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REPORT ON
VARIOUS METHODS OF
FORMATION REHABILITATION
ON RAILWAYS

REPORT NO. GE-39 (FINAL)
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GEO-TECHNICAL ENGINEERING DIRECTORATE
PREFACE

This Report is based on experiences of Railways & Literature Survey on Formation Rehabilitation. The views expressed are subject to modification from time to time in the light of future developments on the subject. The views do not represent the views of the Ministry of Railways (Railway Board), Government of India.

This revised report has been improved a lot with inclusion of 6 new para/sub-para and modifications made in existing para of draft report based on details collected from Railways & suggestions received during discussions. Many a new illustration has been added to make the content more technical and lucid, for the engineers.

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SYNOPSIS

Occurrence of unstable formation due to foreseen or unforeseen reasons is the bane of all railways. Stretches of unstable formation, with or without speed restriction, are potential constraints against utilizing line capacity and introducing heavier axle load traffic. In addition to this, there is huge expenditure involved in maintaining such stretches because of avoidable loss of ballast and the frequent tamping effort.

Various methods have been tried in the past on Indian Railways as well as world Railways to rehabilitate unstable formations satisfactorily. The first report on this subject was circulated to all Indian Railways as draft Report No. GE 39 for their feedback. This revised and final version has incorporated their experiences and examined various other aspects to help in deciding most practical, effective and economical method of rehabilitation.

The report discusses the basic design concepts, links various administrative orders, and gives present and past practices of rehabilitation of formation. It introduces the reader to the developments taking place the world over and the R&D effort being put in at RDSO.

Inclusion of new paras on methodology of blanket laying with mechanical means now available internationally, make this report more relevant to modern times. At the end of discussion, a comparative table has also been included laying down the criteria on which any rehabilitation scheme could be evaluated.

It is hoped that this report will be of help to Engineers in matters of rehabilitation of unstable formation.
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Report on Various Methods of Formation Rehabilitation on Indian Railways

1.0 SCOPE:
This report is based on the studies and feedback gathered by the RDSO over the last several decades of trials of formation rehabilitation over Indian Railways. The report elaborates on methodology of laying blanket layer under traffic conditions, as blanket layer is found to be the most effective technical solution of formation problems. It also draws upon the case studies of rehab. work tried abroad, and the modern technology being employed to achieve reliably good results. In the end, it gives a comparative analysis of various methods available, and affords a choice to the field engineer to take a decision based on the resources at his command.

1.1 INTRODUCTION:

Railway formation may develop instability for reasons of poor bearing capacity of formation, inadequate factor of safety against slope stability, excessive settlement, subgrade attrition due to mud pumping and loss of soil from formation on account of erosion, ants, termites, burrowing animals etc. Formation failure may be on one account or in combination. Existence of one or more of these causative factors may lead to development of others.

The problem of formation failure is quite severe on Indian Railways, owing mostly to poor soil type. More than 700 km track is under permanent speed restriction, and about three times that is put under temporary SR(speed restriction) during monsoon season every year. A brief summary showing Zonal Railway wise break up is enclosed as appendix A.

Formation failure for poor bearing capacity, alone or in combination, comprises most of the unstable stretches (about 95% or so). Increase in axle load & GMT also have a significant effect on bearing capacity of formation. Therefore, strengthening of formation against bearing capacity failure is the most important rehabilitation work.

Among various methods tried in past to improve bearing capacity of formation, laying of blanket has been the most successful. However, it is quite a difficult task to lay blanket on unstable formation in existing track. Therefore, various methods have been/are being tried to find most suitable one to lay blanket.

This report will enlighten the field engineer right from the stage of identification of formation trouble to its causes and remedies, with the options as per the available resources.
2.0 IDENTIFICATION OF FORMATION TROUBLE:

Uneven settlements cause disturbances to track geometry. If this happens beyond certain limits defined either by the envisaged track tolerances or safety considerations, the formation is termed unstable. The perceived severity obviously depends on track tolerances with or without a speed restriction. A criterion for identification of formation trouble has been laid down by the Railway Board vide letter no. 91/CE-II/SF/9 dt 27.7.94 & 3.8.95, depending upon the number of track attentions given. The Board has laid down that a 5-step action plan be followed first before undertaking other rehabilitation measures. The same have been listed below (Ref: letter dt 4.7.91).

- Make the formation width, cess level and side drains strictly in accordance with prescribed profile.
- Carry out shallow screening of ballast section (or deep screening where required).
- Ensure no loose or missing fitting.
- Increase the depth of ballast section to 30cm or even up to 35cm.
- If the problem still persists, increase sleeper density to 60 cm c/c spacing or even upto 55* cm c/c spacing.

*Spacing of 55 cm withdrawn subsequently due to problems with machine packing.

3.0 CAUSES OF UNSTABLE FORMATION AND REMEDIES:

Excessive and frequent disturbance to the levels at rail top may occur to one of the following:

1. Ballast attrition
2. Subgrade attrition and mud pumping
3. Consolidation settlement
4. Massive shear failure and creep
5. Volume change of subgrade due to moisture content variation
6. Frost heave
7. Progressive shear failure from repeated wheel loading.
It is possible to avert and delay failure associated with all these causes. However, the remedies and restoration are comparatively much cumbersome and time consuming. These aspects have been discussed item wise, with different aspects of blanket laying elaborated in greater details, as that has a great potential of averting most of the causes enumerated above.

3.1 **Ballast Attrition:**

In service, the ballast is pulverised under traffic loading, chemical and mechanical weathering degradation and tamping operation. This fouls the ballast bed and the layer loses its elasticity. The levels of the track it supports are disturbed permanently till another round of maintenance is done. The causes can be mitigated by adopting stricter quality control on the new material and fouling by external agents. Timely deep screening operation helps the most.

3.2 **Subgrade attrition:**

Abrasion due to traffic and thermal forces on the top surface of subgrade causes wear of top surface. Moreover, ballast puncture and fine particles from ballast and subgrade create conditions of poor drainage and retention of water at the bearing surface. Ballast layer itself gets checked and track sleepers start moving up and down in grooves leading to suction of fines slurry into the groves and pumping out of the same alternatively with the movement of wheel loads. This condition can be avoided only by deep screening and provision of a separator/filter layer between ballast and subgrade.

3.3 **Consolidation settlement:**

If sub base and subgrade are made up of cohesive soils, consolidation takes place under imposed loads. However, if the sub base soils are properly compacted up to the prescribed level (98% of modified proctor density), consolidation of embankment will not be a major consideration. Consolidation of sub base is to be calculated after testing and will have to be accounted for during construction. However, if due care has not been exercised during construction, there maybe a major maintenance problem to be remedied only by provision of a confining layer.

3.4 **Massive Shear Failure and Creep:**

Due to reduction in peak shear strength parameters under repeated loading, as characterized by the typical stress-strain relationship of cohesive soils, there is large creep strain failure of slopes. In such cases bearing capacity failure also takes place leading to penetration of ballast into the
formation. The failure is avoidable by exercising the right choice of subgrade soil. CH&MH soils are to be avoided for embankment construction. Remedy lies only in rebuilding the slopes after removal of the failed soil. This aspect will be further touched upon in the following paragraphs.

3.5 Volume change due to moisture content variation:
Soils sensitive to moisture content variation exhibit a marked change in volume with minor changes in the moisture content. As such, they may not lack in shear strength and behave well when isolated from the effects of precipitation and evaporation. The distress to track in mostly experienced during dry season when shrinkage cracks of the soil become wide enough to consume large quantities of ballast. Hence, the best remedy against the problems of volume change lies in confinement of these soils within a nearly impermeable layer on all sides.

3.6 Frost heave:
Frost heave is one of the more disturbing causes of the soil instability in the European and Canadian railway systems due to subzero temperatures encountered for long periods. This is essentially due to increase in the volume of frozen water within the capillaries of the soil. Luckily, such frosty conditions do not occur over Indian subcontinent railways. Studies have established that silts are the only susceptible soil group and if covered with a designed layer of granular material the effect of frost can be minimised.

3.7 Progressive Shear Failure under dynamic loading:
Stresses imposed on the subgrade top by the axle load may be large enough to cause a progressive shear failure (general shear failure). This condition is most likely to occur on the top most part of the subgrade where the effect of the imposed live loads is the greatest. Repeated imposition of axle loads (known as dynamic loading) causes cumulation of strain in the soil. If the imposed stress is higher than a threshold limit, such cumulation is very rapid and the soil fails to carry the load safely. (Fig 1). During the research conducted over RDSO and IIT Kanpur, it has been possible to establish a concept of threshold stress for cohesive soils, and a design theory based on this concept. Simply put, the design of embankment has to cater to limit the imposed stresses on top of the subgrade to below the threshold stress of the soil (Ref RDSO's TM -54).
4.0 FORMATION DESIGN PHILOSOPHY:

4.1 OVER INDIAN RAILWAYS:

Indian Railways have broadly accepted a rational design philosophy based on the concept of threshold stress of cohesive soils. However, no design calculations are done for individual soils, and the blanket layer thickness is pre decided as per the soil type. All soil types are divided in four groups, which may be provided nil, 45 cm, 60 cm or 100 cm thick layer of blanket depending upon plastic content and/or particle size gradation of the former. CH and MH type of soils are to be avoided for embankment construction. (Details in Annexure 2).

4.2 WORLD RAILWAY PRACTICES OF FORMATION DESIGN:

World over, in all the major Railways, formation designs are based on layered construction. Besides having a designed sub-grade, the top layer of formation just below the ballast, has to qualify either the modulus of elasticity, CBR or bearing capacity criteria.

