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FEM Analysis of Railway Embankment with Enhanced Load Capacityon Poor Subgrades

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ABSTRACT: Increased capacity in the railway infrastructure demands the improvement of poor subgradestrata. Modernization and expansion of railway networks whole across country requires theconstructionofraillinespassingthroughsoilwhich maynotbeacceptedto supportsuchheavyrepeated rolling axle loads. Problems of failure of formation due to poor subgrade capacity andsubgrade attrition is quite severe in Indian Railways. Several remedies has been purposed tillnow by using various external additives such as brick dust, cinder, ashes of fly ash, pond ashesin combination with lime, stone columns etc. Still formation improvement against bearingcapacityfailureisthemainchallengingrehabilitationwork.Thispaperenlightenstheimprovement of formation strata comprising of black cotton soil using strength improvementadditives such as brick dust, fly ashand optimizedlime percentage.Lab test have beenperformed for natural strata and with additives. It has been seen that there is significantimprovementinCBRvalueupto42percentage.Decrementinshrinkageandswellingpropertyin the soil with optimized additives has been recorded. Numerical modelling using FEMtechnique has been simulated for the natural founding soil and improved soil. Various layershave been modelled using Mohr-coulomb elasto-plastic soil model and sleepers and rail aselastic model. It has been observed that there is excessive vertical displacement due to rollingloadspartiallyunableintransferringthestressesintodeepformationlevel.Useofimprovedsoilformationstrataleadingtopropertransferofload,consequentlyreductioninverticalsettlements.

Keywords:Poorsubgrade,numericalmodelling,CBR, railwayinfrastructure,foundingsoil,settlement.

I. INTRODUCTION

Modernization of old railway tracks and lying new tracks is need of present to accommodatehigh speed trains. Apart from this there is need to expand the rail networks so as to connect allregions for development in all domains. Problem occurs when rail lines pass through stratawhichmaynotbeacceptedtosupportsuchheavyrepeatedrollingaxleloads.Problemsoffailureof formation due to poor subgrade capacity and subgrade attrition is quite severe for IndianRailways. Many researches has been conducted in the field of improving the bearing capacityofnatural formation andto address shrinkageswellingproblems.

In this technical paper, a study has been done for stabilization of railway track laid on blackcottonsoilusingFEMtechnique.Crosssectionofrailwaycomponentlayershasbeensimulatedwithvarious material in finite element modelling usingPhase2v8 software.

Formation plays key role in good performance of track and yielding formation becomes abottleneck in running of traffic to its full potential. Future formations need to be designed andconstructed for sufficiently heavier axle load which is likely to operate on the line in distantfuture. Indian Railways has already stabilised running of axle loads up to 22.8 tons. Theprovisions for blanket thickness, as per ‘Guidelines for Earthwork in Railway Projects’, NO.GE: G- 1, July 2003 are applicable up to 22.5t, and is based on soil classification of underlyinglayers.Theseprovisionsarenowrequiredtobereviewedandbasedonfirmtheoreticalconsideration for heavyaxle loads 25tto 32.5t, keepingin viewWorld Railway practices.

RDSOGuidelines,definesstrengthcriteriaconsideringCBRvalueofsubgradelayer,recommends Specifications & thickness of two alternative systems of formation layers, viz. (i)aconventionalsingleblanketlayersystemoverembankmentfill,(ii)twolayersystemcomprising of blanket and prepared subgrade layer over the normal fill layers. Both the twoalternate systems have been specified for 25T, 30T & 32.5T axle loads. Fig. 1 depicts typicalcrosssection offormation components.

