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Analysisoftheconstructiondetailsandsecurityaspectsof Ataltunnel

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Abstract
Theconstruction ofunderground structuresisextremelyeffectiveinsolving varioustrafficissues.Inthetransportationsystem,undergroundstructuresplayavitalpartusingimmersedtubeconstructiontechnique. Various civil structures essentially depend on underground frameworks dug through surroundingsoil or rock with enclosed form except for the entrance and exit. Underground structures are utilized fordifferentpurposesincivilengineering.Themostremarkableofthesestructuraldesignusesistheutilizationofthe underground framework of the metro tunnels or highwaytunnel in various hill ranges. However objectiveof the work is to carry out experimental investigationsof Atal tunnel construction design on various fieldconditionshasbeen analysedinthispaper..Duetoavarietyofadverseconditions,performingthein-situtestsin the field is extremely difficult. As a result,an advanced digital compressing testing facility is employed foranalysingthestabilityandsecurityon theAtaltunnel.Thecompressiontestingunitcalculatesthebehaviouroftunnels under static and dynamic loading conditions. The behaviour of the tunnel is measured with the help ofLVDTs. The reading obtained from the LVDTs is recorded in the CPU data. From the results it can beconcluded that both experimental and numerical modelling results are in close agreement with each other.Fromthestudy,itcanalsobeconcludedthattherearevariousfactorssuchascover depthoftunnels,strengthproperties of rock, spacing between the tunnels and presence of liner material is factors employed forconstruction of tunnels under the effect of static and dynamic loading conditions. Hence, it can be concludedfromthepresentstudy,thetunnelstructurecanremainsafeifthedesignparametersarewellselected.
Keywords:AtalTunnel,Underground structures,LVDT,TunnelDeformation,SupportPressure,Stabilityanalysis
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I. INTRODUCTION

Tunnels are horizontal underground manmade passageways that are built without causing anysurfacedisruption.Tunnelsaregenerallyusedfortransportingmaterials.Tunnelscanbeconstructedthroughrockmasshillsandriversetc.Inthepresentera,tunnelsareusedforvariouspurposes.Tunnelshave a wide variety of applications such as highways, railroads, water supply and sewage tunnels,undergroundpowerstations,storageconcernsetc.

In this work, Design analysis of the Atal Tunnel has been carried out on various aspects. Especiallystudy of the state of stresses around the underground structure provides an insight into the basicphenomenon such as displacement and stress fields and aids in the provision of appropriate supportfor theundergroundstructure[1].Variousmethodsavailabletoassessthebehaviourofundergroundstructuressubjectedtostaticloadingincludelarge-scalein-situtests,physicalmodellingandnumerical simulations. For practical reasons, the in-situ experiments are difficult to conduct andhence physical model tests and numerical methods have to be used. However, the accuracy of thenumerical model has to be verified through calibration of either the in-situ tests or physical modelresults.

Due to the advancement in tunnel boring methods, it is possible to deal with any type ofgeological complexity. Tunnels were excavated in hard rock with the help of hand mining methods.Timber wasusedasthetemporarysupporttoprovidesafetytotheworkersworkinginsidethetunnel.Furthertowardscoolingtherocks,thevinegarisusedinplaceofwatertoattacktherockchemicallyaswell as mechanically simultaneously [3]. Fire is used as a disintegration agent to disintegrate therock.Shaft is implemented to work at the several points simultaneously. The presence of tunnels canleadtoimprovingtheconnectivityissueanditalsoshortens thelifelines.Theconstructionoftunnelscanbeeconomicalandsafeifitdesignedparametersareaccurate.

1. PrincipleObjective

When the tunnel is excavated beneath the soil or rock strata, it is subjected to various typesofloading such as static loading, dynamic loading or impact loading etc. As a result of that, thesetunnel structures experience stresses which may cause the deformation of the structure[. Thesecontinuousactingstressesontheundergroundtunnelstructuresmayleadtothedeteriorationoftheirengineeringand mechanicalpropertiesasshowninFig.1

Figure1:Deteriorationinthetunneltowardsextending

Henceitisveryessentialtoensurethecorrectevaluationofthestressesactingonthetunnelstomakeit a safe and economical design. The stability of tunnels depends upon various factors. Some of themainfactors which are responsible for the deformation of tunnels are the type of tunnel section,inaccuratecalculationofloadsactingonthetunnels,insufficientspacingbetweenthetunnelsincaseof twin tunnels, the cover depth of the tunnel etc. The stability behaviour of tunnels is studied understatic loading and dynamic loading conditions. Especially strength characteristics of rock, coverdepth of thetunnel, spacing between the tunnels and introduction of liner material is studied onexperimentalanalysis.

