Construction information computer assisted decision making system for highway tunnels

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Abstract: In order to improve and develop techniques and methods of highway tunnel building, it is quite important to raise the quantitative levels of tunnel building by synthesising theory analysis, experienced judgment, monitoring measurements and computer techniques. The highway tunnel construction information and computer assistant decision-making system is studied systematically in this paper.

Firstly, all kinds of theories and methods for traditional construction information for tunnels is generalised and summarised in the paper. Also, the paper develops the contents of traditional construction information, brings the surrounding rock classification, high geostress distinguishing and rock burst forecasting into construction information category. In this way, the tunnel construction information is more applicable and correct.

On the basis of the above, the total design of a computer assisted decision-making system for highway tunnel construction information is put forward using software engineering technology. The detailed design of the system is finished and the software is realised by use of database technology and software engineering technology. The software system has four important functions, namely the intelligent classification of the wall rock, the analysis and forecast of wall rock stress, analysis and forecasting of wall rock deformation, and security determination of wall rock supporting structures. The system has a user-friendly interface.

Finally, taking Zhegu Mount highway tunnel located in west China as an example, its intelligent classification of surrounding rock, discrimination of high geostress, analysis of wall rock deformation, and evaluation of supporting structure security are conducted by the computer assisted decision-making software system. The results show that the software system basically meets the needs of highway tunnel construction information; it gains a good user effect.

Résumé: Pour augmenter le niveau de la qualité de la construction informatisation du tunnel routier, il est important que les techniques et les méthodes sont améliorées par l'analyse théorique synthétique, jugement experimental, mesure en surveillance et technique d'ordinateur. La construction informatisation du tunnel routier et un système de la décision assistée par ordinateur sont étudiés dans notre article.

A base de l''étude, un système de la decision assisté par ordinateur pour la construction informatisation du tunnel routier est établié en utilisant une technique du logiciel engineering. Ce système (Tunnel-CAS 1.0) est réalise par utilisation de la base de données et de technique du logiciel engineering. Le système a quatre functions importantes: la classification intelligente de la roche du mur, l'analyse et la prevision de la tension de la roche du mur, la deformation de la roche du mur et la determination de la sécurité de la structure supportée de la roche du mur. Le système a une interface amicale en utilisant.

Keywords: tunnels, database systems, geodata, deformation, stress, safety

INTRODUCTION

Although the New Austrian Tunnelling Method (NATM) has been widely used in China for about 30 years, there is still a large amount work to do on the automatic management of in situ monitoring data and it's feedback application. Computers are generally used to undertake simple data processing and intelligent functions are seldom used, which makes the feedback difficult to utilise in the construction information for highway tunnels. There are two reasons; one is that computer assistant decision-making systems for highway tunnel construction have not been developed, and the second is because of the restriction of people's recognition of the complexity of soil and rock. With the development of computer techniques, visualised programming code (such as Delphi,VC++), database management, OOP and ADO are developed quickly. At the same time the theories of construction information of tunnel and underground engineering have been developing step by step. This provides good conditions for developing computer-aided decision-making systems. Under such background, the concept model of construction information for highway tunnels is given in this paper. In addition, the computer-aided decision-making system for highway tunnel construction information (Tunnel-CAS 1.0), is introduced which is developed by the authors on the basis of tools of programming codes and database.

CONCEPT MODEL OF CONSTRUCTION INFORMATION

Tunnel construction information is the key part of NATM. The basic process is that during construction in-situ monitoring systems to test the surrounding rock displacements, convergence and the stress on structures are installed analysed. The information obtained from the field monitoring system is fedback to the dynamic designing and construction decision-making, that is, adjust the scheme of cutting and supporting, modify the supporting parameters. Finally, optimise the tunnel construction.