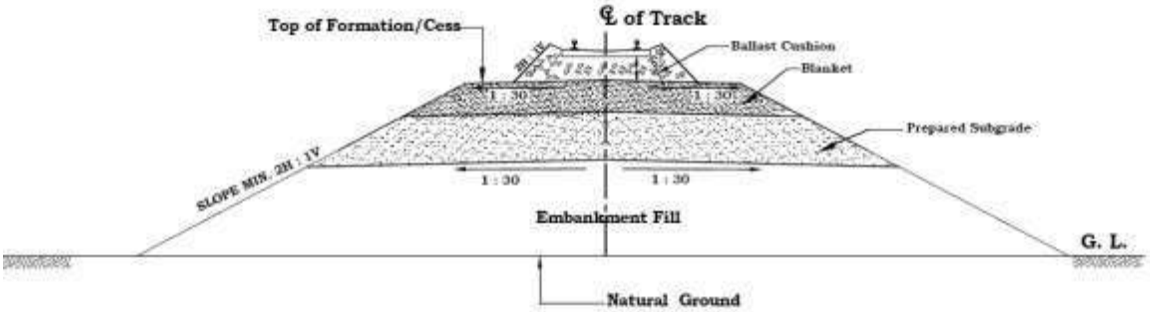


Fig1.Typical crosssectionofformationcomponents

II. METHODOLOGY

1.1.Geotechnicaldescription

Exploratoryboringwithhand/augersamplers andsoilsamplingundertakenalongthealignmentand soil samples also collected from borrow pit area, at an interval of 500 meter interval. Theboringwas doneup to 1.5 to 2.0 m depthbelow existingground level.

In-situ vane shear tests was conducted to determine its shear strength and depth of underlyingcompressible clay black cotton layer. Undisturbed tube samples was also be collected to knowactual moisture content, natural dry density and shear and consolidation parameters of the soil.Themaximumpressureonformationatbottomofballast,typicalvaluesasgooddesignpractice,should not exceed 0.3MN/m^2 or 3 kg/cm^2, and the pressure on sub-soil should not generallyexceed0.1MN/m^{2}or 1 kg/cm^2, as shown in Fig. 2

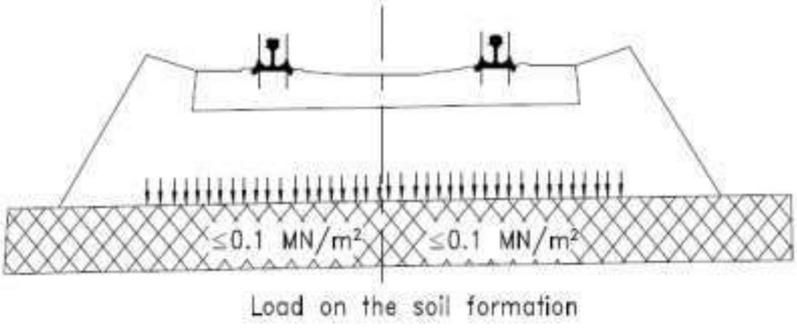


Fig.2Pressuredueto FormationonGroundSoilLayerTable1. Material Properties

Material Type	Sleeper(Elastic)	Ballast	Blanket Layer	Prepared Subgrade (belowBlanket)	Subgrade Base	Black Cotton Strata
Unitweight (kN/m^3)	25	27	22	21	20	18
Cohesion (kN/m^2)	350	20	30	26	18	14
Friction angle(degree)	35	30	18	16	22	15

Table2.ImprovedMaterialProperties

MaterialType	Sleeper(Elastic)	Ballast	BlanketLayer	PreparedSubgrade (belowBlanket)	Subgrade Base	BlackCotton Strata
Unitweight (kN/m^3)	25	27	22	21	20	18
Cohesion (kN/m^2)	350	20	30	32	28	32
Frictionangle (degree)	35	30	18	18	22	18

1.2. Dimensioningofcomponentsbasedonstresstransfer

Most of stresses for heavy axle load up to 32.5 T load are dissipated up to 1.5 m depth belowbottom of ballast, thereafter the stresses are within tolerable limit of stresses including reasonablefactorofsafetyforsoils.Themajorstress region occursup to depthof 1 to1.5m below bottomofballast. This region is to be provided with blanket layer which or in lower layers supplemented/replaced by prepared subgrade particularly in bottom portion. Also, below the blanket layer, thelayer of prepared/ good imported soil with minimum prescribed CBR value is essential and hasbeenrecommendedaspreparedsubgradelayerupto depthofabout1.5mbelowtopofformation.

