3D Visual Modeling Technique for Complex Surface Configuration above Mined-out Regions

WANG Shu-ren[1], ZHANG Hai-qing[2] , WANG Shu-li[3,] CHENG Dun-wu[4]

[1,2]*School of Civil Engineering and Mechanics , Yanshan University, Qinhuangdao, China*

[3,4]*School of Engineering & Technology, China University of Geosciences, Beijing, China*

Email: W_sr88@163.com , Wsl6666@yahoo.com

Abstract: It is the premise and base of numerical calculation to build a 3D visual model that reflecting the engineering reality based on representation of land form of engineering geologic body, occurrence of ore-rock and distribution of complex mined-out regions. On the background of MC_6 mined-out regions under Yangquan-Yuxian highway, the three-dimension geometry model and mesh are built firstly, through the strong pre-processing capacity of MIDAS/GTS, according to the engineering geological survey data (topographic contour, geologic section, prospect drilling and physical prospecting, and so on); secondly, by the interface program of MIDAS/GTS-FLAC^{3D} complied with MATLAB language, the mesh model built in MIDAS/GTS is imported into FLAC^{3D}, thus the correct 3D visual model of complex mined-out regions is fast built in FLAC^{3D} with high efficiency. The engineering example verifies the feasibility and effectiveness of the coupling method which can provide new thoughts for building three-dimension numerical model for complex engineering.

Keywords: three-dimension model; coupling modeling; mined-out regions; MIDAS/GTS; FLAC^{3D}

1. Introduction

Hazardous assessment and surface subsidence analysis for the mined-out regions under the highway mainly include predicting method, analytical method, semi-predicting and semi-analytical method and numerical method. At present, it mainly adopts numerical simulation method to make hazardous assessment for coal mined out area which has relief surface, interlaced gullies, complicated occurrence condition of coal seams and complex mined-out regions. Therefore, it is the premise and basis of a credible result to build a 3D visual numerical model which reflecting the engineering practice, meanwhile, the implementation of 3D visual modeling for complex geological body is still a difficult problem.

At present, research on 3D modeling method for geological body of mined-out region, coal mine and underground chamber is to be unfolding. For example, the generalized tri-prism (GTP) model[1] (Wu, 2004) and similar tri-prism (STP) method[2] (Cheng et al, 2004) have been proposed ; Wu et al[3] presented super-volumetric model, fault mathematical model and fold geometric model to express the spatial geometric forms of complicated geological structure. He et al[4,5] developed a 3D visual modeling system for engineering rock-mass and proposed vertical generalizing rule and layered method of processing generalizing rule for original drilling data and the method of blocking of data, reference TIN and slabbing of interface have been proposed by Zhang and Zhu et al[6], providing thoughts for magnanimity data processing and complex strata modeling. The above researches are mainly aiming at 3D visual modeling for geological body from which a visual model according with engineering practice can be obtained while, the visual grids of 3D geological model in geoscience simulation software can not be directly used in finite element method because of the difference of data structure and algorithm[7,8].

In order to establish a reasonable 3D model of engineering geologic body accurately and rapidly, some researchers study on data transformation method by which the model data in 3D geoscience modeling software are transferred to numerical simulation software, such as the data interface between GOCAD and ABAQUS[9], and the data transformation from SURPAC to FLAC^{3D}[10]. Aiming at the dual target of geoscience visual modeling and numerical simulation modeling, coupling modeling methods for both visualization and numerical calculation are put forward by some other researchers, for instance, the local-whole (L-W) model for 3D visualization and FEM[8] (Wang and Bai, 2004), the refined 3D engineering geological integrated model[11] (Li and Zhong et al, 2007), the CRM Geologic Model Transforming Method[12] (Li and Zhu et al, 2008) and the new method of building a 3D engineering geological model suitable for numerical simulation by Xu[13] (2009). The achievements above promote the further development of the combination of 3D geological modeling and numerical calculation.

