Unit 1

Railway Subgrade

Learning Objectives

After learning this unit, you'll be able to:

1. know the forms of cross sections of the railway subgrade;
2. know the composition of the railway subgrade;
3. understand the construction process of subgrade filling;
4. grasp the craftsmanship and requirements of the embankment filling below the subgrade.

Part One Lead-in

1. Directions: Look at the following structures and write the corresponding names of them under each picture.

(1) _____

(2) _____

(3) _____

(4) _____

2. Directions: Answer the following questions in your own words.

(1) Have you ever traveled by train? What's under the running train?

(2) Have you observed the parts under the rails? What do the parts consist of?

3. Directions: Look at the pictures below and discuss the following questions.

(1) Could you tell which parts are railway subgrades?

(2) What is the fill material of the railway subgrade?

(1)

(2)

(3)

4. Directions: Have you ever seen the form of railway subgrade in the picture below? Do you know how this form of subgrade is built?

Part Two Reading Materials

Material A

Introduction of the Railway Subgrade

1 Concept of the railway subgrade

A railway subgrade is a geotechnical building constructed to meet the conditions of track laying and railway operation. The railway subgrade is the foundation of the track structure, and is a kind of linear structure exposed in the atmosphere on the natural ground according to the plane position and the longitudinal slope of the lines, which may require excavation or filling to form a certain section shape. The design elevation of the top of rail (TOR) shall be maintained in the construction of railway subgrades to make sure the subgrades are smoothly connected with bridges, tunnels and other buildings to form a complete and smooth railway line for the safe, stable and

uninterrupted operation of the train at the specified speed.

The railway subgrade bears the static and dynamic loads from tracks and locomotive vehicles, and at the same time it can also be affected by various natural factors. The stability, sturdiness and durability of the subgrade are directly related to the quality of the line and the safety of the train. Therefore, the railway subgrade should deliver a satisfactory performance in its overall stability, strength and stability against water temperature. The stability of the subgrade means that trains and natural factors would not cause unacceptable deformation and damage to the subgrade. The strength of the subgrade refers to the ability to resist deformation and damage under the load of the train. The stability against water temperature refers to the ability to maintain its strength under the action of water and temperature, which includes the stability against both water and temperature.

2 Cross section of the railway subgrade

The cross section of the subgrade is the first part to be designed. The main task in the design is to provide shapes and sizes of various parts of the cross sections. Then, what is the cross section of the subgrade? The section perpendicular to the center line of the track is often referred to as the cross section of the subgrade.

There are six types of cross sections of the railway subgrade: embankment, cutting, mostly embankment, mostly cutting, embankment and cutting, and none filling and cutting, as shown in Figure 1.

(1) Embankment

Embankment refers to the structure formed by filling in subgrade construction when the track formation on which tracks are laid is higher than the natural ground level.

(2) Cutting

Cutting refers to the structure that is formed by excavation work in subgrade construction when the track formation on which tracks are laid is lower than the natural ground level.

(3) Mostly embankment

Mostly embankment refers to the structure that is developed through partial and most filling in subgrade construction when the natural ground is inclined laterally.

(4) Mostly cutting

Mostly cutting refers to the structure on either side of which excavation work is performed when the natural ground is inclined laterally.

(5) Embankment and cutting

Embankment and cutting, known also as mostly embankment and mostly cutting, refers to the structure which is constructed by both filling and excavation when the natural ground is inclined laterally.

(6) None filling and cutting

None filling and cutting, also known as the subgrade without filling and cutting, refers to the subgrade on which tracks can be laid directly without any filling or cutting and the track formation of which is flush with the cleaned and cleared natural ground.