Construction information can ensure the safety of the project, and bring economic benefit and benefit to society. Considering the complexity of tunnel engineering, it is necessary to adopt construction information, especially when the geological conditions are very complicated and the quality of information required is high. Traditional construction information hasn't payed much attention on tracking geological change along the tunnel alignment and adjusting the class of the surrounding rock mass. It emphasises the monitoring on rock mass deformation, but little on the feedback application of test data. Combining the properties of engineering construction (around high geostress and at great depth) in southwest of China, this paper expands the contents of construction information for tunnels, and put forward its concept model (Figure 1). It details the new idea that besides the monitoring of displacement and stress, it is more important to pay attention to the feedback of field information and optimisation of construction parameters. Besides the traditionally measured items, the geological tracking investigation and testing, the frontage forecasting on geology, the dynamic classification of surrounding rock, the judgement of high geostress and the rock burst prediction should all be involved in the domain of construction information.

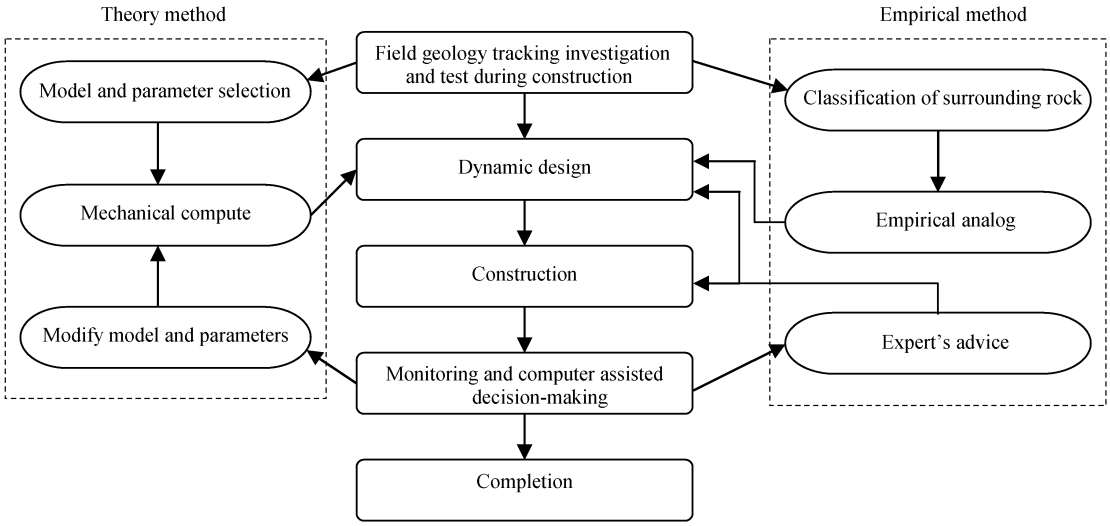

Figure 1. Concept model for tunnel construction information

TOTAL DESIGN OF THE SYSTEM

The computer assistant decision-making system of construction information for highway tunnels is made up by database systems, an intelligent judgement sub-system for surrounding rock mass classification, a surrounding rock mass stress analysing and forecasting sub-system, a surrounding rock mass deformation analysing and forecasting sub-system and a safety judgement sub-system for support structures (Figure 2). In the whole system, the database system is the public sub-system, which stores and manages the total files and data obtained from the whole tunnel construction, and it is the base of all the sub-systems. The classification of surrounding rock mass and the rough selection of support measurements are to be finished by the intelligent judgement sub-system for surrounding rock mass classification. The high geostress analysis and the rock burst prediction are to be finished by the surrounding rock mass stress analysing and forecasting sub-system. The stability analysis of surrounding rock mass is to be finished by the deformation analysing and forecasting sub-system, and the support structure safety judgement sub-system mainly deals with the stress analysis in structure and alarm of it's safety.