MIDAS/GTS is a geotechnical and tunnel analysis system which enables engineers to intuitively generate complex geotechnical and structural models with its windows type interfaces operated through clicking the interactive menu and its strong features of geometry modeling and mesh generation. MIDAS/GTS can carry out data exchange including data import and export, for example the AutoCAD DXF data can be imported into MIDAS/GTS (Wireframe only), and the model meshes in MIDAS/GTS can be exported as excel files of element and node data through the "Model" menu, and also there is a internal Terrain Geometry Maker (TGM) which can read DXF data of topographic contour to generate complex curve easily.

On the background of MC_6 mined-out regions under Yangquan-Yuxian highway from which the engineering geological survey data (topographic contour, geologic section, prospect drilling and physical prospecting, and so on) obtained, the three-dimension geometry model and mesh model are built firstly through the strong pre-processing capacity of MIDAS/GTS ; secondly, the mesh model built in MIDAS/GTS is imported into $FLAC^{3D}$ by the interface program of MIDAS/GTS-$FLAC^{3D}$ complied with MATLAB language, thus the correct 3D visual model of complex mined-out regions is fast built in $FLAC^{3D}$ with low difficulty. The flow chart of model data transformation from MIDAS/GTS to $FLAC^{3D}$ is shown in Chart 1.

2. 3D Engineering Geology Modeling

2.1. Terrain surface

According to site investigation and engineering geological drilling data, the topographic contour of MC_6 mined-out regions are processed from two-dimensional to three-dimensional in view of terrain and physiognomy and engineering characteristics (Fig.2).

With the DXF file of topographic contour obtained from the last step, the terrain surface is generated by using Terrain Geometry Maker (TGM, Fig.3) built-in MIDAS/GTS which is then imported into the pre-processing module of MIDAS/GTS for cutting entity, the resulting geomorphologic shape of surface rock-soil mass is shown in Fig.4.

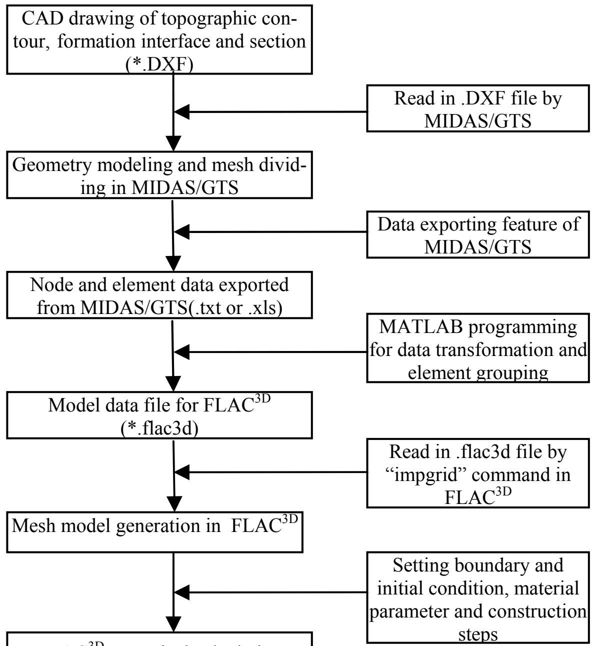

Figure 1. Flow chart of model transformation.

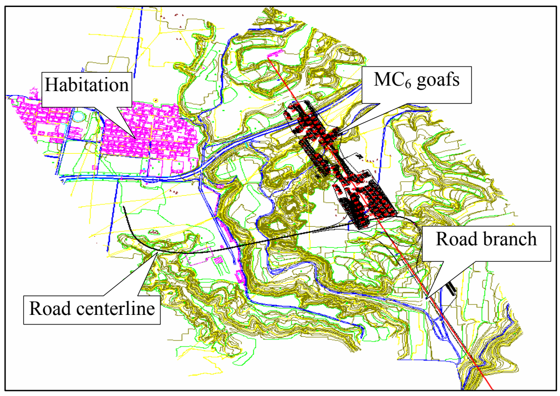

Figure.2 Relative position relationship of highway line and mined-out regions.