II. TerminologiesinTunnelling

2.1 CrossSection

Crosssectionofthetunneliscomposedofthefollowingentities

- Crown:Thetopsurfaceofthetunnelisknownasthecrownofthetunnelalsoknownastheroof of the tunnel. It is referred to as the highest point of the curved surface of the cross-sectionofthetunnel.
- Lining: Lining act as a cover for rock and soil profile at the periphery of tunnel excavation.Liningcanbeoftwotypesi.e.primaryliningandsecondarylining.PrimaryLiningisreferredto as the structural lining which is placed against the ground surface whereas Secondaryliningis the lining which is used for decoration, improving the flow of fluid and protectionpurposes.
- Bench: The bench is referred to as the in-situ ground surface which is present at the lowerfaceofthetunnel.

- Invert:Thebottomsurfaceofthetunnelcross-sectionisreferredtoasinvert[4].

2.2. TypesoftheTunnel
Thedeformationcausedalonglengthofthetunnelsectionlargelydependsupontheshapeoftunnelsection.Hencetheshapeoftunnelsectionhasanessentialroleindeformationbehaviourofthetunnel.The varioustypesoftunnelsections

- **Circular Section** The circular section is considered the most suitable section where there isheavy radial pressure is exerted on tunnels. This type of section is capable of taking heavyloadexertedbyoverlying strataandwaterpressure.Figure2representsthestructure

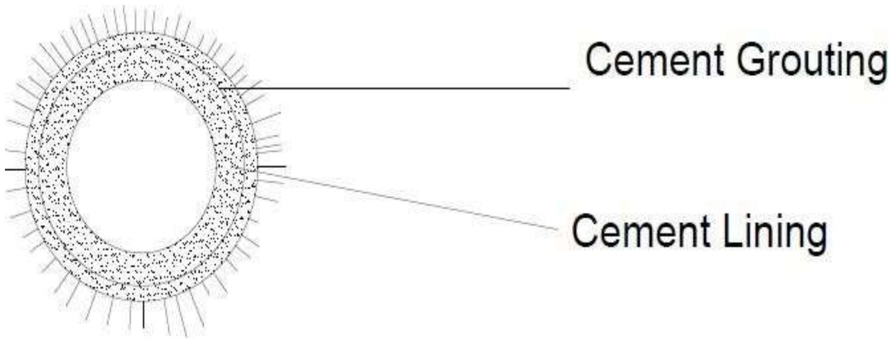


Figure2:StructureoftheCircularsectiontunnel

Horse Shoe Section: This type of section is considered the most popular and suitable typeof section for highways and railway tunnels worldwide. It is a combination of a circular andsegmentaltypeofsection.Asthenameimplied,theshapeofthistypeofsectionissimilartothe horseshoe. This section is made of three components i.e. semicircular roof, arched sidesand curved invert. The horseshoe type of section provides good resistance to the externalground pressure if it is lined with cement concrete. This type of section is most commonlyfoundinthe case of soft rock.Because of its flat floorsurface, during the process ofconstruction,itprovidesmorespaceforkeepingthematerialwhichisconvenientfor workersalso.

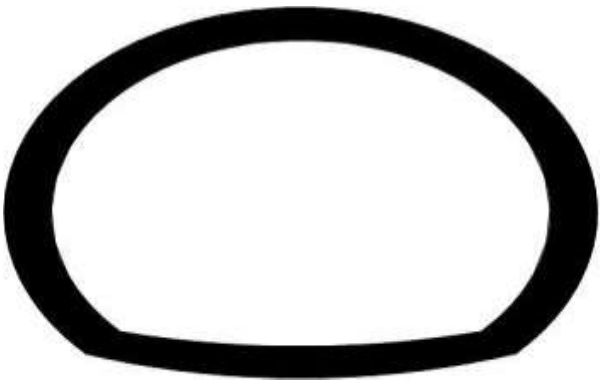


Figure3:Horseshoesectionofthetunnel

- D-Shaped or Segmental Section This type of tunnel section is also known as a segmentaltunnel.Thistypeoftunnelsection isgenerallyrequiredfortunnellinginhardrocks.
- EggShapeSectionThistypeoftunnelsectionisusedforcarryingsewageasitprovidesself-cleansingvelocityinweatherflowalso.Theegg-shapedsectioncanresistbothexternalandinternalpressuresduetoitscircularwallsgeometry.Thistypeofsectionisnotrecommended for traffic purposes as the construction process of the egg shape section isquitedifficult.
- Rectangular Shaped Section A rectangular type of tunnel section is highly used in the caseofhardrockstrata.Thistype ofsectionisalsousedforpedestriantraffic.Thedisadvantageof a rectangular type of section is that it is very costly to construct and also the cost ofconstructingarectangularsectionisalsoveryhigh[5].

