

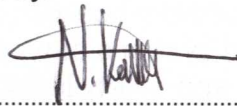
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Level 3

Management of Coal Mining Subsidence Affecting Track Infrastructure

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Issue record

Issue	Date	Comments
01	5 th December 2009	First Issue

Reference documentation

NR/L3/CIV/037	Managing the Risk Arising from Mineral Extraction and Landfill
NR/L3/CIV/038	Managing the Potential Effects of Coal Mining Subsidence
NR/L2/TRK/001	Inspection and Maintenance of Permanent Way
NR/L2/TRK/3011	Continuous Welded Rail (CWR) Track
NR/L2/TRK/2049	Track Design Handbook
Mining Agreement	The Agreement between the British Railways Board and the National Coal Board dated 26 th January 1982

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1 Purpose

This document gives advice to technicians, engineers and managers who are engaged in the management of coal mining subsidence affecting track infrastructure. Advice includes how to interpret mining reports and other information provided by the Network Rail Principal Mining Engineer (PME).

The need for this document arises following the transfer of railway maintenance to Network Rail in 2004, to give clarity to the track management requirements on sites subjected to coal mining subsidence.

2 Scope

This document applies to all track infrastructure adversely affected by coal mining subsidence on the railway. For infrastructure other than track, guidance should be sought from the relevant Functional Engineer specific to that discipline.

Contact the PME for information on the detrimental affects caused by quarrying and the mining of other minerals.

3 Roles and Responsibilities

Roles and responsibilities for key staff are dealt with in NR/L3/CIV/037 'Managing the Risk Arising from Mineral Extraction and Landfill Operations' and NR/L3/CIV/038 'Managing the Potential Effects of Coal Mining Subsidence'

4 Definitions and Abbreviations

BRB	British Railways Board
CRT	Critical Rail Temperature
CWR	Continuous Welded Rail
IBJ	Insulated Block Joint
PME	Principal Mining Engineer (Network Rail)
NCB	National Coal Board
SFT	Stress Free Temperature
RaFTs	Rail Force Transducers
RCF	Rolling Contact Fatigue
VERSE	Vertical Rail Stiffness Equipment
TME	Track Maintenance Engineer (Network Rail)
PMSE(T)	Principal Maintenance Support Engineer (Track)

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5 Main clauses

5.1 Background

The current method of working underground coal is by longwall faces which advance, or retreat, between underground roadways used for access, ventilation and the transportation of coal. Individual faces are known as Panels and are rectangular in shape, up to 350 metres wide and 1500 metres in length. The strata behind the working face is allowed to collapse into the worked out void and results in subsidence at the surface. Where mining activities occur within the vicinity of the railway, Network Rail must manage the detrimental effects to the infrastructure or limit/prevent the subsidence occurring.

In order to limit or prevent the potential subsidence effect of any panel of coal, Network Rail has the right to reserve support. In essence, the compensation paid to the mine operator for the loss in profit of the coal sterilised is dependent upon evidence that the coal could have been mined and becomes payable on the date that the coal would have been mined in the normal course of events. However where practicable in terms of engineering and operations, the preferred option is to manage the subsidence by undertaking preventive and remedial work on the infrastructure affected.

If mining proceeds, ground movement induces vertical and horizontal movement across the site changing stresses within the rail, causing track levels to drop and changing track geometry. This document gives guidance on how anticipated mining activities are reported, monitored and addressed.

5.2 Principal Mining Engineer

The Network Rail Principal Mining Engineer (PME) administers the obligations under the British Railways Board/National Coal Board Agreement dated 26 January 1982. This Agreement governs the underground working of coal in the vicinity of railway property and places obligations and liabilities on Network Rail, the Coal Authority, their licensees and lessees.

Information on this agreement can be found in Network Rail Business Process Document NR/L3/CIV/037 'Managing the Risk Arising from Mineral Extraction and Landfill Operations' and NR/L3/CIV/038 'Management the Potential Effects of Coal Mining Subsidence.

The PME provides a specialist service, which includes the provision of mining reports outlining the potential effect of coal mining subsidence on railway infrastructure.

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In terms of deep mining the PME:

- analyses deep mining parameters using a three dimensional software model to produce subsidence and ground strain predictions for both continuous (e.g. track) and discrete (e.g. structures) assets.
- maintains an archive of mining records and geology.
- has the right of access to underground workings for the purpose of inspection.
- acts as the intermediary between the mine operator and the asset maintainer, to ensure the railway industry has visibility of mining activities, provides expert assessment of the potential impact of such activity on railway infrastructure.
- act as an informed negotiator to deal with commercial issues relating to the BRB/NCB Agreement dated 26th January 1982 (still standing).

The PME produces a series of set format reports and subsidence prediction graphs that are produced when mining activities are proposed and are active. Examples of this documentation can be seen in Appendices A to F.