Literature survey carried out to understand about latest practices regarding provision of blanket being followed by different World Railways. In brief, the position is as follows:

a) **Japan National Railways (JNR), 1980s**, provide 3.0m high upper embankment of good quality soil. Out of it, top 25 to 75cm mechanically stabilized crushed stone layer & above it, 5cm of asphalt concrete layer are provided. These provisions are for track having GMT more than 2 and speed more than 100 kmph.

b) **American Railways (AREMA Manual, 2002)** provide 30cm thick sub-ballast above minimum 4 ft.(120 cm) of good quality of top soil layer (Plasticity Index < 12) for main track. However, there is no mention of speed, load & GMT of traffic.

c) **International Union of Railways (UIC),1994** have concept of providing prepared sub-grade of which thickness varies upto 50cm for type of soil used in construction of embankment & class of bearing capacity required. Over this prepared sub grade, ballast + sub-ballast of about 50 to 80cm along with geo-grid are provided for various combinations of axle load, GMT, speed & type of route.
4.3 MODERN TRENDS IN FORMATION DESIGN:

Formation has been identified as the single most important component of the technical performance of a Railway system. A lot of research is now being put in search of such problems as, zero maintenance, acoustics, damping of vibrations and higher life cycle performance of track components. There is a revival of interest in Railway systems for suburban transport, which have their own set of requirements of aesthetics and maintainability. Some of the new developments in formation designs are placed on the opposite page for appreciation of the reader.

5.0 REHABILITATION OF UNSTABLE FORMATION:

Development of unstable formation is preventable in all the cases by proper designing and execution. Almost all the causes leading to formation instability have been discussed in para 3 above. However, either due to lack of knowledge or considerations of economy, formation construction did not receive the attention it deserved. Moreover, increase in axle loads and the GMT have put that addition stress on the formations that might have been in conceivable at the time of construction. So multitudes of solution had been tried for rehabilitation of failing formations over Indian Railways. Some of them provided a short-term relief. However, since most of them aimed at symptomatic relief, they were bound to fail in the long run. A comprehensive list of these measures tried in the past is given below. Moreover, the subject calls for further trials and research, which have been summarized below.

5.1 METHODS OF REHABILITATION TRIED AND ONGOING TRIALS:

Development of unstable formation and thereafter, its rehabilitation, is taking place since long. The methods of rehabilitation which were tried in past and have not shown the desired improvement in the long run ( >10 years), over Indian Railways are given below. Some of these techniques are still prevalent on some of the World Railways, owing to their peculiar position in terms of traffic or quality control. However, the more popular methods with almost universal acceptance will be discussed later in this booklet.

5.1.1 Lime Pile & Lime Slurry Pressure Injection:

This method was used for bearing capacity failure and/or excessive swelling & shrinkage of soil. It doesn't help, as there is no change in mineral composition of soil and lime is leached out due to rains. It was reported that the effect is felt only for 3-4 years. RDSO are generally not
recommending this method any more. (RDSO's letters No.RS/G/72 dated 28/11/86 & RS/F/53 dated 18/9/92). Example: at locations km 1/1-15/7, 41/11-42/1 etc in patches; Panskura - Haldia section; S.E.Rly.; year 1991-95.

5.1.2 Ballast Piling:
It further weakens the strength of formation as holes dug in the formation collect lot of water which has no passage / means to go out. Boring of holes through ballast & pockets filled with ballast (formed in unstable formation) is also not possible.

5.1.3 Cement Grouting:
It dose not help as only localized lumps are formed making soil mass further heterogenous in character. There is no change in chemical characteristics of soil. Example: km 364/3-10; Up Line; Section ,Baptala-Tsunduru; S.C.Rly; year 1977.

5.1.4 Cationic Bituminous Emulsion:
It is neither useful nor available also.

5.1.5 Vinyl drains:

5.1.6 Open cross drains filled with coarse grained material:
It causes more damage than being useful. Drains taken upto toe of embankment did not succeed as the coarse material filled in drain was washed away. Example: location : km 431/2 (40m), between stations Mankatha & Barhiya, Danapur Division, E.Rly.; year 1992 ; speed restriction- 70 kmph.

5.1.7 Sal Balli/Sleeper/Rail Piling:
This method has been tried at number of places specially to prevent slope failure. However, it has been total unsuccessful for its extremely insignificant capacity to provide resistance against movement force of comparatively very huge soil mass (RDSO's report no. SMR/Consultancy/SC/12/1989). Example: km 360/2-4 , UP line, between stations Bapatla & Tsunduru; S.C.Rly; year 1972.

5.1.8 Layer of laterite block:
This method has been tried by SE Railway in year 1989-91. Reservations were expressed (RDSO's letter No.RS/G/72 dated 12/12/89) about its usefulness for reasons of increase in water content of sub-soil, as explained in para 4.9 below, and inadequate thickness (125 mm and 250mm against requirement of 450mm) of laterite layer. Example: km 15/11-17, 26/1-6, 28/7-29/3; Panskura-
5.1.9 **Polyethylene and other similar impervious sheets:**

For its being impervious to water, there is increase in moisture content just below them for non-evaporation of water moved up by capillary action. This increase in moisture content causes reduction in shear strength of soil leading to failure of formation (Fig. 2) (RDSO's letters no. RS/SE/1 dt. 29.5.80; no.RS/G/72 dated 28/11/86). Example: location : km 287/12-28, Rajkharsawan-Sini ; S.E.Rly ; year 1968.

5.1.10 **Geotextiles:**

Rehabilitation of formation using non-woven textiles was tried over Northern Railway, and studied systematically by RDSO. (RDSO's CE Report no. C-261, Nov. 1989 on "State of the Art- Use of Geotextile In Railways" & RDSO's letter no.RS/F/57 Vol-VI dt 5/2/90. Location : km 1114/15 (20m) , DN line, Sandila-Lucknow Section, N.Rly.). The work done 12 years ago was very limited and it was concluded that geo textiles alone do not add to the strength of formation. (Fig. 3). However, geogrid can be tried to reduce the designed blanket thickness. Geogrids etc. at present are costly materials; therefore, it should be used wherever found financially justified. RDSO are in the process of studying this subject further (see para 11.2).

5.1.11 **Geojute with sand layer:**

Trials of laying Geojute along with blanket layer have been done in Eastern Railway. However, geojute being a biodegradable material, is considered unsuitable for any other work except for erosion control measures depending on rainfall, nature of soil etc. Jute Manufacturers' Association has come up with polymer coated jute material with enhanced life. They have also claimed improvement in drainage characteristics of embankment treated with a layer of geo jute. These may be matters of further research.

5.2 **METHODS UNDER STUDY/TRIAL:**

5.2.1 **Partial Blanketing**:

The method consists of replacement of heaved up soil on the cess and the slopes by a well graded compacted fill material (referred to as blanket material). It may be provided to take advantage of penetrated ballast and reduced block requirement. It works on principle of increasing counter weight on cess, as does heaved up cess (Fig. 4). However, it would be effective only when ballast penetration has stabilised for present axle load & GMT. Needless to say that pre-requisite for its
success is a stable bank or cutting as the case may be (RDSO's letters No.RS/E/2/III dated 5/10/87 & RS/G/72-ER dated 7/10/90).

5.2.2 Widening of Embankment:

Adequate cess width is not only required from maintenance consideration but also it helps to improve factor of safety against shear failure by increasing confining pressure as explained in Fig. 13a. Normally, **when third line is constructed, the formation problem of middle line disappears.** Example: Howrah – Burdwan Chord line had formation problem on UP & DN both lines. After construction of third line by the side of existing DN line, formation problem of this line (now middle line) has almost disappeared. However, formation problem still continues on UP line. Ballast penetration profile at km 36/15-21 of up line (fig. 5) clearly indicates that ballast penetration is basically below cess side rail for inadequate formation width as there is slope disturbance (existing 1.65:1 against original 2:1).

5.2.3 Combination Trials:

A combination of partial blanketing by widening of embankment along with replacement of heaved up soil from the cess, is being tried at a couple of locations. The Railways are yet to submit a report on the efficacy of these trials. (GE-36, for SC Rly. Itikyala- Kurnool Town).

5.2.4 Other Studies and Research:

Although, research has established the relation between thickness of blanket layer and subgrade strength, the experience of laying blanket in either new or rehabilitated formations over Indian Railways is rather small. Therefore, this shortcoming is being made up by conducting experimental means. The following studies are in various stages of formulation:

- Finite element analysis of various designs of formation.
- Centrifuge testing of various models of formation design and rehabilitation.
- Efficient use of geogrids and geocomposites for formation rehabilitation.
6.0 FULL WIDTH BLANKETING - A SUCCESSFUL METHOD OF REHABILITATION:

A layer of coarse granular material properly compacted is termed as a blanket layer. Theoretical studies have shown that a layer of designed thickness and properties can reduce the stresses transferred to the sub-grade layer to safe levels, known as threshold stress. Different world railways have tried to approach the same solution in different ways. UIC have talked about it as FSG (formation sand and gravel). This is the only method, which is universally acceptable to the World Railways. In fact, all unstable formations in World Railways have since been eliminated long back by laying of blanket of one or more specified materials in suitable thicknesses. A layer of blanket, alongwith the overlying layer of ballast are collectively termed as 'track foundation'. Some Railways provide a mandatory layer of geotextiles. However, this is a design feature and no codes of practice are available as yet. A structurally stable embankment or cutting are a necessary precondition to any formation rehabilitation proposal.

6.1 REHABILITATION PRACTICES OVER WORLD RAILWAYS:

Studies conducted by UIC have been reported in report no 722. They have categorized the methods in three categories:

a) Formation improvement with formation sand and gravel
b) Formation improvement with formation sand and gravel (FSG) and geotextiles.
c) Formation improvement by laying treated material (only from frost consideration).

The above methods have really become popular, and various papers have appeared in the international journals, lauding the experience with FSG (blanket layer), over Austrian, Polish and other Railways. The highlights of such a rehabilitation work are:

i) Graduated grain mixture composed of coarse sand and at least two grades of gravel. The graded gravel should be washed so that the portion of muddy substances is as low as possible;

ii) At least 90% broken grain, surface broken on all sides (for rounded grain, portion of broken surface at least 70%);

iii) Grain size distribution as per the chart (similar to Indian Railway specification), portion < 0.02mm no more than 3%;

iv) Supply of granular material by only technically approved firms.
Most of the Railway systems have adopted only the machine-based methods for laying a blanket layer for formation rehabilitation.