2.2 Methodoftunnelling

During the construction of tunnels, different types of ground conditions have to face.Sometimes tunnels are constructed in soft ground conditions, where the construction of tunnels. isrelatively easy. In such cases, the excavation of tunnels becomes a challenge method of excavationoftunnelsmainlydependsuponthetypesofgroundconditionsthroughwhichthetunnelspass.Afterthe explosive is kept in these hol muck is done after that. This method is suitable for tunnels havinga diameter of less than 6metres.In this method of tunnelling, minimum equipment is required and itiseasytooperateasthe extentof themagnitudeof surfa16isrelativelyeasy.

Insomecases,tunnelsareexcavatedthroughhardrockhavingofcompressivestrength.Insuchcases,theexcavationoftunnelsbecomesachallengemethodofexcavationoftunnels mainlydependsuponthe types of ground conditions through which the tunnels pass. Some methods of construction oftunnelsarediscussed

FullFacemethod:Thefull-facemethodisusedforshorttunnelsi.e.lessthan3metreslengthtunnels.Inthismethod,alot ofholesaredrilledafterplacingverticalcolumnsatthefaceofthetunnelsectionas shown in Fig. 4. After the explosive is kept in these hol muck is done after that. This method issuitablefortunnelshavingadiameteroflessthan6metres[6].

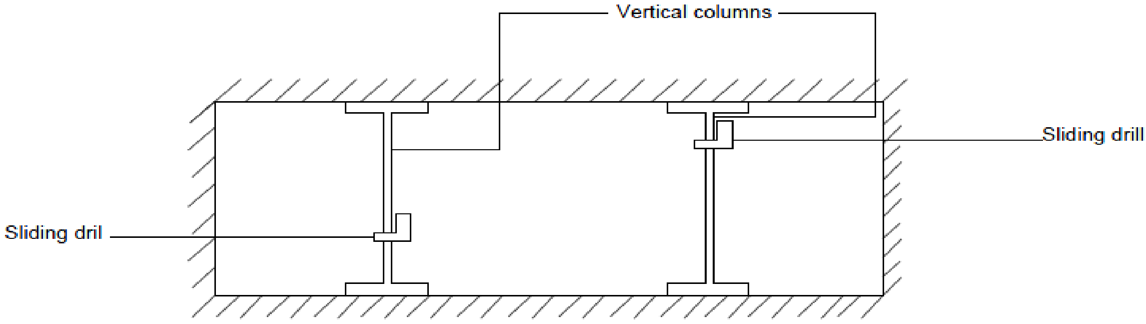


Figure4:FullFacemethodfortunnelling

Heading and Benching Method: The heading and benching method is the heading and benchingmethod,thetopportionknownasportionby3.70to9.6meters.

Inthecaseoftunnellinginhardrock,theheadingwillbeboredfirstandthenthedrilledholeswillbedrivenforthebenchasshownin Fig.5.This methodrequires very less explosive as compared to the full decreased nowadays because of thedevelopmentofdrillcarriage[7].

