# CHAPTER 1

# 1. INTRODUCTION

Rail track structures are designed with an objective of achieving a minimum standard of capacity and track geometry to ensure safer operation of trains at specified levels of speed, axle load and tonnage to be hauled. To realise these design objectives both the strength and stability of the quality of the upper subgrade and the subgrade soils must be carefully assessed. If the subgrade soil cannot achieve these requirements, then a *capping layer* of granular material is placed between the natural ground or the embankment fill material and the ballast to improve the capacity of the track structure and to minimise its ongoing costs of maintenance, especially issues related to track geometry. The basic functions of a capping layer are therefore, i) to act as a working platform for the construction of the ballast layer in the short term, ii) to act as a structural layer with the capability of protecting the natural ground or the embankment fill material by minimising long term permanent and uneven deformations, and iii) to protect the subgrade from rainwater ingress.

## 1.1 Research Aims

The research described in this thesis aims to improve understanding of the behaviour of the capping layer material in addition to developing an inexpensive method of evaluating the elasto-plastic properties of such materials. These aims are achieved through the following enabling objectives:

- A critical review of the literature in this field and a discussion of the findings of this literature.

- Laboratory study of material behaviour through a simple method which can be used instead of the expensive cyclic triaxial tests.
- Numerical modelling of the experiments through a backcalculation technique coupled with finite element approximation incorporating suitable material constitutive relations for predicting the fundamental elasto-plastic material constants.
- Extending the finite element model with the predicted constitutive properties to evaluate the behaviour of the capping layer material subjected to boundary and loading conditions that approximately simulate the field conditions.
- Validating the finite element predictions using full-scale laboratory testing.
- Examining the sensitivity of the elasto-plastic material properties to permanent deformation as a basis for drawing useful, practical conclusions.

Through the above objectives the thesis presents many important aspects of capping layer behaviour that can be applied in practical situations for the design and analysis of an upper subgrade zone.

## 1.2 Scope and Limitation of Research

The research described in this thesis contributes to significantly extending the knowledge of the capping layer behaviour through the following approaches:

1. The development of a small-scale experimental method describing the behaviour of non-cohesive granular layers. This experimental method will be inexpensive and can be used as an alternate method to the conventional cyclic triaxial tests that are expensive.

2. Development of a numerical model that accounts for the pressure dependency of the properties of the non-cohesive capping layer soils.
3. Large scale testing of capping layer in a purpose built large-scale testing apparatus.

This thesis is mainly concerned with the time-independent plasticity of the capping layer material. It does not account for long term consolidation and/or high cycle fatigue failure of the capping layer material.

## 1.3 Thesis Structure

The research described in this thesis begins with a "Review of the Rail Track Substructure", presented in Chapter 2. This review describes the behaviour of support substructure material including both empirical research and analytical methods.

Chapter 3 on "Experimental Method of Characterising Capping Layer Properties" describes the laboratory experiments carried out for examining the behaviour of capping layer material. These tests were intended to develop an alternative economical method to determine elasto-plastic material parameters for capping layer design.

Chapter 4 is dedicated to "Finite Element Modelling (FEM) of Capping Layer Material". The theory behind the modelling of material characterisation is described. This Chapter is subdivided to describe the development of the model with a brief introduction to the theory of plasticity.

Chapter 5 describes the “Backcalculation of the Capping Layer Material Properties”. This Chapter describes the method of prediction of the properties using the capping layer material and compares the predictions with published and other available data.

Chapter 6 presents an “Application of the FE Model for Capping Layer in Practice”. This Chapter presents the application of the FE model to plane strain cases of capping layer material that approximately simulate the boundary and loading conditions that exist in the field operating environment. Large-scale experimental setup has been used for validating the results obtained through the application of the FE model.

Chapter 7 presents the “Conclusions and Recommendations”. This Chapter sets out the main research findings and some future directions for further research in this field.