6.2 REHABILITATION PRACTICES WITH BLANKET LAYER OVER INDIAN RAILWAYS
Overwhelming advantages associated with laying of blanket layer have now been accepted by Indian Railways also. Different methods for laying blanket under traffic conditions have been tried over the years, which are highly manpower intensive and slow. Relative merits and brief description of these schemes has been given below. Some of the mechanical means tried abroad during the evolution of modern machines are also discussed with the purpose of giving a wider perspective.
A tabulated summary at the end of discussion is also given as Table 1.

7.0 PROPERTIES OF BLANKET MATERIAL:
The following paragraphs discuss the importance and specifications of blanket material, as there are widespread misconceptions prevalent in the field regarding this subject. The principles and the concepts are generally valid both for 'New Constructions', as well as 'Rehabilitation' activities.

7.1 FUNCTIONS OF BLANKET:
A layer of coarse-grained blanket helps to:

a) Bring imposed stress (induced stress) caused by repetitive loading within permissible stress (threshold stress) in formation to prevent permanent /plastic deformation in subgrade,
b) Reduce thickness of ballast to minimum requirement of maintenance,
c) Improve resiliency & energy absorption of moving load , and
d) To act as separation layer between ballast and sub-grade to prevent percolation of water to soil and mud pumping.
e) Almost eliminate the variation of moisture content in subgrade soil below it.

7.2 SPECIFICATION OF BLANKET MATERIAL:
In order to perform the desirable functions as described above, the blanket material has to pass through a strict qualifying criteria of grain size distribution etc. Detailed specifications are given in the Annexure 1.
7.3 SELECTION OF BLANKET MATERIAL:
Blanket material of desired properties is to be selected carefully, after a thorough survey of the project area. The chosen material could be natural (from hill or river quarries), or manufactured. It could be by-product from a crusher, or bottom ash of a thermal power plant. Blending of either natural or manufactured materials could also produce the blanket material. Crushed stones blended in the proportion have the best-desired properties.

7.4 MACHINE MANUFACTURED MATERIAL:
When it is not possible to locate a reasonably economic source of blanket material, trials for either crushing sound rock material or have a blend of 2 or more crushed or natural materials are to be made. A study of Indian markets/industry has shown that it is possible to produce controlled quality material at an extra cost of less than Rs. 100/- per cum. This aspect must be clarified in detailed estimates of the project, as well as in tender documents. Machine manufactured blanket is the best guarantee of assured quality. Specification No.IRS-GE-2 may be followed.

7.5 DEPTH OF BLANKET LAYER:
Depth of blanket layer of specified material depends primarily on type of subgrade soil and axle load of the traffic. Based on research, it has been decided to have four different categories of soil types for new constructions (para 4.1). However, for rehabilitation works, the depth of blanket will depend on the rehabilitation technique/methodology or access to technology on a given project. In any case, a layer less than 30 cm. thick not accompanied with properly designed geo grids may not be of any help.

8.0 METHODS OF LAYING OF BLANKET:

Laying of blanket under running traffic has always been a challenge to Railway Engineers. Therefore, various methods have been tried in past/are being tried at present to carry out work of blanket laying in cost-effective manner. Some of the methods are as follows:

a) With Aluminium Alloy Girder
b) Track Dismantling Method
c) With manually operated portals.
d) With CC crib & rail clusters (SE Railway Method)
e) With rail Clusters (Eastern Railway Method)
f) Lifting of track with deep screening.
g) Fully mechanized methods tried over the World Railways.
8.1 ALLUMINIUM ALLOY GIRDER METHOD:
Laying of blanket with Al. Alloy Girder has been explained in "SPECIAL REPORT NO: GE-27 FEB –1999" issued by GE Directorate/RDSO. Work has been executed with this method in Wadi-Nalwar section of S.C. Railway. Solapur division of Central Railway and Delhi division of Northern Railway have also started work with this system, though the progress is very slow.

8.1.1 Brief Description:
The method consists of use of a prefabricated lightweight Al alloy girder for relieving the formation. The details of which have been explained in report no. GE-27.

i) Pre block operations:
- Blanket material is collected in advance.
- OMC & MDD are established.
- Side slopes of embankment are cut upto 1.0 m below the cess level.
- Girder is assembled and placed along side.

ii) Under block operations:
- Rails, sleepers and ballast are removed as per size.
- Excavation to facilitate insertion of crib of size 4.2m*1.5m is done.
- Cribs with wooden sleepers etc. are placed.
- Al alloy girder is placed after cutting the formation.
- Track is linked over the girder and restored to traffic.

iii) Post block operations:
- Formation is cut to desired depth And a camber of 1:30 provided.
- Blanket material is placed in layers of 150 mm adding pre determined quantity of water. Compaction is carried out with plate vibrators. Layers are built up upto the bottom of girder. The last layer is hand rammed from the top to the extent possible.

iv) Methodology of progression:
- The above operations are simultaneously carried out at 5 locations 24.0 m apart.
- After completing one location, girders are shifted to the adjacent location.
- Blanketing of crib location is done during traffic block taken for shifting the girder.
A schematic diagram is placed as Annexure 4.

8.1.2 Progress:
The progress being achieved will depend on the manpower deployed. Around 15 m per day may be easily achievable with a set of 5 girders.

8.1.3 Cost:
The cost of work including consumables is around 32 lakhs per km. (Annexure 3).
Details of working with other methods are elaborated, as following, based on Railways' working reports.

8.2 TRACK DISMANTLING METHOD:
The method consists of dismantling a portion of track under traffic block and removal of ballast and weak formation layer and replacement with blanket layer and reconnection of track on ballast.

8.2.1 General
Work with this method has been carried out in Secunderabad-Wadi ‘B’ route section (between Malkhaid Road & Chittapur stations) of S.C. Railway. Work commenced in May 1999 and completed 2.35-km length by May 2000.

8.2.2 Traffic pattern of the section
The section has traffic density of 18.04 GMT. Only 10 passenger / express trains pass this section in the evening hours and accordingly, blanketing work was planned under line block of 10 to 12 hrs a day.

8.2.3 Execution of work
i) BEFORE TRAFFIC BLOCK
Decide longitudinal level & select blanketing material (including required moisture content & density), lay single rails if higher length panels exist, provide ramps on to the bank for movement of tippers to carry blanketing material etc. & remove shoulder ballast.

ii) DURING TRAFFIC BLOCK
a) Lift single rail panels and remove balance ballast with excavators.
b) Excavate formation to required depth with excavator.

c) Roll the formation providing 1 in 30 cross slope in one direction.

d) Spread blanket material to optimum thickness for full formation width + 50 cm on cess side(s) to facilitate compaction.

e) Compact blanket material (being granular cohesionless & well graded) with vibratory roller to achieve min. 70% relative density (IS code no: 2720 (Pt 14 - 1983).

f) Spread ballast & put back track panels (kept on slope of bank).

g) Attend track and allow traffic.

iii) AFTER TRAFFIC BLOCK

a) Dress side slopes. Provide turfing if blanket material is erodable.

8.2.4 Cost

Cost of execution was in range of Rs. 28-30 lakh per km.(Annexure 3).

8.2.5 Progress

Progress of laying of blanket was in range of 55-60m per day. Work can be taken at more number of sites in shadow block.

8.2.6 Quality

There is no constraint in achieving good quality of work.

8.2.7 Flexibility in execution

Depth of excavation of formation & lifting of track both can be carried out to the requirement of site. Similarly, any thickness of blanket also can be laid. It can be adopted in any type of track structure, electrified or non-electrified. Only requirement is that site should be approachable to bring machinaries and space available to keep track panel, blanket material etc.

8.3 WITH MANUALLY OPERATED PORTALS

8.3.1 General
This method was developed by S.E.Rly in year 1997 over Urkura-Sarona section on Howrah-Mumbai Gr A track at km 826/23-25. Lifting of track panels from track and later on placing it back are being done with manually operated portals. Traffic blocks of 3.5 hrs were availed for 2 days.

8.3.2 Fabrication of Portals

a) It is fabricated in Engineering Workshop using a standard dip lorry and 2 nos. of 3.0t chain pulley blocks available with BRIs.

b) Twin channel of the standard dip lorry is cut at two places to separate two wheel-sets. On the left over channel with the wheel set, short channel pieces, at right angles to it, are welded to increase clearance between rail level and main cross channel of the portal. This is also to take care of sag of panels while lifting panels and to enable to stack two removed panels, one on the other, on approach of track. A twin channel of length 3.85 m long is bolted to the channels welded on top of the wheel sets. On top of the channel, a pre-fabricated cuboidal frame is bolted from a 42 mm rod supported on the frame and 3t capacity chain pulley blocks are hung. Details are given in fig. 1

c) Thus, the portal is assembled with its 7 main components (i.e. wheel sets 2 Nos, main twin gusseted channel 1 no, cuboidal framed 2 nos. and chain pulley blocks with supporting rods 2 nos). Bolting of the members can be done by 8 men at site in less than five minutes, with suitable spanners.

8.3.3 Execution of work

i ) ADVANCE OPERATIONS

Collection of blanket material, making of standard width of cess & proper bank slope (2:1) to facilitate excavator to work with one side wheel on cess, linking of auxiliary track at 3.4m gauge (similar to PQRS working) and making of single rail panels (if LWR/SWR exists) are done in advance.

ii ) BLOCK OPERATIONS

a) Re-assemble portal on auxiliary track and lift single rail panels and place them on approach track.

b) Operate excavator to remove ballast & dig formation to width of 3.0m.

c) Dress the formation manually.
d) Fill the excavated trench with blanket material. Level the blanket layer manually & compact.

e) Spread ballast & place back panels with portals.

8.3.4 Limitations of the method

a) Only rail panel handling work is done by the portal. The auxiliary track causes obstruction in free working, using of suitable rollers for compaction of formation & blanket & making 1 in 30 cross slope etc.

b) Height of bank should be upto 2.0m.

c) For space constraints in cuttings, it is not possible to be used.

d) Cess width should be increased to about 3.8m from center of track to facilitate movement of loader.

e) Blanketing layer for remaining formation width would be carried out subsequently. This will create discontinuity in layer.

8.4 WITH C.C.CRIB AND RAIL CLUSTERS

8.4.1 General

S.E.Rly. has developed this method to lay 50 cm thick blanket under running traffic without traffic blocks. Work has been done in Kamptee Yard line.