1.3. Materialused

Sand: Locally available Fine sand, Medium sand and Silver sand were used in this experimentalstudy. The reason for choice of these types of sand was mainly for their easy availability in manypartsofthe countryforpossible usein practice.

Fly Ash: Fly ash in the form of bottom ash has been used for this study. Percentage of fly ash hasbeenvaried to stabilizethezonebelow ballast layer.

BrickDust/Murum:Consideringtheoptimum limepercentage at2%,andoptimizedbottom ash

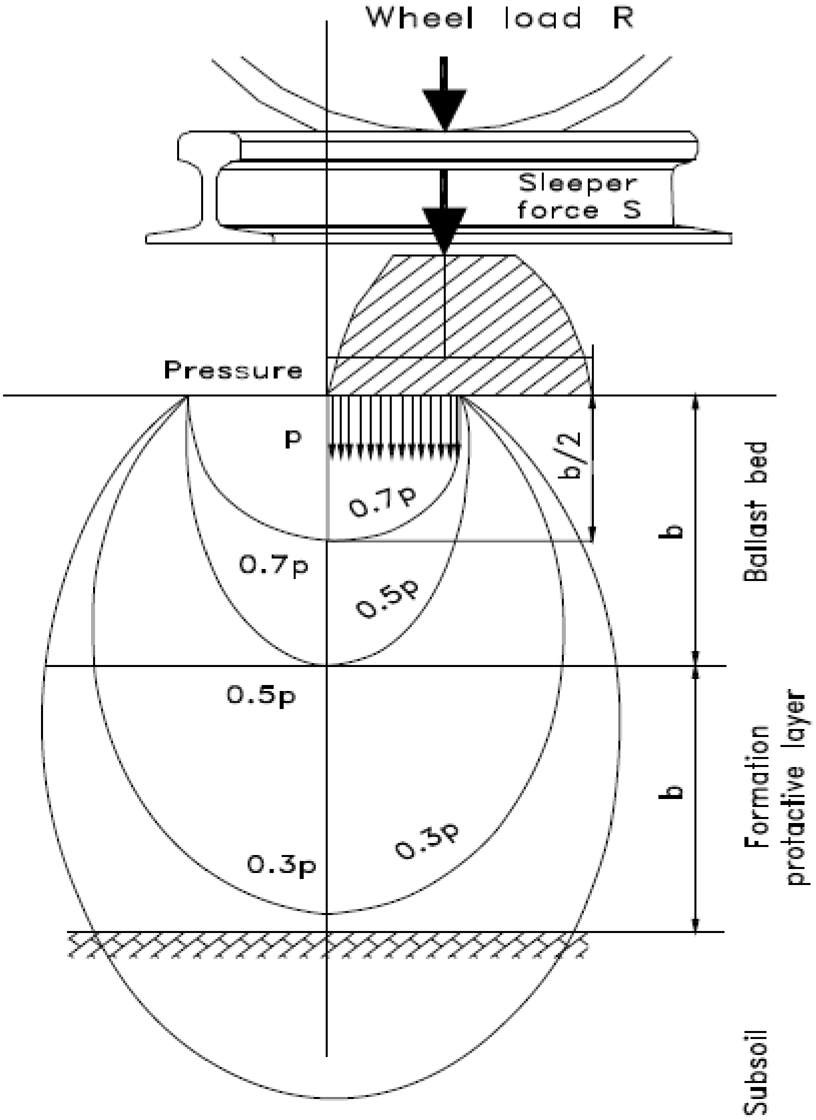


Fig.3StressTransferthroughdifferentFormationLayers

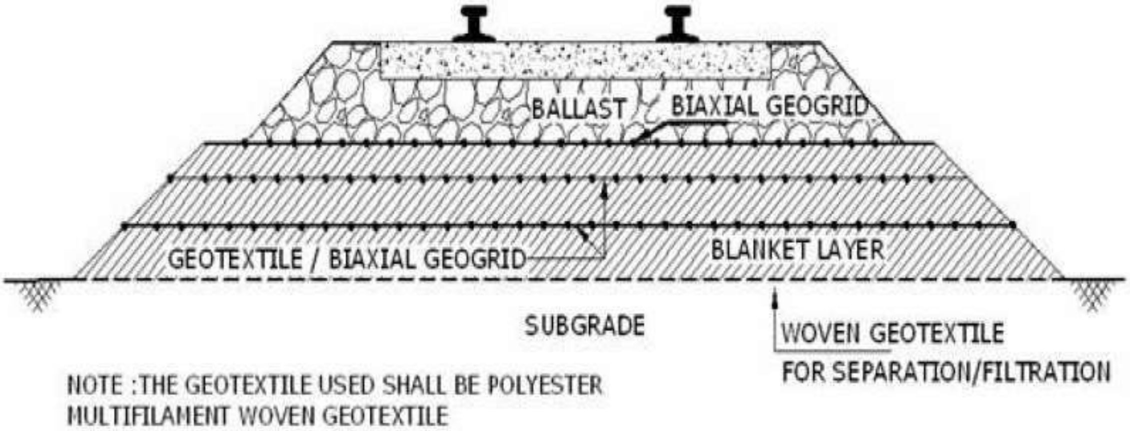


Fig.4SchematicDiagramofArrangementofStabilizationSystem

III. RESULTS

Percentage of fly ash (bottom ash) and brick dust has been varied and 4% lime optimized. Aftersoaked CBR (7 days) testing at 4% lime and bottom ash percentage from 2 to 16%, brick dustvaried up to 18 percentage and resulting CBR was noticed. It has been seen that CBR increasedfrom 2 to 2.84 at 4% lime, 12% bottom ash and 14% brick dust. FEM analysis shows that there is65%increasein safetyfactorunder staticcondition.