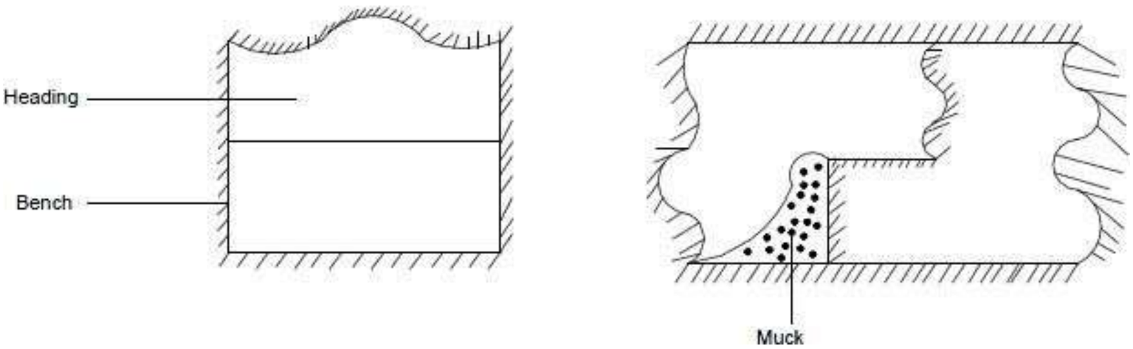
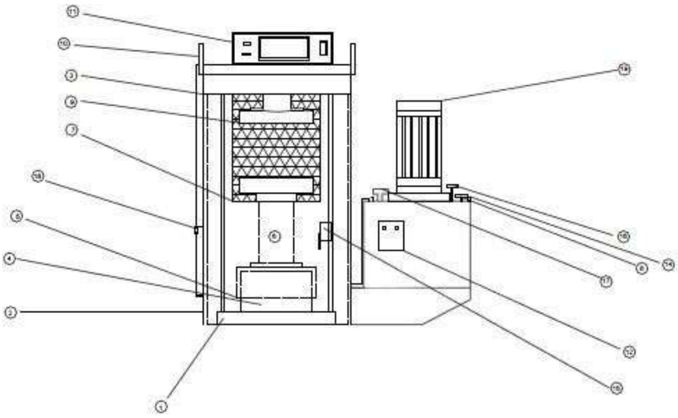


Fig.5:HeadingandBenchingMethod

III. Experimentalinvestigations

Accuratemeasurementofthecompressivestrengthanddeformationbehaviouroftunnelsisveryessentialforassessingthe stabilitybehaviouroftunnelsinrockmasswhichcanbeveryusefulforproposingsafeeconomicaldesignparameters.AnLVDTtransducerunitisalsoattachedtothecompressiontestingmachinetorecordthe deformationoccurringalongthetunnelaxis.



S.NO	DISCRIPTION
01	BASE PLATEN
02	SIDE PLATEN
03	UPPER HEAD
04	JACK
05	JACK COVER
06	SPACER
07	LOWER PLATEN
08	RELIEF KNOB
09	SPHERICAL SEATING
10	HOOK
11	ELE. DISPLAY UNIT
12	ON/OFF SWITCH
13	FLOW CONTROL KNOB
14	LIMIT SWITCH
15	BOOSTER LEVER
16	RELEASE LEVER
17	PRESSURE SENSOR
18	MOTER

Figure6:Schematicdiagramoftheloadingunit

Tunnels are investigated through a detailed and compressive method under static loadingconditions experiments are carried out in the laboratory with different parameters. The findings oftheexperimentsrevealed thatrockstiffness,the pressure exerted,and tunnel spacing playsasignificant role in the deformation of underground constructions[8]. In the case of rock with poorstrengthproperties,theextentofdamage isgreater.

Therefore to solve this problem, a material is found that can be used to prepare rock tunnelsamples and can be simulated to actual field situations. Three geo-materials are modelled in thelaboratorywhichrepresentstheweakrockproperties.Thesematerialsareselectedaccordingtotheirstress-strain behaviour. As the rock has an unconfined compressive strength the selection of modelmaterialisdonekeepinginmindthestrengthcharacteristicsof therock.

Figure7:InvestigationoftheAtalTunnelSiteduringConstruction

Numerical simulation is considered an affordable method as compared to experimentalstudiesinengineeringdesignandanalysis.Theboundaryofthenumericalmodelisdecidedaccordingtotheboundaryconvergencestudy.Thebaseofthetunnelmodeliskeptfixedforhorizontalandvertical movement whereas all other faces are kept free for movement. Direct Investigation of theataltunnel siteduringconstructionisrepresentedinthe figure7.

Meshing is the most important part of numerical modelling of tunnel. To decide the meshingsize ofthe different parts of the tunnel model, a mesh convergence study is carried out. From the meshconvergence study, it becomes easy to decide mesh density. Based on the mesh convergence study,the global meshing size for rock mass is taken as 8mm in the case of a single tunnel whereas in thecase ofa twin tunnel sample due to its large size, the mesh size for rock mass is taken as 10mm asrepresentedinthefigure8

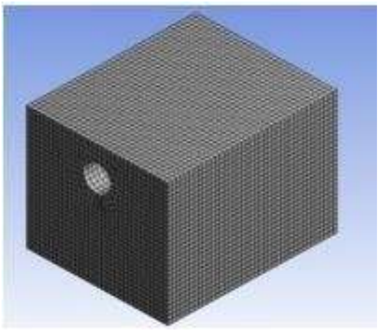


Figure8:SingleTunnelModel

In the case of numerical modelling,ANSYSsoftware isused forthe analysisof thedeformation behaviourof tunnel.Numerical modelling using FEM wasdone for modelling andmeshing of the tunnelin 2D. From the results, it was concluded that the horseshoe type of tunnelsection is the best section from a vertical stress point of view. The variation in the displacement ofthetunnel,internalforcesactingalongthelengthofthetunnelandstressacting nearbythevicinityofthe tunnel section are studiedand their variation with change in the thickness-radius ratio (t/r) is alsoinvestigated[9].Furtherfigure9illustratesthegasdetectionandlifesafetydisplayunit.