8.4.2 Principle of working

Rail cluster is used to relieve the small patch of track. One end of the rail cluster is supported on single layer of 12 ft long C.C. Crib and the other end is supported on wooden sleepers put across the track. The formation below the rail cluster and just in front of C.C. Crib is excavated upto bottom level of CC Crib. The CC Crib as well as rail cluster are moved forward leaving behind a gap in the formation which is immediately filled up with blanketing material. Details are shown in Annexure 5

8.4.3 Required arrangements & its assembly

Materials required for the work are: one pair of CC Crib, one set of 2 clusters each of 3 x 90 R rails 10 ft long, steel plates, a few wooden sleepers and steel bearings, sheets, bolts etc.
Assembling:  a) **2 C.C. cribs** are bolted together by means of high tensile nuts and bolts and covered all-round by thin steel sheets, except in the back side and at the bottom, where thicker plates of 3 mm and 5 mm are provided for better load bearing characteristics.

b) The **rail clusters** of 3 x 90R rails 10ft long is a standard CE’s drawing and can be adopted upto a span of 10 ft on B.G. track with 20 kmph speed restriction.

**8.4.4 Execution of works**

a) Traffic block of 30-45 minutes is taken. Ballast is removed and formation is dug to desired depth and size to accommodate one pair of CC crib.

b) Rail clusters are inserted below the sleepers. These are kept on the top of the C.C. Cribs at one end and on the wooden sleepers at the other end.

c) The block is cancelled after supporting the track properly over rail clusters. Speed restriction of 20 kmph is imposed immediately thereafter and traffic is allowed to pass.

d) The work will proceed against the direction of traffic.

e) Remove the ballast from in between the sleepers. Dig the formation in front of CC cribs and below the rail cluster for 2 ft depth x 2 ft length and 12 ft width i.e. 6 ft on either side of center of track.

f) Push the CC Crib forward by 1 ft by means of ropes, manually. This will leave a gap of 1 ft behind the CC Crib.

g) Before laying the blanket, geo-synthetic material if required, is spread in the gap as shown in the figure-2.

h) Blanket material, kept ready in gunny bags by the side of track, is poured in the formation dug space left behind the CC Crib and the gap is filled.

i) The blanket material is topped upto sleeper level where it is left for compaction under traffic.

j) While this process is going on, a further cut in the formation in front of the CC crib is made for further movement of CC crib forward.

k) The process is repeated in a cyclic manner.

l) The rail cluster is shifted forward by means of rope at suitable interval by incremental method.
8.4.5 Other aspects

a) At a time, 5-6 sets of such rail clusters and CC Cribs can be inserted to expedite progress.

b) In the present method, the compaction is achieved by the movement of trains itself.

c) The ballast removed during execution of the blanketing work is screened and inserted back in the track after removal of top layer of the blanket or resorting to lifting of track.

d) Blanket laying work is done with cutting of formation about 50 cm and / or partly lifting of track as per site conditions.

8.4.6 Advantages

a) Capital cost involved is hardly anything as all the materials are available with the PWI and BRI within the Division itself.

b) Requirement of traffic block is, minimum 30-45 minutes, taken only in beginning of work.

c) Depth of blanket layer is ensured even with slack supervision because unless proper depth of formation is dug, (equal to the depth of C.C. Crib), the C.C. Crib cannot be pushed forward.

d) At a time, 4-5 sets of rail clusters and CC Cribs can be inserted and used at a work site simultaneously over a stretch of 250 to 500 m length of track to expedite progress.

e) Safety of the running train is ensured at all point of time.

8.4.7 Scope for further improvement

a) Compaction of top of subgrade soil at 1 in 30 cross slope should be done.

b) Strengthening/modification in support system to facilitate work on single lines also where traffic moves in both directions.

c) Movement of CC crib is a difficult task. Its movement over roller on foot of rail or some other suitable facility should be developed.

d) Activities of excavation of formation, pulling of C.C. crib, compaction etc. could be mechanised to improve progress & quality.
8.4.8 Performance

Work should be executed on main line & for longer length, say 3-5 km or so to evaluate its overall performance.

8.5 WITH RAIL CLUSTERS

8.5.1 General

E Rly has developed this method. It has been tried for laying of 50cm blanket on Howrah - Bardhman chord line, in km 31/15 –21. This line was opened in year 1917. The basis being relieving of formation on rail clusters resting on the sleepers provided on the sides.

8.5.2 Arrangements for execution of work

Materials used are rails, wooden sleepers, clamps etc. Operations involved are as follows:

a) 2 Nos. of standard size wooden sleepers are placed along the track on both sides of the track at 5.5m distance of their inside faces.

b) 5 Nos. rails of 6.5m lengths each to make one rail cluster is placed in position & clamped together at both ends. These are laid over wooden sleeper supports in every alternate sleeper spacing.

c) The level of rail cluster is adjusted by packing of wooden sleeper supports. To provide firm contact between top of rail clusters & bottom of running rail flange, wooden wedges are driven between them.

Details are given in Annexure6

8.5.3 Execution of work:

a) Collect adequate number of rail pieces ( suitable for 20 nos. rail clusters ) at site along with the materials required for blanketing.

b) Impose speed restriction of 20 kmph.

c) The location of blanket laying should be isolated from the approaches by cutting the rails on both ends. De-stress the track, if required so.

d) Impose speed restriction, remove ballast from the inter-spaces of sleepers and from the shoulder portion and place wooden sleepers along the track on both sides at a suitable distance.

a) Insert two sets of rail clusters in alternate sleeper spacings. The rails are inserted separately one by one. Once all 5 rails are inserted they are clamped together.

b) After placing the rail clusters, the wooden sleepers are packed so that the rail clusters provide firm support to the running rails.
c) Remove remaining ballast and earth within an area of 1.2 m (length) x 4.0 m (width) & upto a depth of 800 mm below bottom of the sleepers.

h) Provide wooden shuttering on vertical faces of trench to prevent intermixing of blanket material with earth.

i) Lay blanket in two layers of 25 cm thickness each & do compaction with vibrato rammer.

j) Place ballast, do packing.

k) Rail clusters are left at site till the settlement of track stabilizes. Packing is done to lift the track every time rail touches the rail cluster, so that bottom of rail remains 10 –15 mm above top of the rail clusters.

l) Work proceeds in both directions as mentioned in figure 3 i.e. after space 1 to space 2, 3 etc.

8.5.4 Considerations for further Improvement

a) Execution of work is in compartments of about 1.2m length. Continuity of blanket layer has to be maintained by compacting in overlapping length.

b) Blanketing for full formation width will require execution of work when support sleepers & rail clusters are removed. Thus, there will again be discontinuity in blanket layer. Additional precaution is to be taken to maintain continuity & proper compaction.

c) Scope of mechanization in excavation of formation, placement of blanket material & ballast should be explored to expedite progress.

8.6 LIFTING OF TRACK INCLUDING DEEP SCREENING METHOD

8.6.1 General

With deep screening method, ballast and soil below sleeper for 300 mm are removed. This depth is filled up with blanket material. Thereafter lifting of track on blanket material is carried out depending on requirement. Further lifting is carried out on 300 mm ballast.

This method is most commonly used on Indian Railways. Some of the sections/locations in which this work has been/are being executed are: Sirpur Town – Vempalli and Manikgarh-Gad Chandur sections in S.C.Railway, no of locations in Jabalpur Division of Central Railway, Chennai – Arakkonam & Aakkonam – Tiruttani sections in Southern Railway and Cuttak – Paradeep and Bhadrak – Cuttack sections in South Eastern Railway.
8.6.2 Methodology of execution

a) Methods of deep screening and lifting of track as prescribed in IRPWM are to be followed.

b) Excavated earth below 300 mm of bottom of sleeper for full formation width may be used for bank widening.

c) Extent of lifting of track will depend on
   i) Extent of sag in track to remove longitudinal unevenness,
   ii) Depth of ballast penetration which forms part of blanketing and
   iii) Obligatory points such as approach of Girder Bridge, point and crossing etc.

d) In case lifting of track over blanket material is not possible, then also minimum lifting of 300/250mm to provide ballast cushion would be required, so that minimum 300 mm uniform blanket support is available.

Step by step execution of the work is explained in Annexure 7.

8.6.3 Other aspects

a) There is no requirement of traffic block or any other special infra-structural arrangement.

b) Lifting by 40-50 cm is normally possible even in electrified sections with/without adjustment of OHE & elimination of sags for track settlement on unstable stretches.

c) Deep screening of 30 cm & filling with blanket material will help to recoup ballast, improve drainage from ballast pockets, increase counter weight on cess to strengthen against cess heaving, decrease porosity of ballast pocket, thereby, less water retention in pocket as well as significantly reduction in water evaporation leading to almost no variation in moisture content of subgrade soil & provide uniformity of support.

d) In this method, thickness of blanket can be further increased if there is further settlement of formation for inadequate thickness of blanket and/or increase in axle load.

e) Wherever lifting to required extent is not possible, laying of geo-synthetic material may be considered in consultation with RDSO.

f) In non-electrified section, this is the most suitable method.

g) Blanket material used in deep screened portion & thereafter for lifting will get mixed up below with the penetrated ballast and make it quite effective blanket layer.
h) Only routine maintenance works are involved in this method. Therefore, it can be adopted simultaneously at no. of locations.

8.6.4 Limitations

In approach of girder bridges, points and crossing etc., if lifting of track is not possible, suitable ramp has to be provided.

8.6.5 Cost

Cost of execution is the least, may be in range of Rs 15 – 20 lakh per km for 40 cm lifting. Compaction of blanket material is achieved in the most natural way by traffic movement itself.

8.6.6 Progress

There is no limit of progress, as it will depend on no. of labours engaged & no. of sites being operated. If traffic block of even 2 –3 hrs can be availed, extent of lifting can be increased & thus the progress will improve a lot.

8.6.7 Quality

Time is the only constraint, as the work is done under a severe speed restriction.

8.6.8 Flexibility in execution

Depth of excavation of formation & lifting of track both can be carried out to the requirement of site. Similarly, any thickness of blanket also can be laid. It can be adopted in any type of track structure, electrified or non - electrified section. Even in sections, which are not approachable to road, blanket material can be brought by ballast train and unloaded in section. However, advance preparation of removing of ballast, to extent possible, from the track should be done which will be used later.