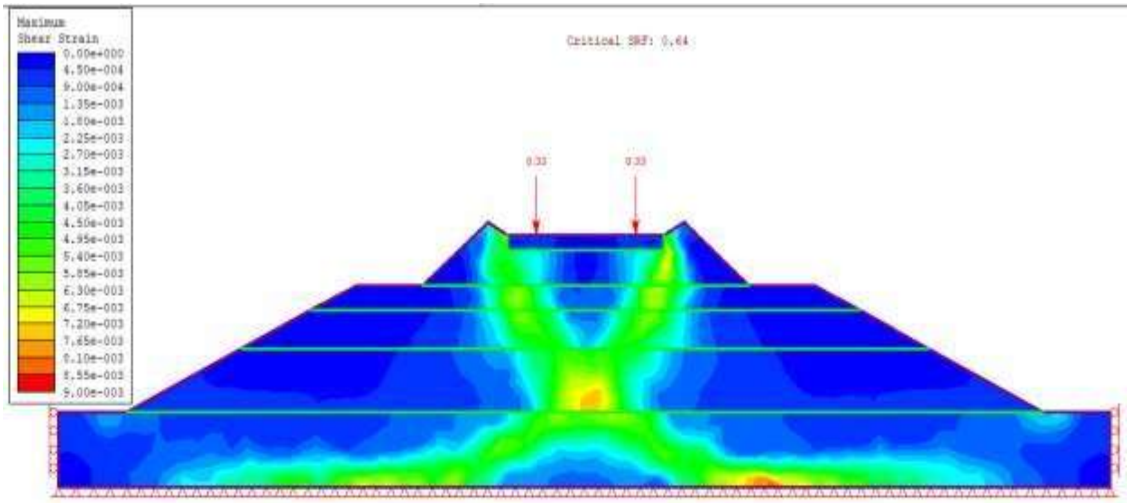


Fig.5CriticalSafetyFactorwithMaximumShearStrainFailure

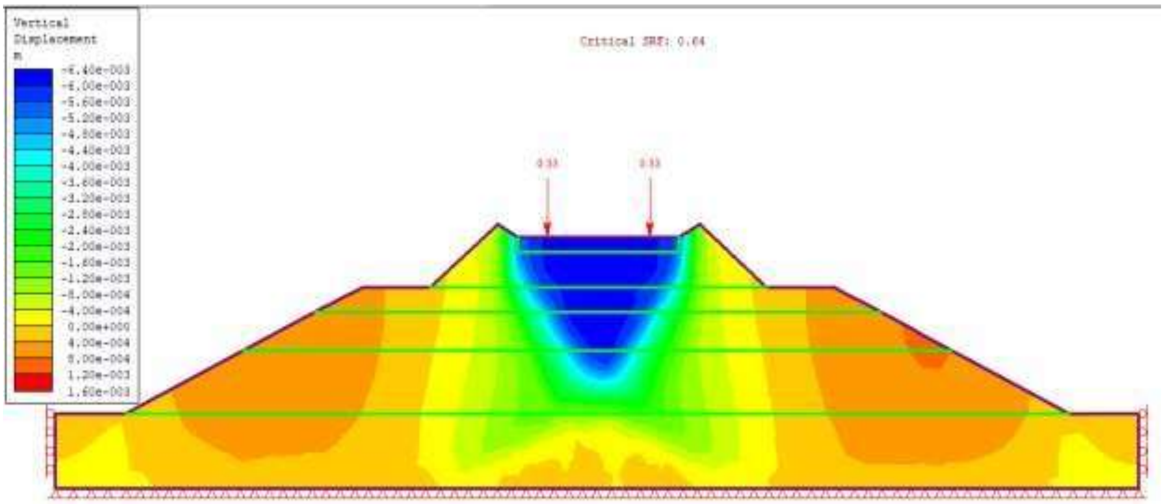


Fig.6 VerticalDisplacementwithContoursPassingthroughSubgradeLayer

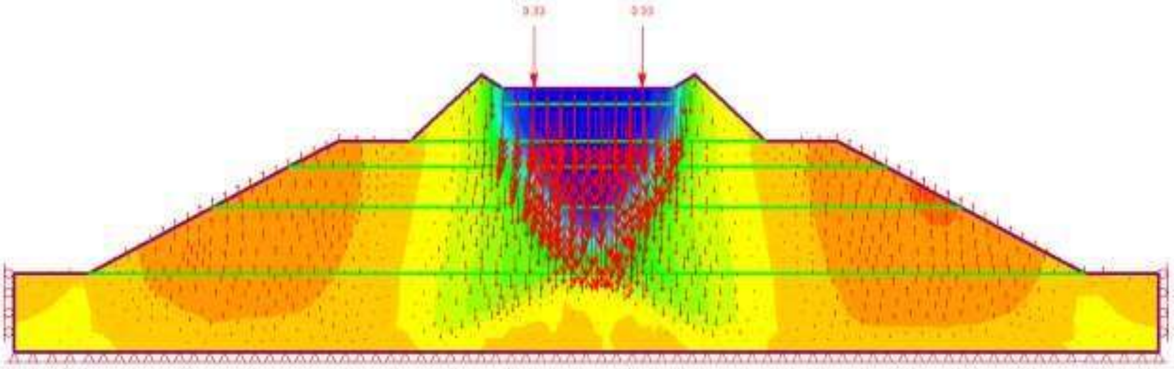


Fig.7DisplacementVectorInfluencingVariousFormation Layers

Biaxial geogrid has been used at the middle of blanket layer for reducing the settlement andincreasingloadcarryingcapacity. Ithasbeenseenthatthefailurehasbeen shiftedfrompunchingfailure to general shear failure due to CBR increment and stress distribution by biaxial geogrid intwo dimensions.