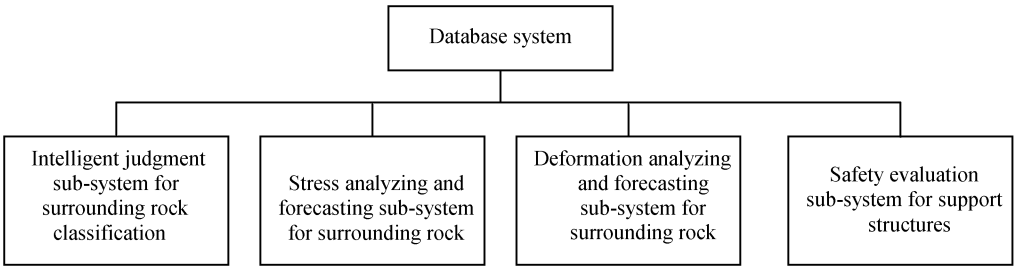

Figure2. Basic structure of the computer assistant decision-making system for highway tunnels

REALISATION OF THE SYSTEM AND ITS FUNCTION

Database sub-system

The database sub-system is the basic part of the whole system. It includes most of the parameters in the construction of highway tunnels, such as geological parameters, support structure parameters, monitoring instrument parameters and test data. Due to the complicated relationships among these parameters, a new way is needed to display them. In this paper, an ER (Entity Relationship) Model is used to design the database sub-system. The entity, relation and property are the basic elements of the ER Model. Every sub-system's ER Model database is built by system analysis respectively. Figure 3 details the ER model of tested stress on an H-beam steel frame. Entity is defined as an object of data, such as installation information of monitoring sections, parameter information of monitoring instruments and test information of stresses on the H-beams steel frame. The relationship is defined as a kind of action among entities, namely, the relationships among two or more entities, such as the one to one relationship between installation information of monitoring sections and stress testing on the H-beam steel frame and that between parameter information of monitoring instruments and stress testing on the H-beams steel frame. Property is one characteristic of entity, such as the test time, the test value and so on. The only property that can represent the entity is called the main key of entity, such as the serial number.

This software system (Tunnel-CAS 1.0) is developed using Delphi code. The database is driven by BDE (Borland Database Engine), in which Paradox is adopted as its basic format.