8.7 FULLY MECHANIZED METHODS

8.7.1 Almost all the world railways rely completely on laying blanket layers using mechanical means, collectively known as 'Formation Improvement (FI) with Formation Sand and Gravel (FSG)'.

Some of the methods employed by European railways are listed below, followed by brief description. Some of these processes might have become obsolete due to development of better/faster machines. Salient features of machines have been separately discussed in Annexure 9:

- Laying of FSG by earth moving machinery for less than 100 m.,
- Laying of FSG by earth moving machinery in longer sections,
- Laying of FSG by track laying machines,
- FI using ballast screening machines (BRM),
- FI using PUSCAL II train,
- FI using PM200/AHM800R/RPM2002 formation rehabilitation machines.

8.7.1.1 Laying of FSG by earthmoving machinery in short sections of less than 100m.

- After the track has been lifted, the ballast and formation material are excavated with the aid of earthmoving machinery. If the excavated material cannot be laid at the side, it is loaded to wagons on the adjacent track or on to lorries. If neither of these options is available, intermediate trackside storage will be necessary. When the track is restored, the material can then be loaded on to wagons.
- The FSG and ballast are similarly unloaded from an adjacent track or from lorries. Here too, the material can be held in intermediate storage before track removal.
- Once the materials have been laid and compacted, work commences on the track.
- Filling-in, tamping, lining and welding complete the work.
- On double-track lines where a greater thickness of FSG (more than 50 cm) is laid, the length of working sections is limited by the stability of the adjacent track.

Annexure 8(i) shows the flow chart for formation improvement in short sections.

8.7.1.2 Laying of FSG by earthmoving machinery in longer sections, exceeding 100m.

- In principle, the working method is identical to that described under 7.7.1.1, but with the longer sections it is more economical to undertake track lifting and replacement using high-speed track relaying machine.
- Because of the larger quantities of material to be removed and laid (~ 1000m³ for 120 m FI), this method is best applied to double-track lines, with use of the adjacent track.
Annexure 8(ii) shows the flow chart for formation improvement in longer sections.

8.7.1.3 Laying of FSG by track laying machines
- With this working method, it is possible to install a layer of FSG without track removal and replacement. If the track is removed and re-laid, a better quality of finished work is achieved.
- The method may be broken down into the following stages:
  - Total excavation by ballast screening machine in several passes as required. The excavated material is partially stored alongside or loaded on hoppers (e.g. to MFS 40 units),
  - Leveling of the formation,
  - If a geo-textile is being laid the track is lifted, the geo-textile placed in position, and the track replaced,
  - FSG unloaded from sell-discharge wagons and distributed to the necessary level by a ballast regulator with suitably-adjusted leveling equipment,
  - Lifting of the track panel by tamping and lining machine (SRM) and compaction of the FSG beneath the sleepers (enlarged tamping pick),
  - FSG compacted in the sleeper cribs by special crib consolidator, and in the cess by vibrator roller,
  - Ballast discharged from self-discharge wagons and spread; track lifted, tamped, lined and re-welded.
- Preparatory work to be carried out includes:
  - Raising the ballast shoulders, so that the BRM covers the complete ballast cross-section.
  - Lowering of the cess to ensure trouble-free drainage of the formation.
- If the track is removed and re-laid, it is possible to produce a FSG surface with a perfect horizontal and longitudinal profile, which can then be compacted to the required standard using a vibrator roller.

Annexure 8(iii) shows the flow chart for FI using a track laying machine.
8.7.1.4 Formation improvement using ballast screening machines (BRM)

- Formation improvement by ballast screening machine makes possible the laying of a protective covering (PFC) of formation sand and gravel to a max. depth of 20cm and a width of 3.80m at the same time as the old track is lifted. This method is used primarily when protective improvement of the formation is necessary (for increased line speeds, axle loadings). Avoid cutting into the old, compacted track formation if possible.

- The PFC is laid beneath the raised track panel without track lifting and replacement. This method does not require use of the adjacent track.

- The use of this method requires a clean ballast bed, otherwise the ballast should be screened before FI.

- The method can be divided into the following elements:
  - The track must be raised at least 10cm above design level, possibly after provision of extra ballast. At the same time, cant should be reduced to 60mm, since otherwise the FSG will be applied unevenly. The sleeper cribs should be almost empty and no ballast should be lying on the sleepers.
  - The FSG is distributed evenly in the track longitudinal direction from self-discharge wagons (if possible with metering equipment) on to the clean ballast, preferably between the rails and outside them on the side of the adjacent track. The FSG deposited on the outer ballast should generally escape the chain of the BRM and is therefore used to cover the cess.
  - Before the passage of the BRM, the track must once again be lifted as high as possible approx. 10cm above normal top of rail. (This can be undertaken by the BRM's lifting equipment).
  - The BRM is lifted with a top screen with 30mm mesh, the bottom screen being covered with a sheet. The BR, thus modified, must take up all material lying on the formation. (The chain of the BRM should not be set lower than the design level of the formation). The FSG falls through the upper screen on to the covering plate of the lower screen, and slides on to the two distributor conveyor belts, from which it is spread on to the formation. A grader unit
levels the laid material. Two vibrator bars, floating in the FSG, consolidate the material.

- The ballast is withheld from the upper screen and runs on either side of the machine:
  - partly over the distributor conveyor belts on to the track in front.
  - partly through adjustable outlets directly on to the track.

- The automatic, slewing distributor conveyor belts are separated in the middle by an edged profile, so that ballast and FSG can run on the same conveyor.
- By means of a deflector plate on the ballast side of the distributor conveyor belts, the angle of discharge is varied so that the ballast falls on top of the leveled and consolidated FSG layer.

- Following passage of the BRM, the track is as usual ballasted-in, lifted, tamped and lined. Owing to the anticipated settlement of the track, a speed restriction of 40-60 km/h is required.

Annexure 8(iv) is a flow chart for FI by BRM.

**8.7.1.5 Formation improvement using the PUSCAL II track renewal train for ballast screening.**

The PUSCAL II permits FI on a cyclical basis without use of the adjacent track.

A working cycle comprises:

- removal of the old track panel, 18m in length,
- excavation of the bedding material, including the formation material, and loading to the TREVAG conveyor system.
- Laying, leveling and consolidation of FSG and ballast.
- Laying of the new track panel,
- Associated rail replacement on conclusion of FI work.
8.7.1.6 Formulation improvement using the PM 200/ AHM800R/ RPM2002 formation rehabilitation machines.

The PM 200 and later versions make possible a production line approach to formation improvement without using the adjacent track. Common salient features are:

- Removal of the ballast and earth from beneath the track panel is effected using a scraper chain with a width variable between 3.85 and 6.00m.
- The excavated materials are transferred from the main machine, via integrated conveyor belts, to a material conveyance-and hopper unit (MFS 40).
- The formation sand and gravel (FSG) for the protective formation covering (PFC), together with the new ballast, are transported in containers with gantry cranes on the materials train.
- The laying of FSG and ballast to the desired thickness and cross-level including the necessary consolidation, is undertaken by the main machine. Tamping and lining for an operating speed of 70 km/h is carried out by the satellite machine.
- The main and satellite machines are guided in line and level with the aid of a wire guide stretched over rods alongside the track.

All these machines are designed for simultaneous introduction of geotextiles and geogrids.

Annexure 8(v) is a flow chart for FI with the PM 200.
(Also see Annexure 9 for salient features of Formation Rehabilitation Machines).

9.0 CONSTRUCTION OF NEW FORMATION / PERMANENT AND TEMPORARY DIVERSIONS/ DOUBLING

Laying of blanket over unstable formation is very difficult and costly task. In busy routes, the cost of slowing down of train and/or planning for traffic block of even 3 – 4 hours per day is very heavy along with inconvenience of traffic disruptions. For such routes where traffic density is very high and length of unstable formation is also quite large, it may be feasible to adopt any of the following schemes for effecting improvement in the formation.
- Altogether new formation along the old formation or on a new alignment.
- Construction of double line and occupation of old line for improvement.
- Construction of a third line, leading to improvement in the middle line.
- Construction of a temporary diversion, in case the unstable stretch is small enough.

There are several examples of success of these techniques over Indian Railways. such as Balharshah - Gudur 'A' route & Vijaywada - Vishakhapatnam 'B' route, additional new line (third line) may be constructed, which would be required in near future from traffic considerations also, in phased manner and, thereafter, the **Track Dismantling method** may be used for formation rehabilitation.

Doubling of Cuttack-Paradip is a good case in point, proving utility of this approach. In most of the cases, where formation is unstable on both the lines, the middle line will get automatically rehabilitated. Adoption of this method would be not only be cost effective (after adding cost of electrification also) but also a permanent asset, an additional line, would be available without any extra cost, (it may be only marginally higher than the cost of rehabilitation of formation under running traffic).

### 10.0 COMPARISION OF METHODS

Success of any procedure of laying of blanket of required standard depends on its cost effectiveness i.e.

a) Rate of progress per hour of traffic block, including minimum block time required,

b) Extent of speed restriction,

c) Cost of machinery and manpower involved,

d) Feasibility of execution (as per various **site conditions**) and

e) Safety risk involved during execution.