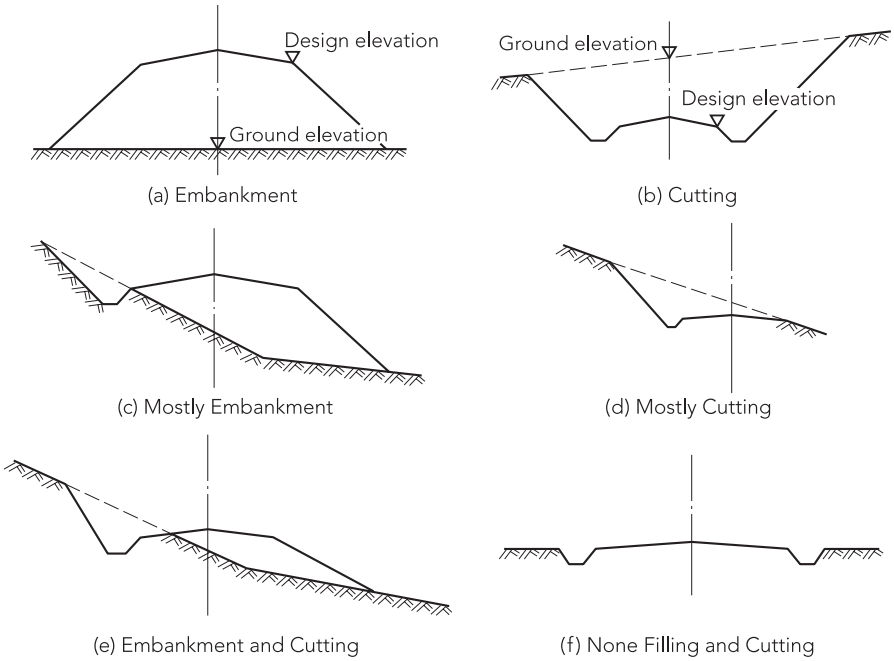
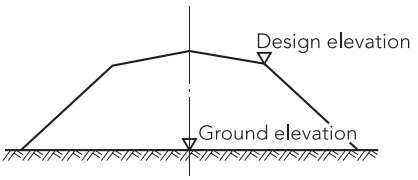


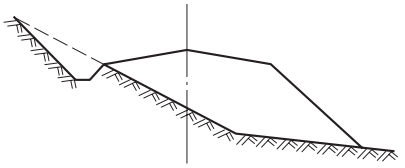
Figure 1 Types of Cross Sections of Railway Subgrades

Exercise A

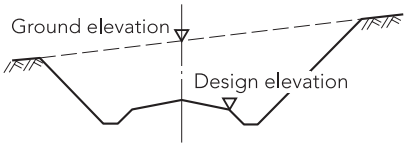
1. Directions: Match the pictures with the corresponding terms.

(1) 

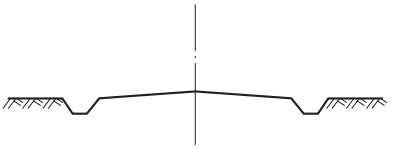
A. Cutting

(2) 

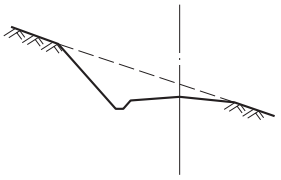
B. Mostly embankment

(3) 

C. Mostly cutting

(4) 

D. Embankment

(5) 

E. None filling and cutting

2. Directions: Fill in the blanks with the words or expressions according to the text.

(1) The types of cross sections of the railway subgrade include _____, _____, _____, _____, _____, and _____.

(2) _____ refers to the subgrade on which tracks can be laid directly without any filling or cutting and the track formation of which is flush with the cleaned and cleared natural ground.

(3) _____ refers to the structure that is filled with soil and stones to the extent that the track formation is higher than the natural ground

level.

(4) Cutting refers to the structure that is formed by _____ when the track formation is _____ than the natural ground level.

(5) Embankment and cutting, also known as mostly embankment and mostly cutting, refers to the structure which is constructed by both _____ and _____.

Mini-project A

Directions: Work in groups of four. Draw the six types of cross sections of railway subgrades manifested in the following pictures on cards before class. Each student draws out a card in turn and tells the whole class the corresponding forms and application conditions of this subgrade cross section on his/her card.