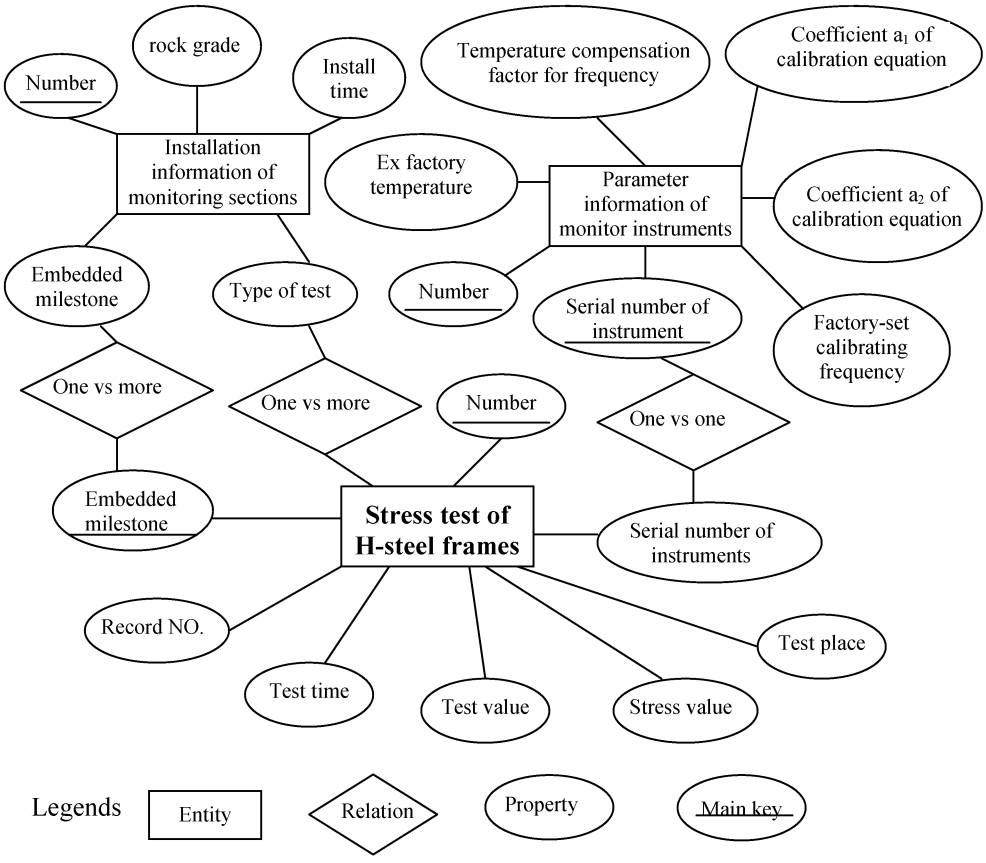

Figure 3. Entity relationship model of H-beam steel frame force monitoring

Intelligent judgement sub-system of surrounding rock classification

The intelligent judgement of surrounding rock mass classification consists of two parts, and is realised by two sub-modules respectively (Figure 4). The first module makes routine classification of surrounding rock mass according the criterion of highway tunnel design in China, and its precision is comparatively low. It builds an improved nerve network model of VLBP to make intelligent judgement of surrounding rock class on the basis of the BP nerve network model, and compares the results with the pre-determined class of surrounding rock mass, and then gives the parameters of initial supports. The second module makes the classification depending on the self-classification scheme of every tunnel that is established in the early tunnel construction, and it has comparatively high precision. It first builds a classification scheme based on the tunnel geological condition, and then combines the field tracking investigation data of surrounding rock mass, establishes and trains the nerve network model of VLBP for the surrounding rock rating, and makes intelligent judgement of the rock mass classification. Finally it gives the initial support measurements and parameters.

Stress analyzing and forecasting sub-system for surrounding rock

This sub-system includes two sub models (Figure 5). The first model is in charge of qualitative judgement on engineering geological phenomena. It determines whether there exists high geostress on the base of field observation information and simple testing data. The second gives quantitative evaluation on high geostress and rock burst according to the rock mechanics theory, that is, differentiate high geostress with the ratio of uniaxial compressing strength of saturated rock (R_b) and maximum initial principal stress (σ_1), and predict rock burst with the rock burst trend index (Wet) or the stress-strength ratio ($\sigma_{\theta max}/R_b$), (here σ_θ max is maximum tangential stress of surrounding rock at the surface of tunnels). In view of the shortage of in-situ test data about initial geostress and secondary stress of surrounding rock along whole tunnel, the former can be obtained by back analysis of the geostress field with FEM, and the latter can adopt the results of the FEM computation on secondary stress of surrounding rock.