A comparative study of eight methods discussed here is placed at Table 1. Any other method, which may be devised in future, will have to score well on these criteria in order to become widely acceptable.
**COMPARITIVE STUDY OF VARIOUS METHODS OF BLANKET LAYING**

Table 1 (Total 3 Pages)

<table>
<thead>
<tr>
<th>S. No</th>
<th>Items</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Al. Alloy Girder</td>
</tr>
<tr>
<td>1.</td>
<td>Maximum Depth of blanket possible.</td>
<td>100cm (for change, support system is to be redesigned)</td>
</tr>
<tr>
<td>2.</td>
<td>Maximum Width of blanket possible</td>
<td>Full formation width</td>
</tr>
<tr>
<td>3.</td>
<td>Continuity in blanket layer</td>
<td>Does not exist along the track</td>
</tr>
<tr>
<td>4.</td>
<td>Flexibility in excavation of formation &amp; lifting</td>
<td>Not possible</td>
</tr>
<tr>
<td>5.</td>
<td>Possibility of laying geo-synthetic layer</td>
<td>Difficult, (Not continuous)</td>
</tr>
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</tr>
<tr>
<td>6.</td>
<td>Quality of work</td>
<td>Not consistent</td>
</tr>
<tr>
<td>7.</td>
<td>Requiremen of infrastructu re</td>
<td>Al. Alloy girder (5 sets) at cost of Rs. 70-80 lakh</td>
</tr>
<tr>
<td>8.</td>
<td>Risk to safety at work spot</td>
<td>Yes</td>
</tr>
<tr>
<td>9.</td>
<td>Cost of execution (Indicative)</td>
<td>Costly (Rs 30-40 lakh per km for 1m thick blanket). Does not include loss due to traffic disruption.</td>
</tr>
<tr>
<td>10.</td>
<td>Level of supervision</td>
<td>Very high</td>
</tr>
<tr>
<td>11.</td>
<td>Site conditions</td>
<td>a)Road approach required b)Not possible in cuttings</td>
</tr>
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<tr>
<td>12. Traffic block requirement</td>
<td>Traffic block requirement</td>
<td>3-4 hours daily for shifting /insertion of cribs and girders</td>
</tr>
<tr>
<td>13. Progress per working day</td>
<td>Slow, 10-15m</td>
<td>Fast may be as much as 0.5 km per day</td>
</tr>
<tr>
<td>14. Feasibility in Electrified section</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>15. Damage to track structure</td>
<td>Rails are required to be cut to single rails</td>
<td>No damage done</td>
</tr>
</tbody>
</table>

Table ends.
11.0 OTHER IMPORTANT ASPECTS TO BE CONSIDERED FOR SUCCESS OF BLANKET LAYING WORK

11.1 Association of RDSO in Planning of Rehabilitation Work
Railway may like to associate RDSO in carrying out of rehabilitation works with their innovative methods or any other methods so that correct rehabilitation measures are decided depending on site conditions. This is necessary to ensure success of the effort since it is the final outcome, which matters and not the trial alone. Therefore, work carried out by any method should be technically correct.

11.2 Involving Zonal/Divisional GE Cell For Quality Work
GE cell of Railways should be associated to assist & guide field officials in planning, designing & execution of rehabilitation work to ensure quality & safety. Depending on quantum of work involved, adequacy of GE Cell and its manning should be ensured.

11.3 Survey of Unstable Formation Stretch
Stretch of unstable formation should be surveyed to find out type of failure, length of affected formation, type of sub-grade soil, depth of ballast penetration, quantum of lifting of track etc. Therefore, longitudinal section and ballast penetration cross section of the stretch are to be plotted and sub–grade & sub- soil samples are to be tested.

11.3.1 Interpretation & Utilisation of survey data

a) Longitudinal Section: L-section will help to decide maximum possible lifting of track along with elimination of sags. Possibility of lifting of OHE should also be explored. This will help to avoid, to extent possible, cutting of formation. Accordingly, revised L –section should be decided.

b) Cross Section: Ballast penetration cross section profile taken at suitable interval, say 50 – 100 m or so, depending on nature of problem, will help to know the extent of ballast penetration & also type of slope failure, if any. Part of penetrated ballast may be considered to perform as a blanket layer.

c) Soil Type & Its Strength: Soil samples, disturbed & undisturbed, are collected from below ballast penetration level, near plane of slope failure and sub – soil, if required so, to assess soil strength and accordingly, design thickness of blanket & slope of formation.
11.4  **Design Of Thickness Of Blanket And Slope Of Formation**

Blanket thickness is to be decided based on type of sub-grade soil and axle load of the traffic expected to run in the section. Undisturbed soil samples tested from Zonal/Divisional GE Cell or GE Lab/RDSO will help to design the thickness of blanket and slope of formation.

12.0  **AREAS OF FURTHER STUDIES:**

The present methods available at our disposal being cumbersome and slow, there is a need for evolving mechanical methods which may be both simple and cost effective. The following areas would merit more research .

12.1  **Utilization of BCMs in formation rehabilitation:** Ballast screening machines have been successfully used for formation rehabilitation for cutting formation by at least 150 mm to make additional space for laying a shallow granular base in conjunction with a layer of geogrid. This aspect has also been publicized by some of the ballast cleaning machine manufacturers. (However, Indian Railways have no experience on this subject as yet. Zonal Railways are being approached to a identify a suitable stretch for taking up rehabilitation work using this method.

12.2  **Utilization of by-product of screened ballast:** BCMs are throwing about 40% degraded ballast during deep screening operation. Experience gathered in the field shows that this material can be a very good blanket material and can be utilized as such. This aspect will need further studies for means of collection/recycling and compaction of this material back on the formation.

12.3  **Laying of blanket in conjunction with geo grid:** Formation rehabilitation with geogrid using a reduced layer of blanket will be a cost effective solution, where the cost of track occupation, as well as that of blanket material are considerably high. Technology at international level is available which has to be studied and modified to suit our needs. Theoretical studies by FEM modeling as well as Centrifuge testing can be done. Different combinations can be tried on a test track also.

12.4  **Partial blanketing with widening of embankment:** This technique may hold a lot of promise in Indian conditions. It has to be given a serious trial. It will also be put to theoretical test by modeling in the days to come.
13.0 **RECOMMENDATIONS:**

13.1 The choice of the right method as well as scheme depends on several factors like extent of problem, projected traffic and axle loads, availability of traffic blocks, accessibility of site, availability of labour and material etc. While guidance of RDSO may be necessary for analysis of data and design of rehabilitation scheme, the detailed planning and choice of method will have to be done by the Railway itself, based on several factors including those enumerated above. Available methodologies of laying blanket under traffic conditions are mostly divided amongst, Rail cluster method, C.C.Crib method, and Al alloy girder method.

To appreciate performance of any of these methods in proper perspective, it would be necessary to execute work for long stretch say 2–4 km and study all aspects involved (para 8). A comparative study of all the methods employed in India and abroad has been given in Table 1.

13.2 The experience already available over world railways is heavily loaded in favour of a fully mechanized system such as AHM800R or CPM2000 that have been discussed above. However, these advanced systems are both very costly and sophisticated. Moreover, they require long track possession time in the range of 8-10 hrs., which is considered prohibitive.(Rly. Bd.'s letter no. 90/track III/TK/24 vol III pt I dt. 24.9.02). These machines have been evolved through many intermediate stages, such as:

- Use of ballast cleaning machine.
- PUSCAL II system, and
- PM 200 system.

These systems are still available in foreign railways and any of these methods can be adopted over Indian Railways depending upon suitability and degree of automation required.

13.3 Formation problems are better preventable than curable. Use of proper material with the correct workmanship needs to be emphasized in all possible fora. Railways need to follow the same construction philosophy for formation, as are followed for structures.

13.4 Rehabilitation is a costly exercise, which involves meticulous planning and resources. It may not be possible to devote this type of attention at the level of Senior DEN in the divisions. For this reason, all formation problems need to be monitored at the Zonal Railway level. Funds for rehabilitation may be allocated from **capital grants (DRF)**. As of now, the works are chargeable to revenue grant B-731 (IRFC, Pt II, correction slip 16 dt 6.3.87), (Rly. Bd.'s letter No. 86/W6/SF/10, Dt 1.4.87). This will help in monitoring the progress as well as deployment of adequate resources.
14.0 REFERENCES:

1. Railway Board’s letter no. 94/CE II/MB/2 dated 10.12.98 containing instruction for laying of 1m thick blanket on new formation.


4. Guidelines of Earth work in Railway Projects, May 1987, along with 3 correction slips.

5. Track foundation design.” Journal of Geotechnical and Geo-environmental Engineering, April ’98.


8. Railway Board’s letter no. 94/CE II/MB/6 dated 10.9.01 enclosing copy of paper & presentation made by E. Rly during C.Es.’ conference held on 2nd & 3rd August,2001 in Rly Board.

9. RDSO'S circular no. 23 on "Strengthening of Railway Embankment with/without partial blanket".


11. RDSO's letters no RS/SE/1 dt 29.5.80; RS/G/72 dt 28.11.86; RS/F/57Vol.V1 dt 5.2.90; RS/F/53I dt 18.9.92.


15. RDSO’s report no. SMR/Consultancy/SC/12-1989 on "Rehabilitation of Weak Formation on Bapatla- Tsunduru Section S.C.Rly".


17. RDSO's Technical Monograph No. TM-54, on Methodology for design of Railway embankment- A rational approach.

18. UIC Code, 1994R.


21. Railway Bd.’s letters Nos. 86/W6/WP/10 dt. 1.4.87, 91/CE-II/SF/9 dt. 3.8.95,
OFFICERS AND STAFF ASSOCIATED WITH PREPARATION OF THE REPORT

This report has been prepared by Sanjay Rastogi, Director, GE, under the guidance of Sri S.K. Raina, Executive Director/GE. Valuable assistance has been rendered by

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The research base created by Shri Ashok Kumar Mishra, former Director, GE/RDSO is gratefully acknowledged.
Table 2