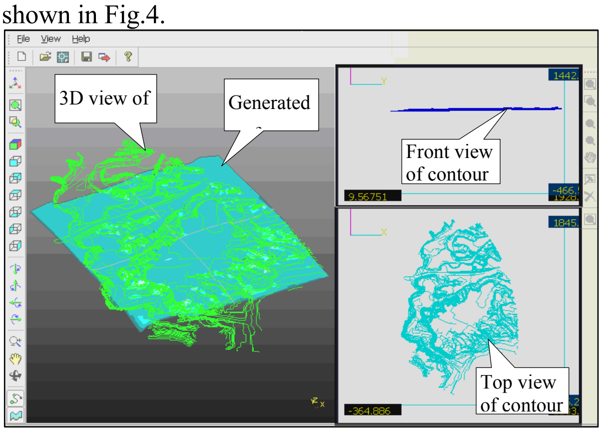

Figure.3 The terrain geometry maker in MIDAS/GTS

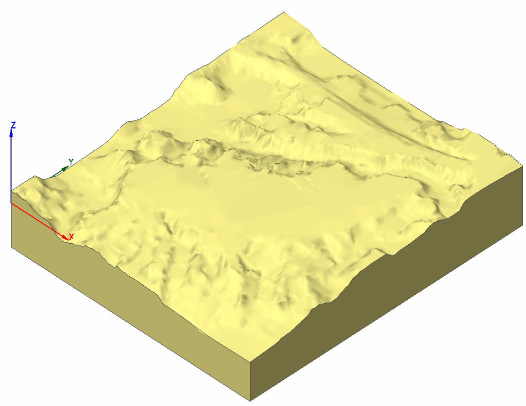

Figure.4 Surface landform features

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2.2. Formation Lithology Determination

Based on strata geologic sections of MC_6 mined-out regions and the lithological geological columns (Fig.5 and Fig.6), the strata are generalized into 11 lithologies with a view to strata thickness and coal occurrence. The final 3D engineering geological model can be seen in Fig.7.