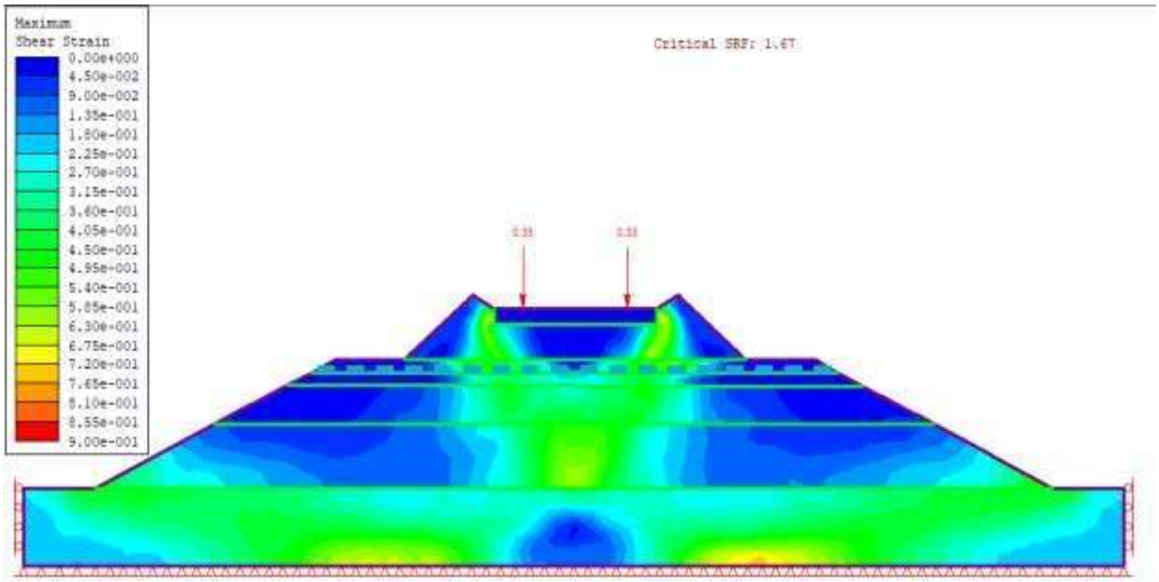
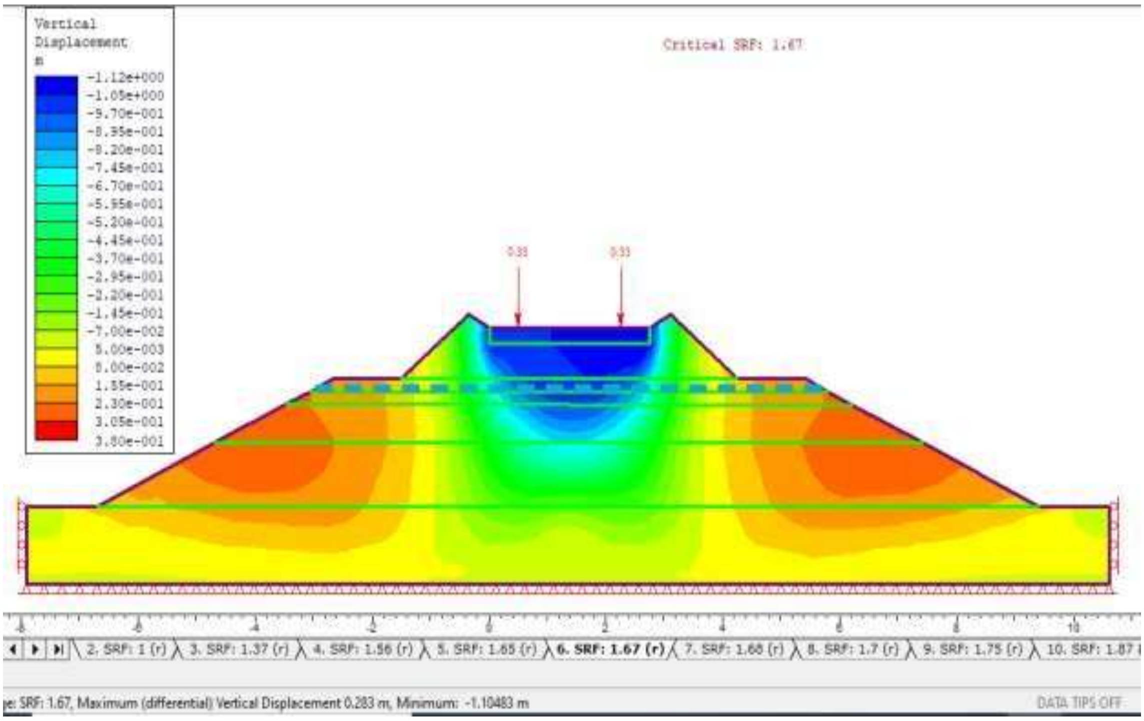


