Chapter
4

# Right-of-Way & Roadway

**For this chapter, think of the railway right-of-way as the area from fence to fence without the track and structures. The roadway is considered to be any construction within the right-of-way except the track, bridge structures, signals and crossings.**

## 4.1 Introduction

The railway right-of-way (often referred to as the roadway) includes the subgrade upon which the ballast section and track are built, along with adjacent improvements and features required to support and maintain the railway track. The right-of-way is often thought of as the strip of land on which the railway and its supporting features are built.

The right-of-way typically includes ditches running along the track and related drainage structures required to divert water past and away from the railway. The issue of drainage is covered in Chapter 5. It also includes any embankments and cuts on which, or through which, the railway is built, their side slopes and the vegetation covering the slopes. It may also include any retaining walls or other earth-supporting structures required to hold railway embankment and cut side slopes in place. It includes fences, signs, utilities and outlying structures.

The bulk of this chapter deals with what the railways are built upon, the soil. Just as concrete and steel are the materials used by the structural engineer, soil is the main building material for the railway. In the same way as there are various types of steel, or diverse mixtures of concrete, there are many classifications of soil. Some soils are suitable for use as ballast and sub-ballast (sand and gravel), some as subgrade materials (sand, gravel, clay, etc.), while others are totally undesirable for any use in railway construction (e.g., organic soils).

A major difference between soils and most other construction materials is that soil is a natural material and is subjected to little or no processing before use. It is therefore essential to identify the various soils and avoid using those that may give problems, since it is seldom that soil can be processed to improve its properties. From a construction and maintenance over the past 100 years. For instance, it is not unusual for track that functioned very well for more than 50 years to suddenly develop severe geotechnical problems.

In solving problems today, the experiences and effects of the last 100 to 150 years of railway practice must be considered. Not only are the railways dealing with ever-increasing loads and ever-increasing traffic, but also a maintenance effort focused on rails and ties. Ballast, being less visible, receives less attention, and the subgrade, less still except when problems develop. Nonetheless, knowing the history of a section of track is an important component of effective track maintenance.

## Components and Functions

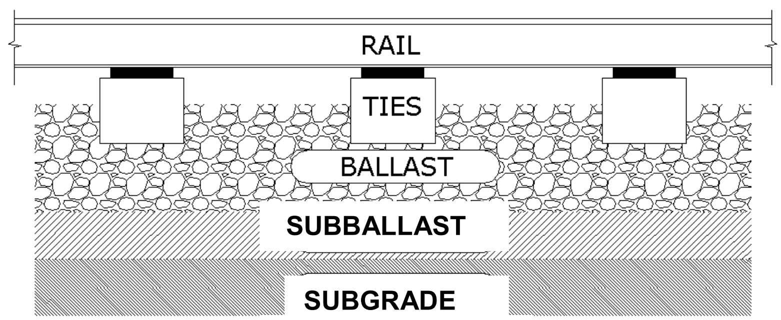


Figure 4-4 The Track Structure

The track structure is made up of subgrade, sub-ballast, ballast, ties and rail as illustrated in Figure 4-4. Each of these contributes to the primary function of the track structure, which is to conduct the applied loads from train traffic across the subgrade safely. The magnitudes of typical stresses under a 50,000 lb axle load are shown in Figure 4-5. These stresses are applied repeatedly, and each repetition causes a small amount of deformation in the subgrade. In theory, the track structure should be designed and constructed to limit rail deflections to values which do not produce excessive rail wear or rates of rail failure. In reality, cumulative deformation of the subgrade causes distortion of the subgrade, leading to formation of "ballast pockets" (Figure 4-6) or outright shear failure.