(1)

(2)

(3)

(4)

(5)

(6)

Material B

Composition of the Railway Subgrade

The railway subgrade is mainly composed of roadbeds and subgrade auxiliary facilities.

1 Roadbed

In the subgrade, the part where the track is laid according to the line design requirements is called a roadbed.

The roadbed consists of five parts: the track formation, shoulder, foundation bed, side slope, and subbase, as shown in Figure 2.

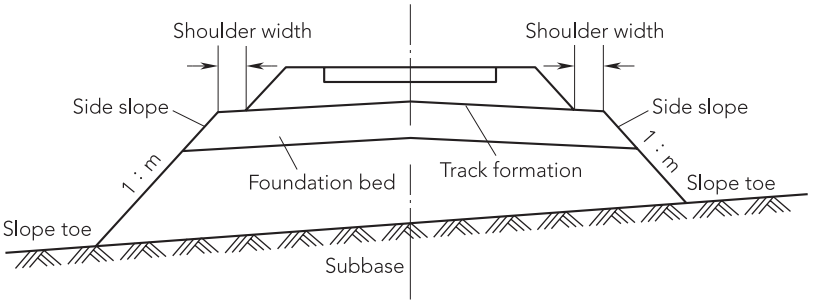


Figure 2 Composition of the Roadbed

(1) Track formation

The track formation consists of the portion on which the track rests directly and shoulders.

Water damages the subgrade. In order to ensure good drainage conditions, the track formation should be made into an arch with lateral drainage slopes, which is called a camber. The shape of the camber is triangular, and a herringbone drainage slope with the gradient of 4 is provided on both sides from the center line of the subgrade, as shown in Figure 3.

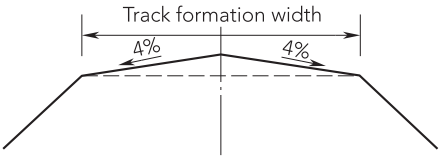


Figure 3 Camber

(2) Shoulder

On the top of the track formation, the part outside the track bed cover is called the shoulder, which is developed to protect the core part of the embankment and to prevent ballast from dropping out. In addition, it acts as the lateral drainage of the track formation, the passage for maintenance personnel to walk on or to avoid the train, the stacking space for maintenance and repair tools, the temporary stacking space for sand and gravel for rescue, and the place for various embedded signs, communication signals, power and water supply equipment, etc.

(3) Foundation bed

The foundation bed is the soil layer which is affected by the dynamic load of the train and the hydrological and climatic changes in the upper part of the subgrade. Its conditions directly affect the stability and speed of the train.

The foundation bed is divided into the surface layer (base course) and the bottom layer (subbase). The thickness of the surface layer is 0.6 m, and that of the bottom layer is 1.9 m, and the total thickness is 2.5 m.

(4) Side slope

A side slope is defined as the slope of the cut or fill expressed as the

ratio of the vertical distance to the horizontal distance in the form of 1: m. Side slopes may take on the shape of straight line, polyline and stair-stepping.

(5) Subbase

The subsoil under the embankment that bears the load of the embankment, the track, and the train, is called the subbase of the embankment. The subbase of the cutting is the part of the soil in the side slope of the cutting or the subsoil below the subbase of the cutting, where the stress of the subsoil changes.

2 Subgrade auxiliary facility

(1) Subgrade drainage system

The subgrade drainage system intercepts the surface water and groundwater above the subgrade, and quickly collects the surface water and groundwater in the roadbed before they are diverted into an unobstructed drainage channel. The water is vented to the bottom of the subgrade through the bridge and culvert. Subgrade drainage facilities are divided into two categories: ground drainage facilities and underground drainage facilities. Ground drainage facilities include drainage ditches, side ditches, overhead ditches, intercepting ditches, hydraulic drops (including drop chutes and chute spillways), chutes, etc. Underground drainage facilities include open ditches, drainage channels, blind drains of side slopes, trenches, seepage intercepting ditches, infiltration trenches, permeable tunnels, no-fines concrete infiltration trenches, vertical water collection seepage wells and horizontal boreholes.