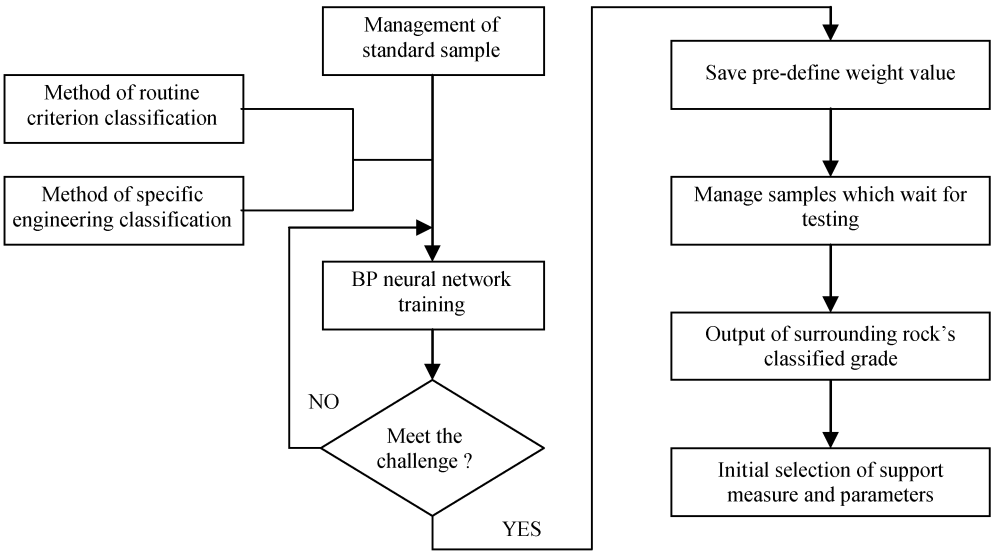

Figure 4. Flow chart of wall rock's intelligent classification subsystem

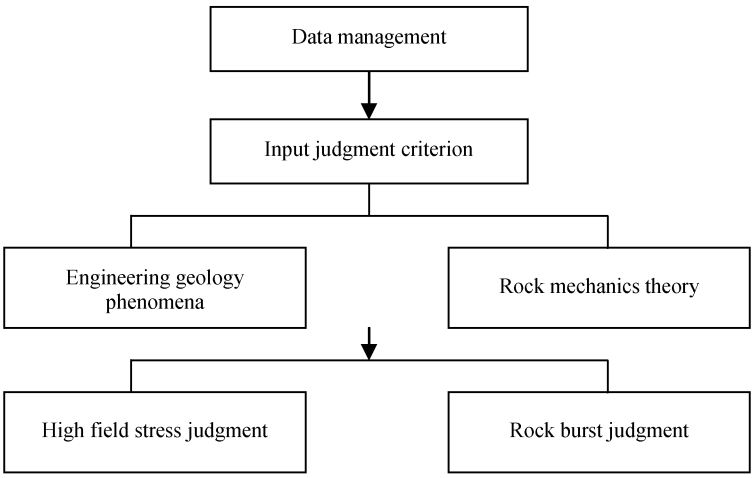

Figure 5. Flow chart of wall rock stress analysis and forecast subsystem

Deformation analysing and forecasting sub-system for surrounding rock

This sub-system mainly analyses and predicts the surrounding rock stability from two aspects (Figure 6) as fellows:

Surface displacement analysis of surrounding rock; using the real-time testing data of the convergent displacement in side wall and the subsidence in arch crown, computing their velocity and acceleration and plotting the curves of displacement-time, velocity-time and acceleration-time. It finally predicts the value of displacement and the displacement velocity of the surrounding rock by a regressive method. If the values are larger than the permitted values, it gives an alarm of surrounding rock instability, otherwise, it outputs the final deformation values.

Interior displacement analysis of surrounding rock; this plots the curve of displacement-time with the real-time testing data of displacement in the interior of surrounding rock, and predicts the final displacement value with the regressive method. Finally, it determines the thickness of loose loop of surrounding rock according to the displacement curves vs. different time and different depth.

Safety judgement sub-system for support structures

The safety judgement sub-system can compute axial stress of anchors, pressure of support steel frames, stress in shotcrete lining, contact stress between initial lining and secondary lining, and stress in secondary lining with the in-situ testing values of sensor's frequency obtained from each kind of monitoring apparatus. It can also make regressive analysis for various data, and finally give the evaluation of the support structure's safety (Figure 7).