5.3 Subsidence & Ground Strain

For practical purposes the extent of subsidence on the surface is bounded by a theoretical line drawn at $\frac{1}{2}$ the depth of the coal seam from the edges of the Panel. The location of the workings relative to railway infrastructure is shown on 'Layout Plans' (Appendix A) accompanying 'Mining Reports'. Such reports (Appendix B & C) provide details of the effect of settlement on railway infrastructure in terms of the extent, magnitude, timing and rate of subsidence. This information facilitates the preparation of appropriate subsidence management regimes.

The amount of vertical settlement and associated horizontal ground strain is a complex calculation, based upon:

- the thickness of extraction,
- depth of the seam from the surface
- width and length of the Panel of coal
- dip of the coal seam and other geological criteria. Geological faulting can increase the likelihood of discrete surface deformation.

The timing of the surface settlement is governed by the planning of the Mine Operator and the rate of subsidence is in turn influenced by the rate of advance of the panel. Geological conditions can have a significant impact on planned dates of extraction and the progress of individual Panels. The 'Subsidence Profile along a Line' graph (Appendix D) provides details of anticipated subsidence in mm relative to position along the track. Additionally, 'Subsidence Development at a Point' (Appendix E) graphs are available and may be requested for mileages at specific features along the track.

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The rate of subsidence can vary from Very Gradual to Very Rapid. Notice Mining Reports (Appendix B) and Periodic Mining Reports (Appendix C), outline the planned rates of subsidence throughout the life of a Panel. A table in the footer of the Mining Report delineates the bands used to specify monthly rates of subsidence.

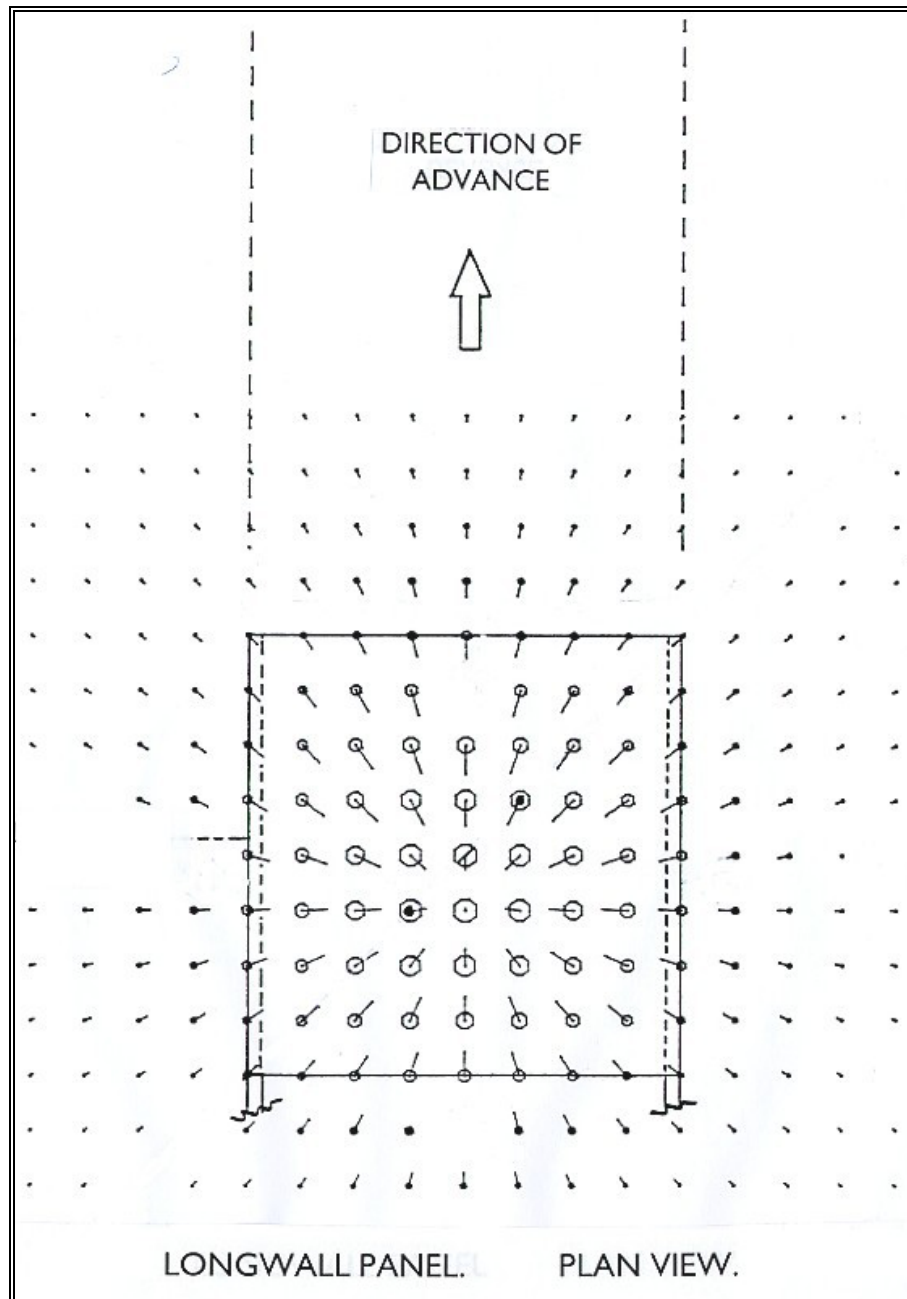


Figure 1 Diagrammatic Representation of Ground Movement

Figure 1 shows how the vertical movement of the surface varies throughout the subsidence basin and the size of the 'O' character is used to illustrate the variation in magnitude. The direction and magnitude of the horizontal movement are also indicated by the length and direction of the lines that point towards the centre of the basin.