(2) Subgrade protection

Subgrade protection is divided into two parts: slope protection and scour protection. Subgrade slope protection is mainly set to protect the surface of the side slope of the subgrade from rainwater erosion, reduce the influence of temperature and humidity changes, and prevent or delay

the progress of weathering and spalling of the soft rock surface. Common subgrade slope protective engineering includes protection by plants, spraying and coating, anchoring and shotcreting with wire mesh on the slope, dry pitching, grouted pitching, mortar rubble or concrete framework revetment, and the grouted rubble retaining wall. Subgrade scour protection is the protective engineering designed to prevent embankments of the benchland, riverside subgrades or subgrades in reservoir areas from scouring for the safety and stability of the subgrade. The subgrade scour protective engineering is divided into three categories: slope protection, diversion, and river improvement works.

(3) Subgrade strengthening building

Subgrade strengthening buildings are developed to stabilize the subgrade through building reinforcement structures or other measures. The commonly used reinforcement structures include retaining walls. According to different building materials, calculation theories and structural forms, retaining walls can be categorized into gravity retaining walls and lightweight retaining walls. Gravity retaining walls are developed with dry rubble, mortar rubble, concrete and other masonry. Stone is widely used since it is abundant in quantity locally, enjoys rich sources of materials, and demands little in equipment and technologies. Since the 1950s, due to the rapid development of geotechnical structures like railways, highways, revetments and underground buildings, lightweight retaining walls have been widely used such as anchor rod retaining walls, anchor slab retaining walls, thin walled retaining walls, anti-slide pile retaining walls and reinforced soil retaining walls.

Exercise B

1. Directions: Fill in the blanks with the words or expressions according to the text.

(1) The railway subgrade is mainly composed of _____ and _____.

(2) The roadbed consists of the _____, _____, _____, _____, and _____.

(3) _____ is the soil layer which is affected by the dynamic load of the train and the hydrological and climatic changes in the upper part of the subgrade. Its conditions directly affect the stability and speed of the train. It is divided into the surface layer (base course) and the bottom layer (subbase). The thickness of the surface layer is _____ m, and that of the bottom layer is _____ m, and the total thickness is _____ m.

(4) Side slopes may take on the shape of _____, _____ and _____. In the subgrade engineering, the side slope ratio is expressed as _____.

2. Directions: Explain the following terms.

(1) Track formation

(2) Shoulder

(3) Foundation bed

(4) Side slope

(5) Subbase

3. Directions: Answer the following question.

What are the functions of the shoulder?

Mini-project B

Directions: Work in groups of four. Draw the sketch of the roadbed and mark the slope toe, the height of the embankment side slope and the height of the subgrade center.

Part Three Further Development

Material C

Filling Process of the Filled Embankment Below the Subgrade

The filling process of the filled embankment below the subgrade with sand pebbles (coarse-grained soil) and clay (fine-grained soil) is divided into three stages, four sections and eight steps as shown in Figure 4.

Three stages: construction preparation stage—construction stage—renovation acceptance stage

Four sections: filling section—leveling section—rolling compaction section—detection section

Eight steps: construction preparation—base stabilization—layered filling—paving and leveling—watering and drying—rolling and tamping—inspection endorsement—subgrade renovation