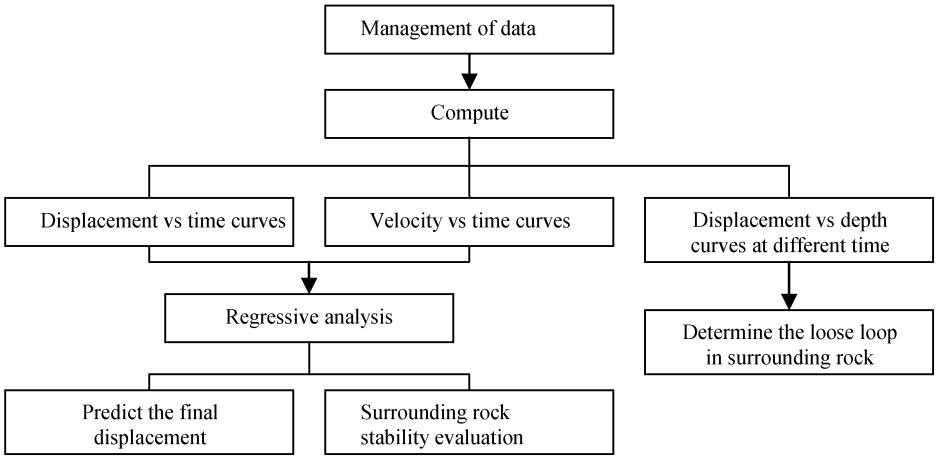

Figure 6. Flow chart of wall rock deformation's analysis and forecast subsystem

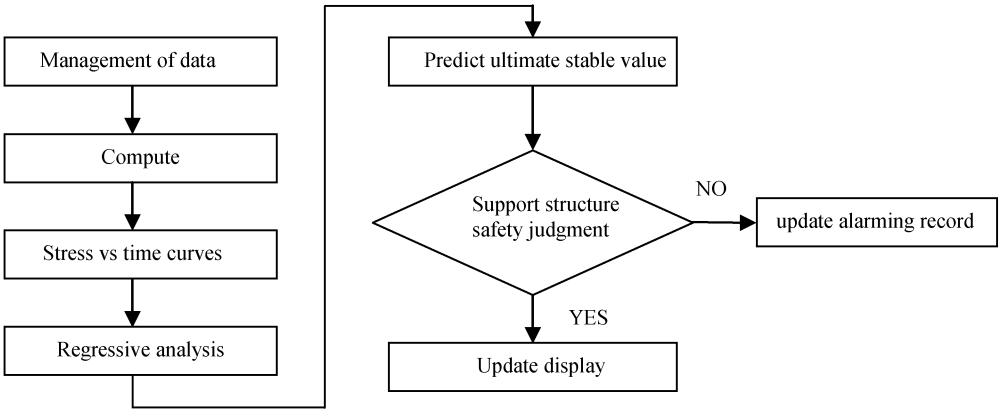

Figure 7. Flow chart of the safety judgement subsystem for support structures

APPLICATION IN ENGINEERING

The main interface of the construction information computer assisted decision-making system for highway tunnels (Tunnel-CAS 1.0) is shown in Figure 8. It was first used in the construction of Zhegu Mount highway tunnel in west China. Tunnel-CAS 1.0 used the intelligent classification of surrounding rock, discrimination of high geostress, analysis of wall rock deformation, and evaluation of supporting structure security. The results show that the software system basically meets the needs of highway tunnel construction information, and gains a good user effect. Selecting the intelligent judgement of surrounding rock classification as an example, Table 1 shows the results after comparing the real ratings on 356 points obtained from real-time field investigation with the ratings on the same points obtained by intelligent judgement by the software. The results show that compared with the field investigation ratings, the

outcome of VBLP's intelligent judgement can satisfy the demand of predefined precision with the total error ratio 18.3%, the right ratio 81.7% and the error ratio of every ratings of surrounding rock lower than 8%.

Table 1. Wall rock's classification statistics between field classification and VLBP judgement

Rating	Numbers of field classifications	Numbers by VLBP judgement	Offset numbers	Error ration (%)
I	7	4	3	0.45
II	98	68	30	4.2
III	159	216	57	8.0
IV	85	53	32	4.5
V	6	14	8	1.1
VI	1	1	0	0
Total	356	356	130	18.3

CONCLUSIONS

- This paper expands the contents of traditional construction information and puts forward the concept model for it. Besides the traditional measured items, the geological tracking investigation and tests in construction, the frontage forecasting on geology, the surrounding rock dynamic rating, the high geostress distinguishing and rock burst forecasting are all involved in the domain of construction information.