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5.4 Horizontal Ground Strain

With more substantial amounts of subsidence, horizontal ground strains can often be more significant than actual vertical movement. The extent to which horizontal ground strain can influence and degrade the safe operability of the infrastructure is influenced by both asset design and their orientation to the development of the subsidence basin. It is usually this ground strain, not necessarily vertical settlement, which poses the greatest risk.

If the movement of the ground was transferred through the ballast and sleepers to the rail, a difference in the inward movement of the ground towards the centre of the subsidence basin, expressed as a ratio, could be equated with a change in SFT, with 1mm/m being equivalent to 87 °C. This relationship can be demonstrated by using the formula for calculation of rail extension **$e = 1000 L X t$**

e = extension in mm

L = the length of the free rail in metres

X = the coefficient of expansion of steel (0.0000115 per °C for normal grade rail)

t = difference in actual average rail temperature and required SFT

Hence for 1mm/m

$$t = \frac{e}{1000 X}$$

$$87^{\circ}\text{C} = \frac{1}{0.0115}$$

However, not all ground movement is transmitted through the formation and ballast, and under normal circumstances it is not anticipated that the measured change in SFT of the rail will accurately reflect predicted movement of the surface. The calculated horizontal strains should exceed the measured quantities, and thus provide a factor of safety in the design of the SFT monitoring regime, enabling the CWR to be managed effectively. Frequent stress equalisation and re-stressing may be required during the period of active subsidence; this would be dependent on the rate and magnitude of the subsidence.

5.5 Ground Strain Transmitted to CWR & Jointed Track

Compressive and tensile strains associated with subsidence redistribute the SFT in CWR and change rail joint gaps along a site; this is demonstrated in the 'Strain Profile along a Line' prediction graph in Appendix F. SFT is lowered by compressive strain 'over' the panel and it is raised by the tensile strain over and beyond the edges of the panel. Joints close over the compressive zone and open over the tensile zone, producing mal-adjustment which, in hot weather, can result in buckles.

The Tensile – Compressive – Tensile Zones associated with mining subsidence relate to strain developing within the ground. When strain is transferred to the rail, many factors will determine the actual forces developing within the rail, including

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ambient temperature, change in SFT, existence and spacing of rail gaps in jointed track and condition of track components.

5.6 Strain to SFT

Investigations into the observed relationship of predicted/actual ground strain & SFT in CWR are very sparse. However experience demonstrates that not all predicted strain could be assumed to reach the rail. Based upon early work by British Rail Research and the management of subsidence in the 1980s, the following are suggested guides when planning monitoring and intervention. Subsidence with predicted compressive ground strains:

- >2 mm/m, estimated 75% of the maximum strain values are used to calculate SFT change against time.
- 1.5 – 2 mm/m, estimated 66% of the maximum strain values are used to calculate SFT change against time.
- 0.75 – 1.5 mm/m, estimated 50% of the maximum strain values are used to calculate SFT change against time.
- <0.75 mm/m, estimated 33% of the maximum strain values are used to calculate SFT change against time.

The 'Strain at a Point graphs' available on request from the PME can be used as a basis for estimating changes in SFT per week or month by assessing the slope of the graph gradient against time. This assessment can be done manually on the graph with pencil and ruler. The relationship of 1 mm/m = 87°C change in SFT (based upon the principles of CWR design) is used on the graphs to produce SFT data. This graph, together with the guidance factors given above, can be used to assess the impact at the resource planning stage. This of course is only a guide, as many factors will influence the levels of strain transferred to the rail including the rate of subsidence. A single graph is sufficient for a panel reasonably perpendicular to the track, or a series of graphs for selected positions where the angle of the panel and geometry of the track results in the maximum compressive and tensile points moving along the track.

The actual transfer of strain to CWR should be monitored using an appropriate method discussed in Section 5.7

5.7 Monitoring Strain in Track

Jointed track

The design of older jointed track with ineffective fastenings and no rail anchors is more likely to result in sleepers moving along the rail with 'bunching up' at the joints, in addition to closing and opening of rail gaps. It is important to put in place a regime of joint monitoring and resetting as the settlement occurs. Preparation of jointed track is therefore important in terms of rail adjustment, squareness and lubrication of joints, fastening and anchorage condition. In short, jointed track adequately prepared for hot weather is adequately prepared for monitoring during subsidence.