RAILWAYWISE BREAK UP OF FAILED FORMATIONS AND PROGRESS OF REHABILITATION

<table>
<thead>
<tr>
<th>Railway</th>
<th>Length under speed restriction as on 1.4.2002 due to weak formation (in km)</th>
<th>Progress during year 2001-2002 (in kms)</th>
<th>Target for rehabilitation for 2002-03 (in kms)</th>
<th>Progress upto July 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR</td>
<td>24.71</td>
<td>5.65</td>
<td>10</td>
<td>3.32</td>
</tr>
<tr>
<td>ER</td>
<td>66.8</td>
<td>10.27</td>
<td>8</td>
<td>1.78</td>
</tr>
<tr>
<td>NR</td>
<td>4.4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NER</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>NFR</td>
<td>1.37</td>
<td>3.30</td>
<td>1</td>
<td>0.31</td>
</tr>
<tr>
<td>SR</td>
<td>24.47</td>
<td>6.03</td>
<td>34</td>
<td>0</td>
</tr>
<tr>
<td>SCR</td>
<td>462.78</td>
<td>0.79</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>SER</td>
<td>60.06</td>
<td>47.39</td>
<td>36</td>
<td>5</td>
</tr>
<tr>
<td>WR</td>
<td>15.95</td>
<td>4.50</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>662.54</td>
<td>77.93</td>
<td>118</td>
<td>10.41</td>
</tr>
</tbody>
</table>
Properties of Blanket Material:
Blanket material should have following specifications:

a) It should be coarse, granular and well graded.
b) No skip grading is allowed.
c) Particles finer than 75 microns can be permitted upto 5% if fines are plastic and the limit can be increased to 12% if the fines are non-plastic.
d) Uniformity coefficient, \( \frac{D_{60}}{D_{10}} \), in no case should be less than 4. Preferably it should be more than 7 to avoid liquefaction under train vibrations.
e) The coefficient of curvature \( \frac{D_{30}^2}{D_{60} \times D_{10}} \) to be within 1 & 3.
f) The particle size gradation curve should more or less lie within enveloping curves as given below.
Fig: Enveloping curves of blanket material
DEPTH OF BLANKET LAYER

1.1 Depth of blanket to be provided for axle loads upto 22.5t for different types of subgrade soils (minimum top one meter thickness) has been given as under. In case more than one type of soil exists in top one meter then soil requiring higher thickness of blanket will govern.

d) Following soils shall not need blanket:

- Rocky beds except those, which are very susceptible to weathering e.g. rocks consisting of shales and other soft rocks which, become muddy after coming into contact with water.
- Well graded Gravel (GW)
- Well graded Sand (SW)
- Soils conforming to specifications of blanket material.

Note: Soils having grain size curve lying on the right side of the enveloping curves for blanket material like cobbles and boulders may/may not need blanket. In such cases, need of blanket and, its design should be done in consultation with RDSO.

e) Following soils shall need minimum 45cm thick Blanket:

- Poorly graded Gravel (GP) having Uniformity Coefficient more than 2.
- Poorly grade Sand (SP) having Uniformity Coefficient more than 2.
- Silty Gravel (GM)
- Silty Gravel – Clayey Gravel (GM – GC).

f) Following soils shall need minimum 60cm thick Blanket:

- Clayey Gravel (GC)
- Silty Sand (SM)
- Clayey Sand (SC)
- Clayey Silty sand (SM-SC)
  
  Note: The thickness of blanket on above type of soils shall be increased to 1m, if the plasticity index exceeds 7.

g) Following types of soils shall need minimum 1m thick Blanket:
- Silt with low plasticity (ML)
- Silty clay of low plasticity (ML-CL)
- Clay of low plasticity (CL)
- Silt of medium plasticity (MI)
- Clay of medium plasticity (CI)
- Rocks which are very susceptible to weathering

1.2 Soils having fines passing 75 micron sieve between 5 & 12% i.e. for soils with dual symbol e.g., GP-GC, SW-SM, etc., thickness of blanket should be provided as per soil of second symbol (of dual symbol). For example, if the soil of the subgrade over which the blanket is to be provided is classified as GP-GC then blanket depth for GC type of soil i.e. 60 cm as per para 6.4.4.2 (c) is to the provided.

1.3 Use of geo-synthetics can be considered at places where it is economical to use in combination with blanket as it reduces the requirement of thickness of blanket. It may be particularly useful in cases of rehabilitation of existing unstable formation and in new construction where availability of blanket material is scarce. Use and selection of geo-synthetics should be done in consultation with RDSO.

1.4 For other types of soil to be used in subgrade, not covered by above clauses, Railway may approach RDSO for getting guidance on deciding blanket thickness depth.

1.5 For heavier axle load traffic above 22.5t and upto 25t & above 25t to 30t, additional blanket thickness of 30cm & 45cm respectively, over and above as given in para 6.4.1 of superior quality material, shown as upper blanket layer in annexure 1, should be provided.
Annexure 3

WORKING OUT COST OF LAYING OF BLANKET.

(COST OF BLANKET MATERIAL TAKEN AS RS. 200/- PER CUM)

A. With Aluminium Alloy Girder (1.0 m)

1) Cost of 1 km blanket material = Rs. 17.80 lakhs

2) Cost of labour = Rs. 10.47 lakhs

Total = Rs. 28.27 lakhs

3) Depreciated cost of machinery i.e. aluminium alloy girder

(P.O. dated 22.5.96)

i) Capital cost: One set of 5 Aluminium Girders = Rs. 55.20 lakhs

One compressor = Rs. 5 lakhs

Others = Rs. 2 lakhs

Total = Rs. 62.2 lakhs

ii) Depreciation per year @ 10% = Rs. 6.22 lakhs

4) Cost per km if 2 km is done in one year = Rs. 6.22 / 2

= Rs. 3.11 lakhs

5) Total cost of blanketing per km = 28.27 + 3.11

= 31.38 lakhs

(B) Manually under Mega Traffic Block (Track Dismantling Method), (upto 1.15m):

Cost per km:-

i) Dismantling of track:                                       Rs. 36,450

ii) Removal of ballast:                                          Rs. 60,750

iii) Excavation of formation:                                 Rs. 31,030

iv) Blanketing (for 115 cm depth including cost of material & labour):                Rs. 20,87,856

v) Cost of labour (for track related work)   Rs.  9.64  lakhs

7) Total Cost :  Rs.  30.5 lakhs

Authority: Report of SC Rly. on track Rehabilitation at km 20/4 to 22/0 UP line between Malkhaid Rd. & Chittapur stations on Secunderabad-Wadi section, - work commenced in May'99

Note:  This method has tremendous scope for improving progress vs. traffic block ratio by employing three-prong development viz.

(1)  Utilize as many locations as possible in the shadow block. Ultimate is to do the whole block section in one go.

(2)  Deployment of appropriate handling and earth moving equipment/machinery for carrying out various items involved for doing the work.

(3)  Ergonomic approach to optimize the out put of all the men and machines.
(C) With Formation Rehabilitation Train (upto 0.5 m):

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>i) Cost of machines for work of ballast screening, excavation of</td>
<td>Rs 80 crore</td>
</tr>
<tr>
<td>formation, using undersized ballast in blanket material, laying</td>
<td></td>
</tr>
<tr>
<td>blanket of 50 cm thickness &amp; compaction, spreading of ballast for</td>
<td></td>
</tr>
<tr>
<td>30 cm cushion and packing (including adequate no. of wagons/systems</td>
<td></td>
</tr>
<tr>
<td>for bringing ballast &amp; blanketing material &amp; taking away of muck</td>
<td></td>
</tr>
<tr>
<td>etc.)</td>
<td></td>
</tr>
<tr>
<td>ii) Cost towards capital recovery @ 14.68% of cost of total FRT</td>
<td>Rs 11.744 crore</td>
</tr>
<tr>
<td>machine</td>
<td></td>
</tr>
<tr>
<td>iii) Proportionate consumption on IOH/POH, annual machine</td>
<td>Rs 8.00 crore</td>
</tr>
<tr>
<td>expenditure, operational expenditure &amp; overheads; total @ 10% of</td>
<td></td>
</tr>
<tr>
<td>cost of FRT</td>
<td></td>
</tr>
<tr>
<td>iv) Total cost against FRT [(ii) + (iii)]</td>
<td>Rs 19.744 crore</td>
</tr>
<tr>
<td>v) Progress of work @ 40-50 km per year, say 45 Km</td>
<td></td>
</tr>
<tr>
<td>vi) Cost of machine working per km [(iv) / (v)]</td>
<td>Rs 43.88 lakh per Km</td>
</tr>
<tr>
<td>vii) Cost of blanketing material</td>
<td>Rs 15.00 lakh per Km</td>
</tr>
</tbody>
</table>

**Total** [(vi) + (vii)] **Rs 58.88 lakh per Km**

Note: There are other miscellaneous expenditures towards stabling of FRT, cost of blanketing from inner edge of the OHE mast to edge of formation, cost of hauling of FRT, depot work to load blanketing material, remove muck brought from site etc.

**Authority:**


D) Laying of Blanket with Lifting of Track (upto 0.4 m): -

Cost Analysis:

a) Cost of blanket material (for 40 cm lifting) = Rs 12 lakh

b) Cost of deep screening and lifting = Rs 4 lakh

Total = Rs 16 lakh

Other Details:

a) There is no requirement of traffic block or any other special infra structural arrangement.

b) Lifting by 40 - 50 cm is generally possible even in electrified section with suitable adjustment of OHE & elimination of sags for track settlement on unstable stretches.

c) Deep screening of 30 cm & lifting of track would be carried out over coarse granular material as per provision of IRPWM.

d) Deep screening of 30 cm & filling with blanket material will help to recoup ballast, improve drainage from ballast pockets & provide uniformity.

e) Penetrated ballast available below blanket layer will be working as blanket.

f) Excavated earth from foundation should be utilized to widen the bank.

g) In this method, thickness of blanket can be further increased for further settlement of formation for inadequate thickness of blanket and / or increase in axle load.

h) Wherever lifting to required extent is not possible, laying of geo-grid may be considered.

i) In non-electrified section, this is most suitable method.

(Note: The analyses of rates for different methods are based on details made available by different Railways. They are just indicative and not exhaustive.)
Annexure 4

First Day’s Work
(a) Demolition of track and ballast

Second Day’s Work
Excavation of earth under sleeper

Second & Third Day’s Work
(a) Positioning of sleeper in layers
(b) Shifting of sleepers in adjacent locations
(c) Filling of gap portion, laying of sleepers and rail fixing.

Notes:
1. Two and half days will be required for placement of one span of sleeper.
2. Placing work at all five locations can be carried out concurrently and will depend on no. of labour available for the work.
BLANKET LAYING USING C.C. CRIB AND RAIL CLUSTER—EASTERN RLY METHOD
(SEQUENCE OF WORK)

1. FIRST DAY'S WORK
2. SECOND DAY'S WORK
3. THIRD DAY'S WORK

RAIL CLUSTER
WOODEN SLEEPER

R. D. S. O.
ADOPTED FROM E. RLY. ORG.
DRAWN BY
S. K. THAKUR
INCH/CE
Fig: Blanketing of track by deep screening and lifting
The need for formation improvement by installing a layer of sand and gravel (FSG) has been established. Also known are:
- the lateral and longitudinal profile for FSG and ballast.
- the track geometry parameters.