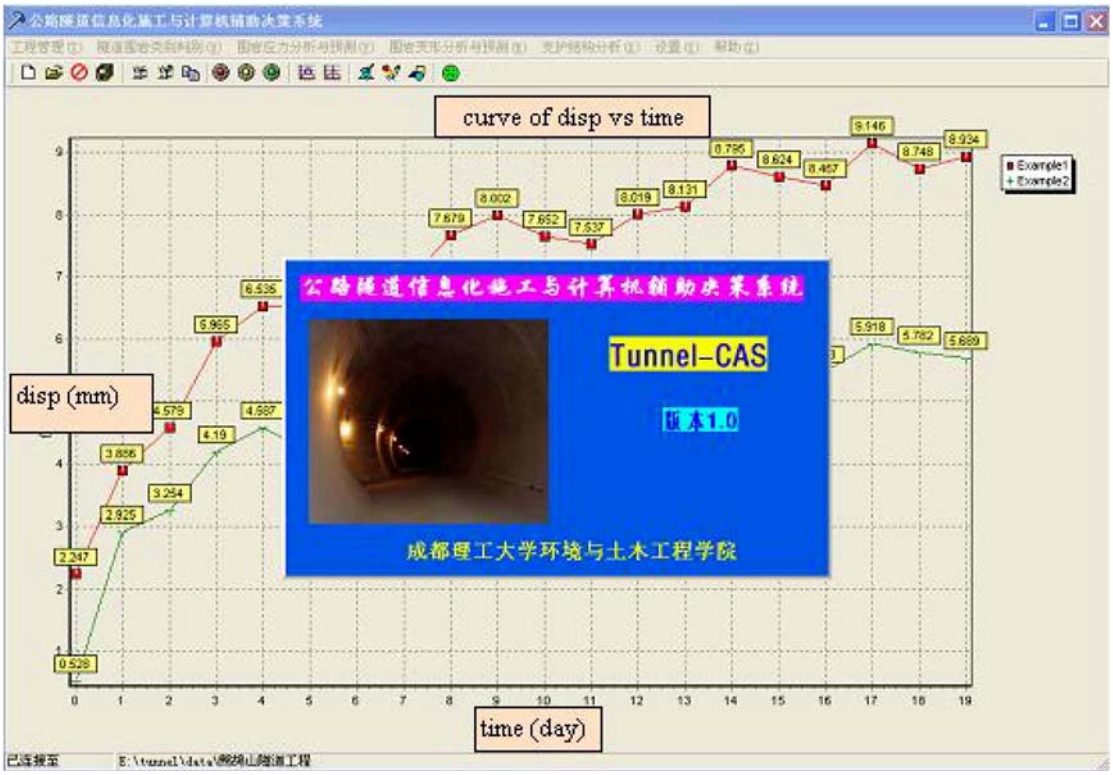

Figure 8. Main interface of the computer assisted decision-making system for highway tunnels

- Under the guide of the system engineering idea and on the basis of new research results in geological engineering and rock mechanics, this paper develops the computer assisted decision-making system of construction information for highway tunnels (Tunnel-CAS 1.0). This software system is built on databases, and has four major function models, namely, intelligent judgement sub-system for surrounding rock classification, stress analysing and forecasting sub-system for surrounding rock, deformation analysing and forecasting sub-system for surrounding rock and safety judgement sub-system for support structures.
- The construction information computer assistant decision-making system for highway tunnels (Tunnel-CAS 1.0) is validated from many aspects in the construction of Zhegu Mount highway tunnel. The results show that it can basically satisfy the demand of construction information for highway tunnels. We can expect that it can provide a good way for enhancing the technical level in tunnel instruction.
- The construction information computer assistant decision-making system for highway tunnels (Tunnel-CAS 1.0) does not have a rigorous demand on computer hardware, and it has a friendly interface and operates easily. Convenience and utility are the software package's strong points.

Acknowledgements: This study was supported by the fund for Prominent Younger Subject Leaders Cultivation Plan in Sichuan Province, PRC. The serial number of research project is 03ZQ026-045.

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