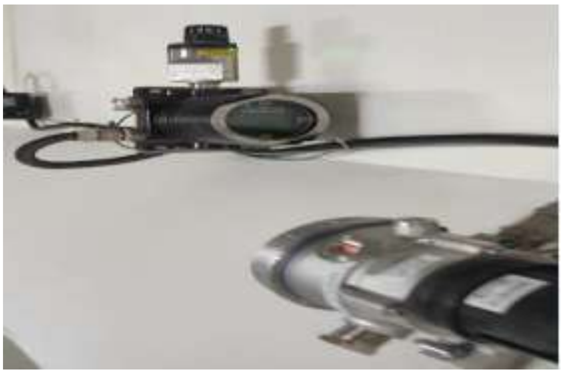


Figure9:Gasdetectionandlifesafetydisplayunit

Finally the effect of displacement, yield zone and stresses on underground structuresprovidesthat Stress concentration was almost the same in range and magnitude. Rock strength underpaired loadsincreases with increasing strain rates at the same axial pre-stress. Rock falls in tensilemode when subjected to combined static and dynamic loads. The stability behaviour of the tunneldependsonthecoverdepthanddiameterof thetunnelopening.

IV. DiscussionandResultsValidation

It was concluded that the stability of tunnels depends upon many factors such as types oftunnelsection,crackinclinationangleandstresscausedontunnelsduetooverlyingstrata.Thestand-uptimewillincreasewithanincreaseintheincreaseinmaximumallowabledisplacementoftherockmass.Figure10representsthedeformationofthetunnelonthevariousmodellingis illustrated.

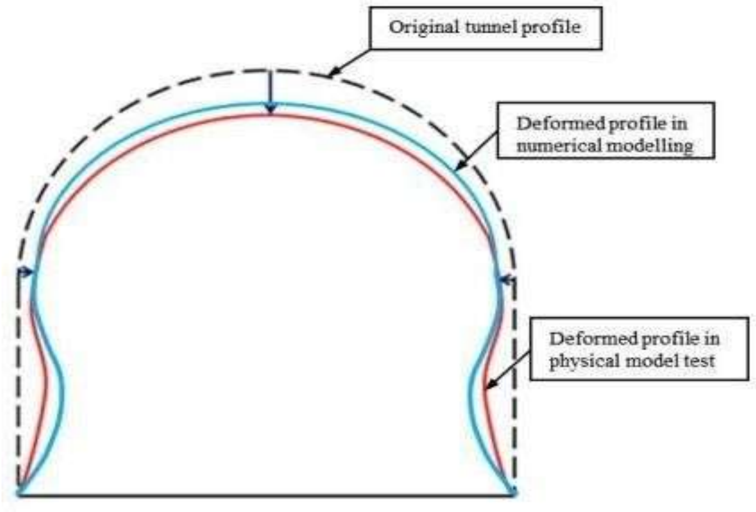


Figure10:Deformationcomparisonofthetunnelmodels

The strain in the lined tunnel is less than the strain in the unlined tunnel because of the resistanceofferedbythetunnellining. Thestrengthoftherockplaysanimportantfactorinstabilitybehaviour.Itis also observed that the extent of damage is maximum at the centre of the tunnel axis and it keepsonreducingtowardsthefaceofthetunnel.Theexcavationofanewtunnelinfluencesthedeformationbehaviour of a tunnel affects the displacement is represented in the figure 11. There is a significanteffectof thequalityofcompactiononthestress-inducedinthetunnellining.

Figure11:Deformationbehaviouranalysis

The variation in the displacement experience along with the tunnel length and velocityvariations experienced in the roof of the tunnel is larger as compared to the value of displacementand velocity noticed on the rest of the tunnel section. The value of displacement and change invelocity experienced on the floor of the tunnel is greater than the rest of the tunnel section. Thedisplacement decreaseswithanincreaseinspacingbetweenthetunnels.Finallysitevisitdetailsoftheataltunnelarerepresentedinthefigure12.

Figure 12: Site visit details of Atal Tunnel

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