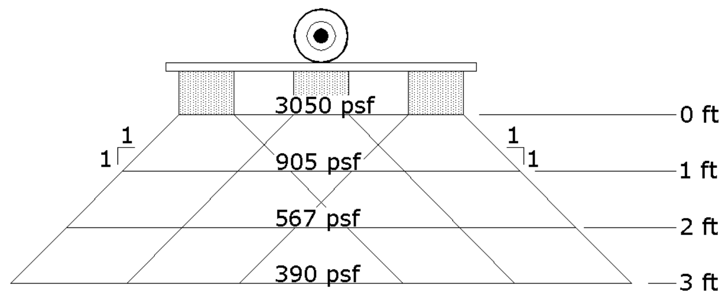


Figure 4-5 Stresses Imposed by Train Axle Load

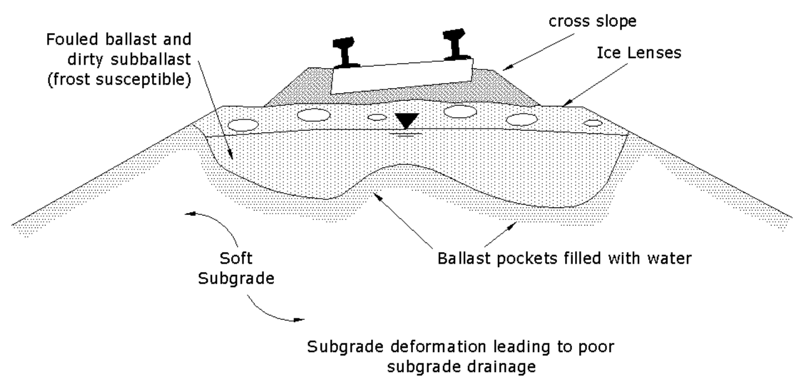


Figure 4-6 Ballast Pockets in Subgrade

## Subgrade

The purpose of the subgrade is to support the track structure with limiting deflections. Every subgrade will undergo some deflection (strain) as loads (stress) are applied. The total displacement experienced by the subgrade will be transmitted to other components in the track structure. The stiffer the subgrade (i.e., the higher the modulus of elasticity), the lower the deflection values will be. It is important that adequate subgrade strength and stiffness be available on a year-round basis, particularly during spring thaw and following heavy precipitation events.

The strength, stiffness and total deflection of the subgrade can be improved by:

- Carefully selecting materials that are naturally strong (sand, gravel, boulders) with a high angle of internal friction.
- Limiting access to water to avoid buildup of porewater pressure and subsequent reduction of strength.
- Improving the soil properties, using techniques such as compaction, in situ densification, grouting and preloading.
- Maintain good drainage.
- Maintain stable subgrade geometry.

## Sub-ballast

The purpose of sub-ballast is to form a transition zone between the ballast and subgrade to avoid migration of soil into the ballast, and to reduce the stresses applied to the subgrade. In theory, the gradation of the sub-ballast should form a filter zone that prevents migration of fine particles from the subgrade into the ballast. In practice, insufficient attention has been placed to sub-ballast gradation historically, and much of the sub-ballast does not adequately perform that function. This notwithstanding, the number of occurrences of subgrade contamination of ballast are relatively few.

## How Track Fails

In a nutshell, track fails when differential rail deflections become excessive. This differential deflection may be expressed in differential elevation between tracks, punching of ties, elastic or plastic deformation of the subgrade, or degradation of ballast.

When the bearing capacity of the subgrade is exceeded, the subgrade will deform plastically, resulting in a small amount of permanent deformation under each wheel load. A progressive deterioration of the track begins, as illustrated in Figures 4-7 to 4-10. It starts with minor deflections and may progress to a fully visible surface heave, where subgrade material is pushed above the elevation of the rail and ties. Under those conditions, ballast drainage is impeded, resulting in further softening and degradation of the subgrade to a point where large, saturated pockets of ballast are trapped in the subgrade. Frost heave and further degradation commonly follow, leading eventually to a severe loss of utility of the track structure.

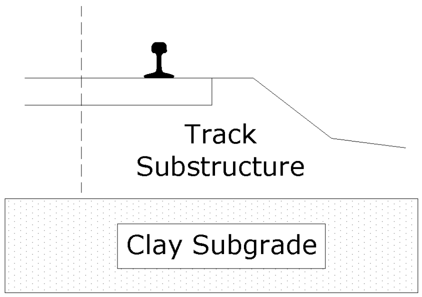


Figure 4-7 Stable Site

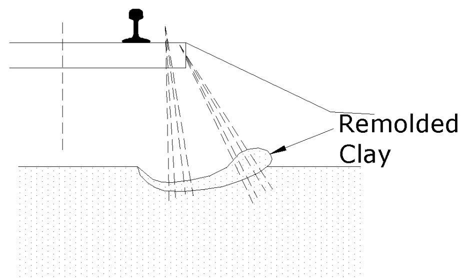


Figure 4-8 Onset of Instability

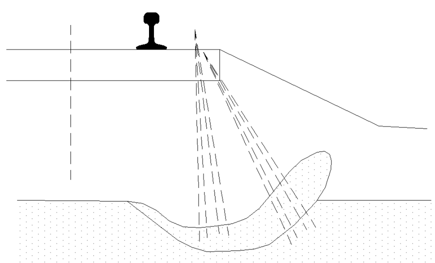

Figure 4-9 Growth of Heave

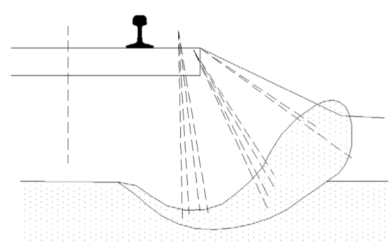

Figure 4-10 Surface Manifestation of Heave

## 4.3.4 Instability

Instability results when the shear strength of the soil is not sufficient to support the loads applied to it. Bearing capacity failures discussed in the previous section are one type of shear failure that occurs when the soil cannot sustain vertical load applied to it and vertically downward movement results. The term landslide is used to define all types of mass movement of soil or rock, where the mass moves down slope under the influence of gravity only. There are many types of landslides, but the distinguishing feature is that a mass of material is moved and gravity is the driving force.

