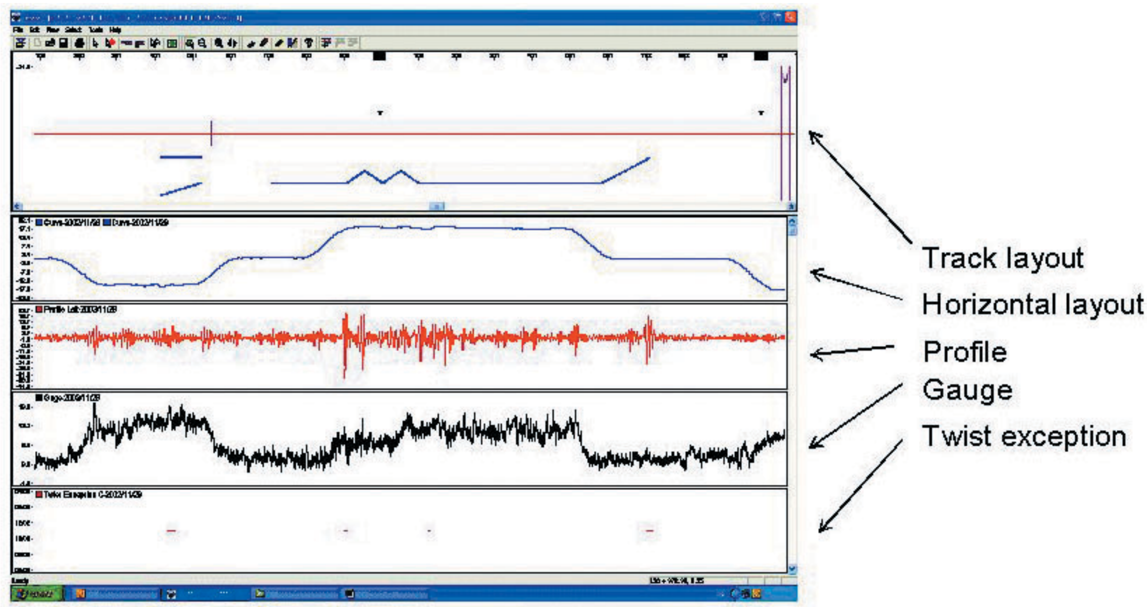

Figure 5—Example of a database viewer to interrelate data

- ➤ Track maintenance inputs (such as tamping, drainages restoration/cleaning, component replacements, etc.)
- ➤ Track geometry measurements (including exception)
- ➤ Track inspection records (list of defects for example, rail, rail joints, sleeper, fasteners, drainage, etc.)
- ➤ Cost information.

An example of database viewer to interrelate data is shown in Figure 5.

Typical underground railway track maintenance activities are listed in Table I.

Construction of new track

Construction methods and the quality have a significant effect on track quality. Many of the geometric deficiencies that are built into the track during construction are difficult to change after construction, for example with tamping. A construction method should be adopted to ensure the best track geometry results. Table II summarizes some of the most important incorrect construction procedures currently used at some of the mines.

Summary and conclusions

Underground tracks in South Africa are generally in very poor condition due to incorrect design and construction procedures and very little maintenance planning. Poor track conditions are a major contributor to railbound transport accidents in the underground mining environment.

Table I

Typical underground railway track maintenance activities

Item/activity	Typical procedure
Correct track geometry: general	• Measure off-set with a 2 m string and compare to standard • Slew the track straight by using Qwalas • Insert rail jacks and lift track to required elevation • Rearrange the upper portion of the ballast layer to fill voids under the sleeper (if run of mine is smaller size, stones of about 25 mm can be used to the surface underneath the sleepers to adjust the track geometry and to fill the voids underneath the sleeper) • Check that all fastenings are correctly installed • Re-measure off-set with a 2 m string and compare to standard
Correct track geometry: curves	• An off-set is required on a curved track • Measure off-set with a 2 m string and compare to standard • Jim-craw rail to allowable off-set after loosening the Pandral clips • Remeasure off-sets to check compliance with design standard • Fasten rails to sleepers • If sleepers were disturbed, pack with beater picks • Ensure that all gauge widening plates are correctly installed on the inside of rails to ensure a 6.0 mm gauge widening through the circular portion of the curve
Joints	• Check for loose bolts and nuts and fasten • Ensure that fish plates are correctly installed—not upside down and all holes matching that of the rails • Check that no dip joints exist to the criteria above • Check for battered joint ends where adjacent rails mismatches (to the criteria above) • Check joint gaps to the criteria above
Switches	• Clear any obstructions restricting switch blades from functioning properly • Check switch blades for wear, straightness and whether they close properly when activated • Check joint gaps and if any vertical misalignments has occurred at joints • Check crossing nose for wear • Ensure that the tumbler as such functions correctly • Check heel blocks, bolts and nuts and tighten or replace if necessary
Sleepers	• Check sleeper spacing against criteria • Check for broken or cracked sleepers and replacing if required
Drains	• Ensure drains are clean to cope with run-off of water • Repair alignment where necessary • Replace broken drain section if required
Fastening systems	• Check missing or loose fastening systems • Replace or tighten if required

Table II

Summary of some incorrect construction procedures

Item	Incorrect procedure	Problem caused	Correct procedure
Rail bending	Proper procedures is not followed for curves	Will cause an uneven 'kink' in rail	Rail bending should designed for each curve and properly and evenly executed
Gauge widening	No gauge widening on curves are used	Tight gauges result in flange wear	Use proper gauge widening techniques around curves
Joint support	Beams or *in situ* concrete is used under the rail joint	The dynamic forces on the track system will increase	Proper ballasting with two sleepers on either side of the joint
Ballast/'run of mine' gradings	No grading specified for the ballast or 'run of mine'	Track settle unevenly Proper super-elevation cannot be achieved Track will not be level	If ballast is used it should have a nominal size 37 mm (grading envelope 20 mm to 55 mm) If 'run of mine' is used the biggest stone should be smaller than 1/3 of the distance from the footwall to bottom of sleeper
Ballast/'run of mine' compaction	No compaction specified	Proper super-elevation cannot be achieved Track will not be level	Compact ballast
Drainage: cross slope	No cross slope defined on formation level	Result will be VERY POOR drainage	Level formation with 1:30 slope towards drain
Drainage: side drain	The side drain is often too high relative to the track	Access water from the track substructure will not accumulate in the drain	Design drain on proper level
Drainage: dewatering system	No or inadequate dewatering system	Result will be VERY POOR drainage	A dewatering system must be installed with pumps at least every 250 m

Currently, very little to no underground geometry measurements are taken. Track geometry measurements can be used effectively to measure track underground condition and to ensure that the safe geometry track tolerances are met. In addition, track geometry measurements also help identify workplaces along the track that require realignment by tamping.

Geometry measurements can be fed into a track maintenance management system to help a condition-based maintenance tactic or a preventative maintenance tactic to be employed. The track maintenance management system can act as an analysing tool for various railway maintenance engineering tasks.

References

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