Is the existing drainage functional and adequate?

No: The existing drainage system should be improved before FI work commences.

Yes: Is the section to be improved less than 50 m?

Yes: The track will be lifted by track renewal machine.

No: The track will be lifted in sections by crane.

Multiple track

Single track

Can the adjacent track be blocked for 50% of the period of possession of the working track?

No: The adjacent track can be blocked for 25% of this period.

Yes: Can the excavated material be removed by lorry?

No: Can earth, sand and gravel and ballast be transported by lorry?

Yes: Is it possible to set up storage areas?

No: Storage areas will be set up for excavated materials, FSG and ballast.

Can the excavated earth be loaded to wagons on the adjacent track?

Yes: The excavated earth will be loaded to wagons on the adjacent track.

No: The FSG is unloaded from wagons on the adjacent track (self discharge or using excavator loaders) laid and consolidated.

The FSG and ballast are laid and consolidated.

The ballast is unloaded from wagons on the adjacent track, laid and consolidated.

Ramps are provided at the transition points between sections with improved and unimproved formation.

Track is laid by track relaying machine or by crane.

Ballast infilling and tamping and lining work.

FI will be undertaken by:
- ballast screening machine (FSG to a depth of 20 cm)
- PM 200 (h = 40 cm)
- Puscal II
FLOW CHART FOR FORMATION IMPROVEMENT (FI) WITH FSG USING EARTH MOVING MACHINERY OVER LONGER SECTION ARE MORE THAN 100m.

The need for formation improvement by installing a layer of sand and gravel (FSG) has been established. Also known are:
- the lateral and longitudinal profile for FSG and ballast.
- the track geometry parameters.

Is the existing drainage functional and adequate?  
Yes → The drainage system should be improved before FI work commences.
No → See procedure described in 7.7.1.1

Is track lifting and replacement to be undertaken by relaying machine?  
Yes → A possession of up to 8 hours.
No → The section to be divided into smaller units.

Is a long-term possession possible?  
Yes → Can the work be completed for the whole section in the possession time is allowed?
Yes → Can the excavated material and the material to be laid be stored at the track side?
No → Can access be provided at the side for transport of excavated material?
Yes → Is there any adjacent track available for transport of material?
No → Is there a possible means of working in which the track need not be removed e.g. using BRM or PM 200 machines?
Yes → Improvement by BRM, PM 200 or similar machines.
No → The track is ballasted -in, lifted, tamped and lined.

No → No
Yes → Yes

1. Removal of the track by relaying machine.
2. Excavation to the necessary depth; setting up of track side storage areas, or storage on adjacent track if blocked for 40% of total possession time.
3. Grading of the formation; only tracked vehicles may pass over the formation.
4. Laying of FSG with or without geotextile; material brought in from the side from storage areas or adjacent track.
5. Consolidation and inspection.
6. Track laid by relaying machine.
7. Ballasting (ballast from self discharge wagons) and 1st and 2nd tamping passes.
8. Welding as necessary and 3rd tamping pass.
The need for FI by laying of FSG has been established. Also known are:
- the cross-level and longitudinal level for FSG and ballast.
- the track geometry parameters.

Is the existing drainage functional and adequate?

If yes, the drainage should be improved before FI work begins.

Is continuous possession of the track to be worked on possible?

If yes, the planned sections can be dealt with in the possession time allowed?

Do ground conditions permit excavation by ballast screening machine?

If yes, the preparatory work includes:
- raising of ballast shoulders
- lowering of cess

Main stages of work:
- deploy ballast screener (several passes if required)
- level formation if geotextile to be laid, lift track, unroll geotextile and replace track
- unload FSG from self-discharge wagons
- spread FSG to necessary level using ballast regulator
- lift track and consolidate FSG using tamping and lining machine
- if necessary (deeper layer of FSG), repeat the 3 stages above
- compact FSG using sleeper crib consolidator
- consolidate cess using vibratory roller
- if necessary, lift track, consolidate FSG using vibratory roller and replace track
- unload ballast, fill in, tamp, line and weld track
FLOW CHART FOR FORMATION IMPROVEMENT (FI) BY BALLAST SCREENER

Is the aim of the FI
- preventive?
- does it involve the removal of a 'mixed zone' at most 10 cm. Deep?

Yes → Await suitable temperature for mechanized cleaning.

No → Another method must be chosen

Is it possible to raise the track level by 10-20 cm.?

Yes → Preparatory cleaning of the ballast by the BRM.

No → Geotextile must be laid additionally beneath the sand/gravel layer

Does dimensioning indicate that a 20 cm. Protective layer will be adequate?

Yes → Is the ballast bed clean?

No → Is the existing drainage system functional? Are the cesses in good order?

Yes → The drainage system to be improved.

No → The track must be raised at least 10 cm. above design level. Cant should be reduced to 60 mm. The sleeper cribs must be empty, and there should be no ballast left laying on the sleepers.

The sand gravel mixture in the self discharge wagons is spread over the clean ballast

During passage of the BRM, the track should be raised as high as possible.

The BRM is modified to lay protective formation covering.

Has the BRM been modified for laying of the protective covering?

Yes → The BRM is equipped to lay geotextile.

No → Is geotextile to be laid at the same time

Yes → The cross beam of the BRM is mounted.

No → The BRM takes up all material laying on the formation (ballast and sand/gravel mix). The sand/gravel mix is spread first, followed by the ballast.

The cross beam of the BRM is removed.

The track is ballasted - in, lifted, tamped and lined.

The BRM takes up all material laying on the formation (ballast and sand/gravel mix). The sand/gravel mix is laid first, followed by the ballast. When geotextile roll is used up, a new roll is fitted.
The need for formation improvement by installing a layer of sand and gravel (FSG) has been established. Also known are:
- the lateral and longitudinal profile for FSG and ballast
- the track geometry parameters.

Is the existing drainage functional and adequate?

No

The drainage system should be before FI work commences.

Yes

Will a protective layer of 40cm. be adequate?

No

Will an FSG layer of 40cm. + geotextile be adequate?

No

Another method should be selected.

Yes

PM 200/AHM800R can be used. See 7.7.1.6 for description of method.
PM 200

These machines have been in operation for the past 15 years. The machines excavate ballast plus part of the formation and load them into conveyor and hopper units (MFS cars) coupled to the front of the machine. The sand blanketing material and the new ballast are carried in skips loaded on wagons attached to the rear of the machine and a gantry crane travelling over the wagons is taking them to the working zone where the moistured sand blanketing material is dumped, graded, consolidated and new ballast put on top of it. The rear part of the machine contains a tamping satellite, which is providing the proper ballast consolidation. Like all our formation rehabilitation machines also this one is guided by a steel chord, which is fixed on the side of the track, before work commences.

SVV 100

This machine was developed for another German contractor; it works in combination with a high output ballast cleaner, which is set on "total excavation" mode. The machine will therefore, only be used for introduction of the sand blanket material which is fed into the unit from behind via MFS cars. A lifting mechanism is lifting the track in the working zone and introduction of the sand blanket material will be done as above. The machine can lay ballast in a second run, alternatively the ballasting train can be sent and the track tamped up.

AHM 800 R:

Operated by an Austrian contractor this machine is excavating the old material with 2 separate cutter chains, the first one picking up the top ballast layer, which is sent to a stone crusher and the crushed material thereafter added to the sand blanket material. With this recycling process, the amount of dumped material is reduced, and at the same time the costs for sand blanket material are lowered. The second, large, cutter chain is excavating the rest of the ballast plus the top of the formation, and that material is loaded into MFS cars in front of the machine. Sand blanket material is carried and brought to the machine in the same manner as described for PM 200. As the machine leaves the site the track skeleton is resting on the formation protective layer, fit for the passage of ballast trains, which are doing the ballasting thereafter.
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This is the latest version of a formation rehabilitation machine. A consortium of Austrian-German contractors is operating this machine, which also uses 2 cutter chains, the first one for excavating the ballast, cleaning it and adding it at the rear end of the machine to the new ballast fed in. The second cutter chain is excavating the unusable bottom layer of ballast and part of the formation and off-loading them into MFS cars in front of the machine together with muck left over from the ballast cleaning operation. The sand gravel material and the new ballast are brought by MFS cars from the rear end of the machine. This machine also has a 09-type satellite at the rear end for tamping/levelling/lining.

All these machines are designed for simultaneous introduction of geotextiles and geogrids. A geogrid is a kind of reinforcement, which increases the stability of the formation protective layer and which allows a reduction of the depth of the said layer.
Fig 1: Settlements of formation on stable and unstable sites (Selig E.T., Ref 7)
Fig 2: Formation treatment using polythene sheets—failed within 6-7 years
Fig 3: Geo-textile observations over N Railway (1989)
Fig 4: Typical cross section profile for partial blanketing
Fig 5: Ballast penetration after ineffective moorum treatment, SE Railway
Fig 6: Performance of 100 cm thick blanket layer (SC Railway), (Blanket not as per specification)
Fig 7: Ballast penetration after thin moorum blanketing
Fig 8: Typical ballast penetration profile on 100 year old track
FIG BALLAST ATTENTION AND MUD PUMPING (ref para 3.1)

FIG: MASSIVE SHEAR FAILUR (ref para 3.4)
FIG: PROGRESSIVE SHEAR FAILURE COUPLED WITH GRESS HEAVE (ref para 5.7)
FIG: MODERN TRENDS IN FORMATION DESIGN (ref para 4.3)
FIG TRACK REHABILITATION BY ALUMINIUM ALLOY GIRDER METHOD

(ref para 8.1)
FIG: TRACK REHABILITATION WITH MANUALLY OPERATED PORTALS (ref para 8.3)
FIG: TRACK REHABILITATION USING CC CRIBS (ref para 8.4)
FIG: REHABILITATION USING RAIL CLUSTERS (ref para 8.5)
FIG: BLANKETING OF TRACK BY DEEP SCREENING AND LIFTING