Fig.8CriticalSRFwithMaximumShearStrainFailureusingGeogridand ImprovisedSoil



pe: SRF: 1.67, Maximum (differential) Vertical Displacement 0.283 m, Minimum: -1.10483 m

Fig.9 VerticalDisplacementwithContoursPassingthrough GeogridReinforcedSubgradeLayerandImprovised SoilLayer

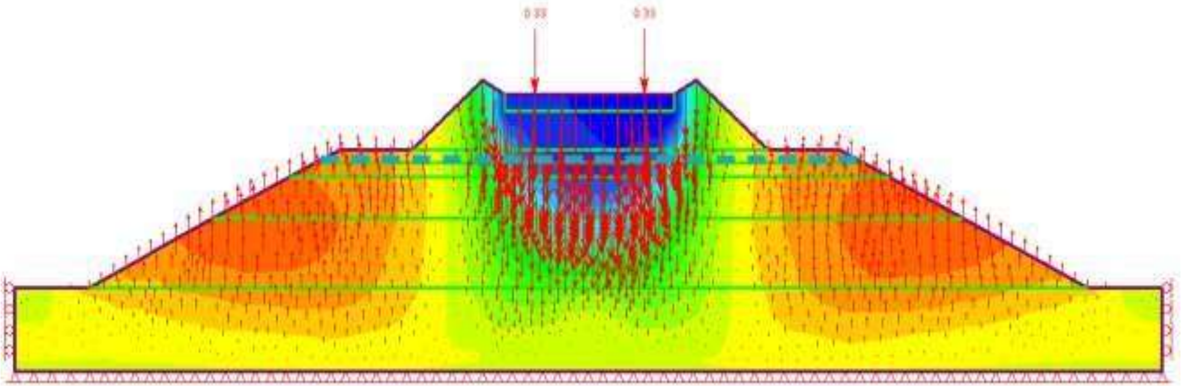


Fig.10 DisplacementVectorInfluencingVariousFormation LayerswithGeogridReinforcedLayer andImprovised SoilLayer

IV.DISCUSSION

Stabilization of poor subgrades region is very vital. The condition becomes more critical, when ithas to carry heavy axle rail loads. Use of improvised soil by addition of external additives addsCBR.Biaxialgeogridinblanketlayerreducessettlementbytransferringthestresseseffectivelytounderlyinglayers.Itisclearfromtheexperimentsthatuseoflimeimprovesshrinkageandswellingcharacteristics. 4% lime with optimized 12% bottom ash and 14% brick dust improves CBR. It isclear from the above finite element analysis results that there is significant improvement in thecritical safety factor results. It has been observed that there is 65% improvement in safety factorvalues under static condition after inclusion of biaxial geogrid layer at blanket layer and usingimprovised soil properties. The mechanism behind the stabilization is due to increase in the shearstrength,friction between the layers.

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