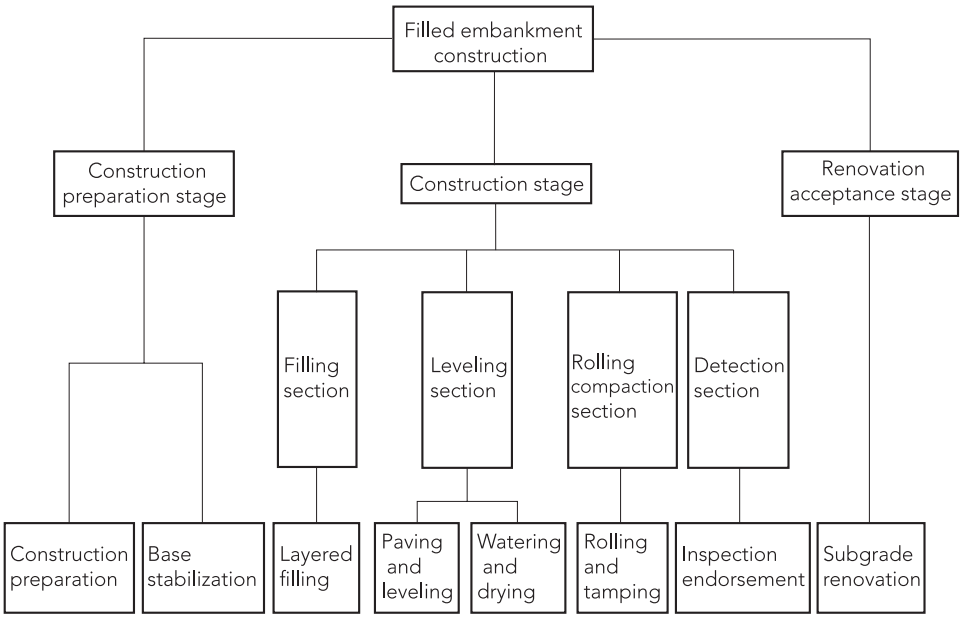


Figure 4 Filling Process of the Filled Embankment Below the Subgrade

1 Construction preparation

In this stage, we mainly carry out the following work: surveying, setting out of route, organizing relevant personnel to learn the design documents and the technical design and construction specifications, preparing construction organization plans according to the fill materials and construction machinery, establishing a geotechnical laboratory and carrying out relevant geotechnical experiments, and preparing the instruments and equipment required by on-site quality tests.

2 Subbase stabilization

The subbase stabilization shall be treated according to the actual conditions of the ground and soil in the construction process, as required by the design documents.

3 Layered filling

The embankment should be filled and compacted in different layers on the full width of the cross section along the longitudinal direction. In order to ensure the uniformity of the compaction degree in the entire section of the embankment and to maintain the compaction quality of the side slope, both sides of the side slope are filled to the level of 0.4 m–0.5 m in excess of the one designed, and the slope shall be flattened. In the process of embankment filling, different fill materials must not be mixed.

4 Paving and leveling

After the unloading of one layer of soil in the filling section, bulldozers are used for the initial leveling and graders for the final one. The filling surface should be smooth in both the longitudinal direction and the horizontal direction, and the main layer should have no significant local unevenness. For a good rolling (compaction) effect, the wheel's surface of the roller should be in full and uniform contact with the ground.

For the water-permeable filler, the drainage slope to both sides should be 4%. While the subgrade is being paved, shoulders shall be roughly compacted to avoid the landslide when the roller is on the shoulder.

5 Watering and drying

Before compacting, the water content of fine-grained soil, silt and the silt filler shall be controlled within the allowable water content of construction determined by the compaction process of the test section. When the water content of the fill materials is low, water should be sprinkled in time. When the water content is high, trenches should be dug to decrease the water in the borrow field, and at the same time the bulldozer and the ripper should be used to loosen and dry the fill materials to reduce the water content. Another method is to transport the filler to the embankment for sun exposure.

6 Rolling and tamping

Before compacting, technical disclosure shall be made to the roller driver. Two sides of the subgrade shall be compacted first and then the middle. In the beginning, the progress shall be slow and later fast, and static pressure imposed first and vibration compaction later. Different districts shall be overlapped and compacted. The longitudinal length of the overlapped section shall not be less than 2 m, and the longitudinal length of the overlapped district of two layers shall be above 0.4 m.