### Main Features of Landslides

The diagnostic features of most landslides include a scarp that forms at the head of the landslide. This is usually a near vertical wall of soil, usually freshly exposed by movement. The slump blocks are unique, identifiable blocks of soil, usually bounded by scarps that show both vertical and horizontal movement. The main body of the slide is the mass of soil that is pushed ahead by the slump blocks, and may be marked by numerous tension cracks. Bulging of the soil, and thrusting of the slide debris over the natural surface usually mark the toe of the slide. The slip plane or shear zone is usually a distinct and identifiable plane that marks the lower limit of movement and the upper limit of undisturbed soil. It should be noted that the shear zone is not usually planar, but rather may be circular, or a composite curvilinear surface that passes through the weakest zones in the subsurface.

### Slides that Affect the Track

Instability that affects the track can be classified according to the impact that it has on the track. These are described in various illustrations.

- Figure 4-11 illustrates a slide that encompasses a track and will disrupt the track by cutting the alignment. Once the track moves out of line, it is no longer serviceable.

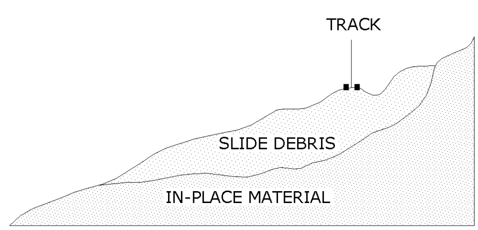


Figure 4-11 Slides Cutting Track

- Figure 4-12 illustrates the effect of a landslide upslope where the toe crosses the track, burying it in under slide debris.

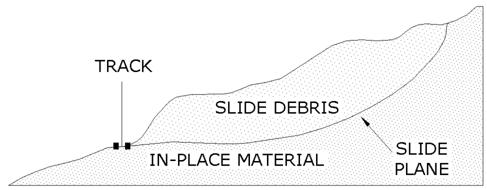


Figure 4-12 Slides Covering Track

- Figure 4-13 shows the track being heaved up in response to upward movement of the toe of a landslide.

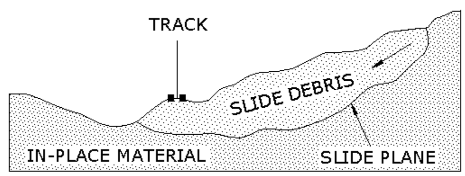


Figure 4-13 Slides Heaving Track

- Figure 4-14 illustrates an event where a landslide threatens the track, perhaps by encroaching on the down slope shoulder.

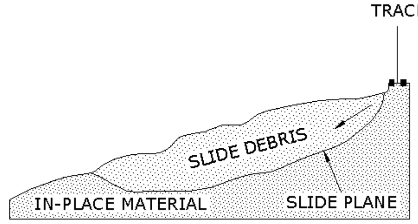


Figure 4-14 Slides Threatening Track

- Figure 4-15 illustrates how base failure in fills on soft foundations can cause the fill to spread and settle. While this may be mistaken as settlement, it is actually a shear movement involving the foundation soils. It is common on organic terrain and other soft foundations.

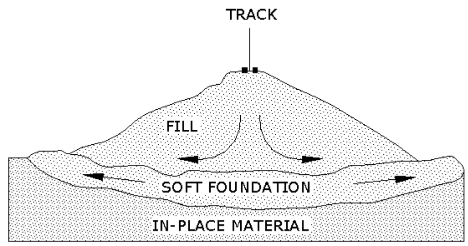


Figure 4-15 Base Failure

- Figure 4-16 shows how locations over old landslides may be reactivated due to a change in stresses within the landslide mass. Many of the ancient landslides are extremely large, and the limits of the landslides may be difficult to detect.

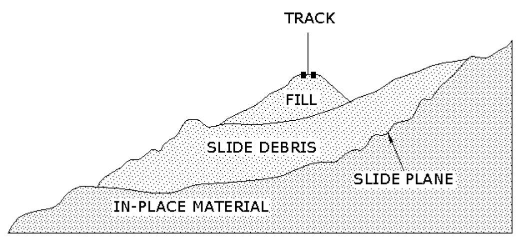


Figure 4-16 Reactivation of Old Slide

## Triggering Mechanisms

The stability of a slope is dependent upon:

- The shear strength of the soils.
- Porewater pressure within the soils that make up the slope (this can be roughly measured by knowing the water table).
- The geometry of the slope, particularly the slope angle and changes of slope.
- Any surcharge loading such as fill or bank widening material stored on the slope or train loads.

Landslides occur either as a result of reduction in soil strength or an increase in the loading on the slope.

Reductions in soil strength can occur as the result of:

- An increase in porewater pressure, reducing the available shear strength of the soil. In the case of moisture sensitive soils, the amount of water needed to cause this