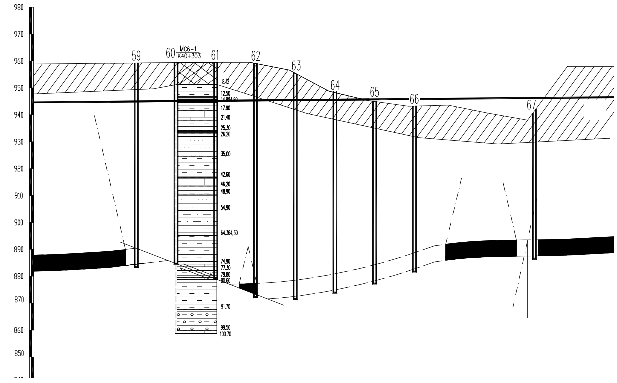


Figure.5 Strata vertical section of MC_6 mined-out regions

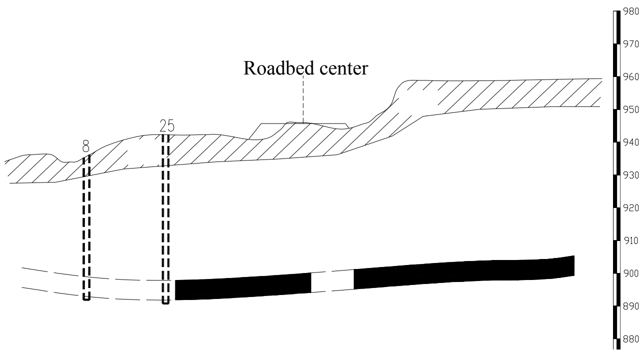
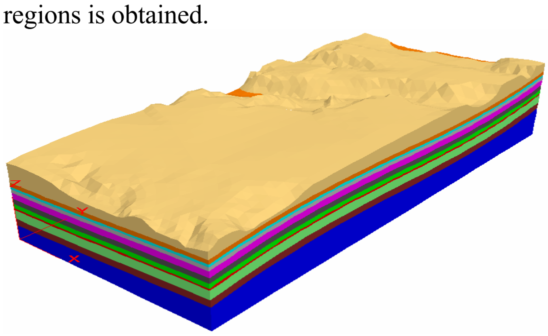
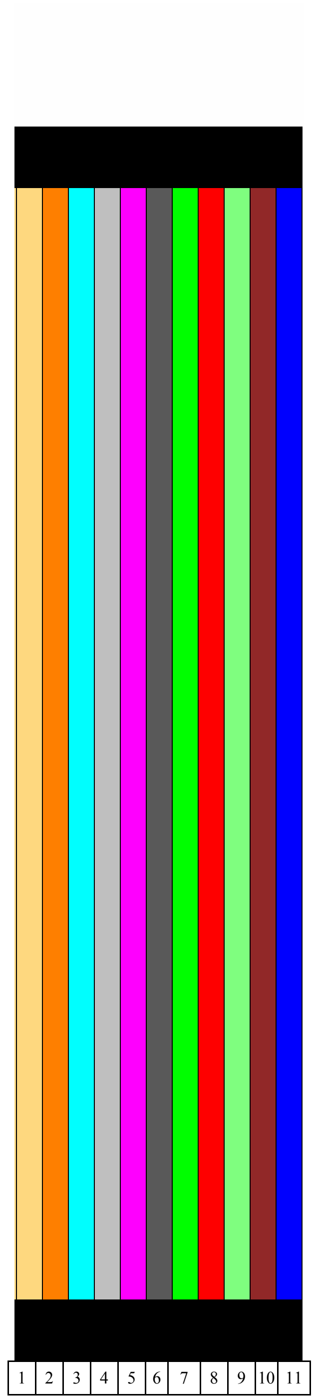


Figure.6 Strata cross section of MC_6 mined-out regions

3. Coupling Modeling Method with MIDAS/GTS-FLAC3D

With the help of coupling modeling method of MIDAS/GTS-FLAC^{3D}, the mesh model built in MIDAS/GTS is imported into FLAC^{3D} by the interface program complied with MATLAB language, thus the complex FLAC^{3D} model of highway above mined-out regions is obtained.





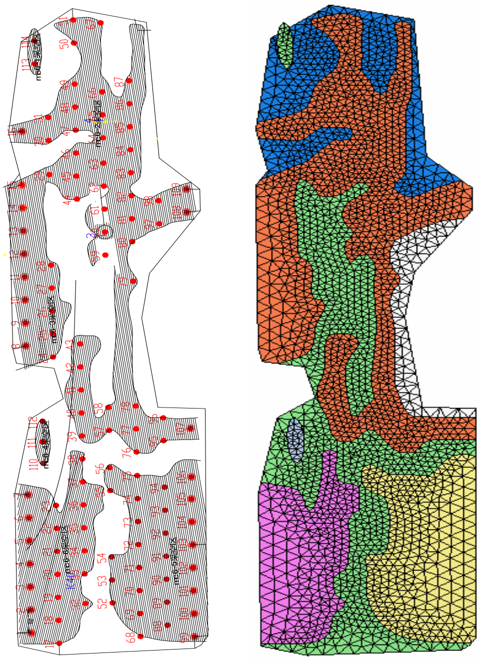
1—clay; 2, 4, 6, 9—mudstone; 3, 7, 11—limestone; 5—sandstone; 8—coal seam; 10—sandy conglomerate

Figure.7 Engineering geological model

3.1. Abbreviations and Acronyms

It can be determined that the goaf treatment length is 540 m and the treatment width is 129 m according to the treatment engineering design report of MC_6 mined-out regions. And the goaf outline is depicted in the form of DXF file based on the marked mined-out regions (Fig.8(a)) which is subsequently imported into

MIDAS/GTS for 3D modeling. Distribution of the mined-out regions in the model is shown in Fig.8(b).