7 Inspection endorsement

Every layer of the compacted subgrade shall be tested by the form of compacting coefficient or the subgrade modulus. The compacting coefficient is determined by the core cutter method, sand cone method, water replacement method, rubber balloon method or nucleon density and humidity tester method. The subgrade modulus K_{30} is determined by the plate loading test. The test results or frequency should comply with relevant

regulations. If the standard is not met, the acceptance certificate shall not be issued, the quality failure notice shall be released and compaction shall be redone until the standard is reached.

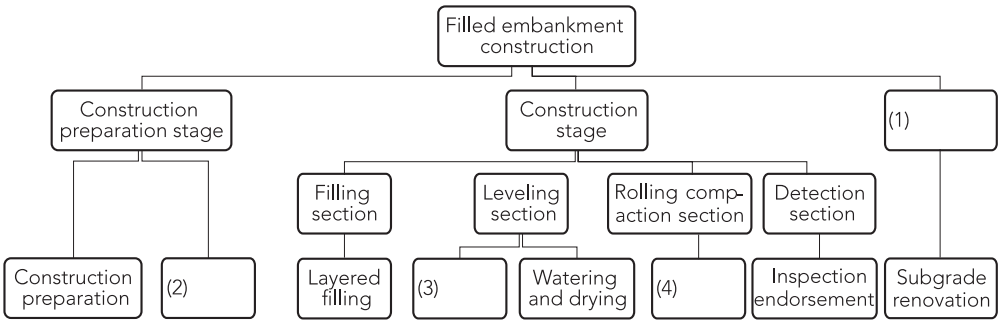
8 Subgrade renovation

Leveling and surveying shall be carried out after the embankment reaches the design elevation. The center line shall be restored and one pile shall be set every 20 m for elevation measurement, leveling height calculation, shoulder pile setting-out, and construction of the camber. The road surface shall be compacted with the roller, and it shall be smooth without loose dirt, and the lateral drainage slope shall meet the design requirements.

The side slope shall be trimmed and compacted in light of the location of the shoulder pile to the extent that the slope is smooth and even, and the standard of the compaction density is met. The renovated side slope shall be clean and clear at the curves, straight at the level surface, and round and smooth at the change points.

Exercise C

1. Directions: Complete the diagram. Fill in the blanks according to the text.



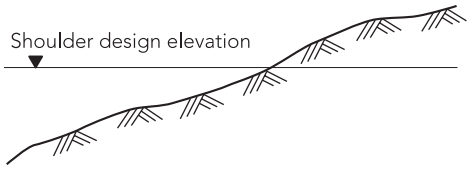
2. Directions: Answer the following questions in your own words.

(1) What sections are included in the construction stage during embankment filling?

(2) What are the requirements during paving and leveling?

Part Four Workshop

1. Directions: Work in groups of four. Discuss and indicate the form of the cross section of the subgrade that shall be employed for each part. Discuss the flow chart of embankment filling below the subgrade and its standards and report to the whole class in turn.



2. Tools: pencils, erasers, rulers, colored pens, A3 white paper

3. Steps:

Step One

The group determines the subgrade cross section form to be used for each section of the railway line.

Step Two

The group draws the subgrade cross section form that should be adopted for each part on A3 paper.

Step Three

Select one group member to explain the subgrade cross section form that should be adopted for each part of this railway line, and elaborate the construction process of and requirements for the filling process of the filled embankment below the subgrade.

Step Four

The lecturer in each group will remain unchanged, and the other three members will study in other groups. Meanwhile, the lecturer in this group will introduce their ideas of completing the task to the members in other groups.

Step Five

The teacher makes a summary.

Self-assessment

Directions: Check the box (☺ , 😐 and ☹) given for each learning objective and tick the one that best matches your performance.

Learning Objectives	My Performance		
	☺	😐	☹
1. know the forms of cross sections of the railway subgrade;			
2. know the composition of the railway subgrade;			
3. understand the construction process of subgrade filling;			
4. grasp the craftsmanship and requirements of the embankment filling below the subgrade.			