(a) survey (b) model

Figure. 8 Distribution of the mined-out regions

Fig.9 shows the roadbed model including fill and excavation according to roadbed elevation (with reference to the relative elevation of roadbed and coal seam) and width (24.5 m).

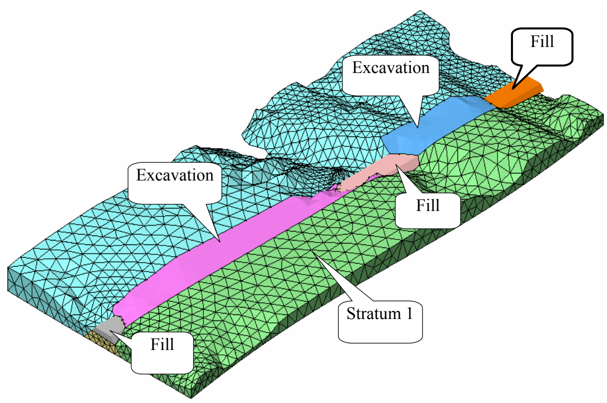


Figure. 9 Roadbed model including fill and excavation

Through a series of body segmentation, insertion and boolean operation, the 3D geometric model is obtained. Then tetrahedral mesh is generated by free meshing function of MIDAS/GTS and mesh groups is divided. Finally, the 3D calculation model of highway engineering above mined-out regions is established in MIDAS/GTS.

3.2. Data Export of MIDAS/GTS 3D Model

By means of the export function of MIDAS/GTS, the node and element information is exported from MIDAS/GTS and stored in two text files known as node.txt and zone.txt which can be called by a self-compiled interface program, thus the *.flac3d file according with FLAC^{3D} data format is generated.

3.3. 3D Model Imported from MIDAS/GTS to FLAC^{3D}

By using the FLAC^{3D} command "impgrid", the above-mentioned *.flac3d file is read in and by which the 3D mesh model used for numerical calculation is generated in FLAC^{3D} (Fig.10). Then numerical analysis can be carried out in FLAC^{3D} after setting the material parameters, boundary conditions and construction steps.

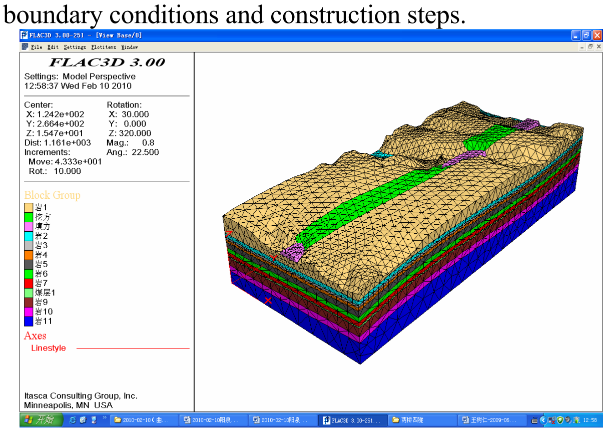


Figure.10 3D computation model

4. Conclusions

A coupling modeling method with MIDAS/GTS-FLAC^{3D} is put forward in view of the technical difficulties and deficiencies in pre-processing for complex geological body and structural engineering with FLAC^{3D}. The new method can not only avoid the complex programming work for developing geoscience modeling software, but also overcome the limitations of common FEM software in its tedious modeling process for complex geological body.

A MIDAS/GTS-FLAC^{3D} interface program is compiled in MATLAB, with a view to the strong geometry modeling, flexible mesh dividing and fine mesh localization features of MIDAS/GTS and the speciality of FLAC^{3D} for geotechnical engineering calculation and analysis. After element and node data is transformed by using the interface program, the model is imported into FLAC^{3D}.

It is verified by the 3D visual modeling example of MC_6 mined-out regions under Yangquan-Yuxian highway that the feasibility and effectiveness of the coupling method which, can provide new thoughts for building three-dimension numerical model for complex engineering.

5. Acknowledgment

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