

Management of Mining-related Damages in Abandoned Underground Coal Mine Areas using GIS

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Abstract: The mining-related damages such as ground subsidence, acid mine drainage(AMD), and deforestation in the abandoned underground coal mine areas become an object of public concern. Therefore, the system to manage the mining-related damages is needed for the effective drive of rehabilitation activities. The management system for Abandoned Underground Coal Mine using GIS includes the database about mining record and information associated with the mining-related damages and application programs to support mine damage prevention business. Also, this system would support decision-making policy for rehabilitation and provide basic geological data for regional construction works in abandoned underground coal mine areas.

Keywords: Abandoned Underground Coal Mine, Ground Subsidence, Acid Mine Drainage(AMD), Shafts and drifts, Abandoned Mine GIS(AMGIS)

1. Introduction

Due to decrease of coal demands and closure of the 336 coal mines, safety accidents and environmental contaminations caused by mining-related damages such as ground subsidence, acid mine drainage(AMD), and deforestation in abandoned underground coal mine areas have been socially issued.

That is the reason why the Coal Industry Promotion Board(CIPB) has continuously carried out mining-related damages restorations and environmental improvements.

Also, CIPB has plan to establish AMGIS(Abandoned Mine GIS) for mining-related damages for 336 abandoned underground coal mines (1,121 km²) in South Korea from 2003 to 2009. This system will work out analytical management and synthetic prevention for countermeasures against mining-related damages.

2. Mining-related Damage Restoration by CIPB

1) Ground Subsidence Prevention

The project of ground subsidence prevention is composed of primary and detailed investigation, survey measurement, reinforcement work, and verification of effectiveness in order to prevent the safety accident

caused by ground subsidence in abandoned underground coal mine areas.

Primary and detailed investigations are the processes that survey and evaluate the ground subsidence probability for surface and subsurface geological condition through mining record, geological mapping, geophysical prospecting and drilling for the site beneath which abandoned underground coal mines may exist.

After the investigations, survey measuring the deformation of surface and bedrock overlying shafts and drifts by measuring instruments is conducted.

Based on the results of the surveys, ground reinforcement using grouting material such as cement mortar and cement milk is conducted and its effectiveness is verified by drilling or survey measurement.

2) Remediation of Acid Mine Drainage(AMD)

Most coal mines are located in mountainous areas, particularly the Gangwon Province from where the uppermost of the Nakdong and Han rivers are originated.

CIPB has applied the natural purification engineering method to treat AMD caused by heavy metal leaking from mine opening. The AMD is purified by SAPS (Successive Alkalinity Producing System) I and II to neutralize acidic mine water, and reduce and settle iron; at the swamp, remaining iron is removed by sulfate reducing bacteria.

Also, it applies physio-chemical purification method to the site where the natural purification engineering method is hard to apply because the volume of waste water and the degree of contamination are too high.

3) Restoration of Forests

Forest restoration before 1995 was simply for preventing waste stone from being washed away, so it could not achieve afforestation over time but rather the restored area was washed away or the view was ruined.

The CIPB adopted an engineering method considering the characteristics of waste stone and vigorous trees. Using the method, the restored areas were protected from torrential downpours and afforestation was achieved in a short period.

3. Geographic Information System for Mining-related Damages

AMGIS includes building database and developing an expert system which can support decision-making policy for rehabilitation in abandoned underground coal mine areas and provide basic geological data for regional construction works.

In pilot project, the CIPB built up spatial and attribute data for 8 abandoned underground coal mines in the Samcheok City, and developed application programs to analyze and estimate the mining-related damages in server/client system environment. Fig. 1 shows the system configuration of AMGIS.

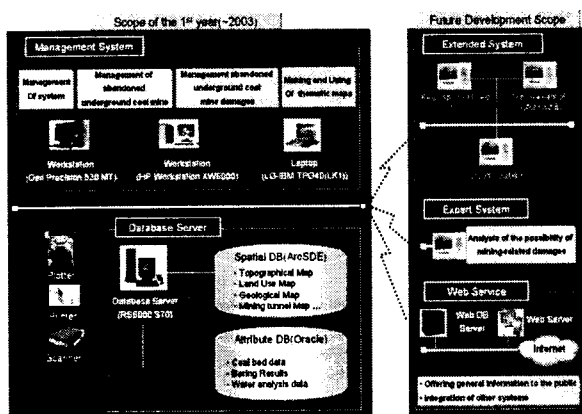


Fig. 1. System configuration of AMGIS

The server side consists of ArcSDE for management of spatial database and Oracle RDBMS. The client side consists of workstations where the client applications based on ArcGIS are loaded.

1) GIS Spatial Database

1. Topographical map: road, railroad, river, building, administrative districts, height contour etc., 1;5,000 scale, published by NGII (National Geographical Information Institute)
2. Land Use Map: represents the land use based on land registration map, 1;5,000 scale, published by NGII(National Geographical Information Institute)
3. Geological Map: geological unit, boundary, structural line, strike and dip etc., 1;50,000 scale, published by KIGAM(Korea Institute of Geoscience and Mineral Resources)
4. Mine Lot Map : represents mining land registration, overlay of unit and free style mine lot map
5. Mining Tunnel Map : represents the location, depth, and width of shafts, drifts, and mine opening. mine openings were surveyed by GPS for the use of Ground Control Points

6. Satellite Image :

Ikonos and landsat-7 ETM+ image

7. Spatial data from mining-related damages prevention project :

areas of investigation, reinforcement work, and remediation facility, cross-lines for geological and geophysical interpretation, and drilling point, etc.

2) GIS attribute Database

1. Abandoned underground coal mine Information : Mining record, information of shafts and drifts, etc.
2. Geological Interpretation Data : coal bed, field survey data, cross section interpretation, etc.
3. Geophysical Prospecting Interpretation Data : seismic, electrical resistivity, GPR, etc.
4. Borehole Data : Standard Penetration Test(SPT), water pressure test, borehole lateral load test, Rock Mass Rating(RMR), BIPS, Numerical Analysis, etc.
5. Results of Survey measurement : Multi Point Borehole eXtensometer(MPBX), Slope Inclinometer, etc.
6. Reinforcement Work Data : Grouting material, method, etc.
7. Purification of mine wastewater : information of facilities, water quality, and pollution status, etc.
8. Restoring the ruined forest : ruined status, afforestation information, etc.

3) Application development

1. System administration :
 - registering and editing users and codes
 - setting up the work areas and group layers
 - managing functions of spatial and attribute data
2. Management of abandoned underground coal mines :
 - searching and editing abandoned underground coal mine data and maps(mine lot map, geological map, etc.)

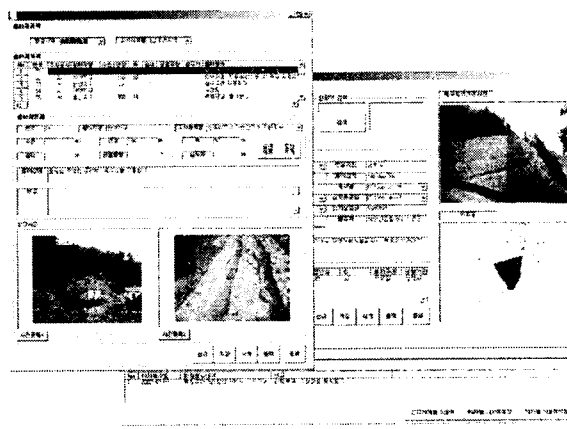


Fig. 2. management of mining-related damages

- making the charts and reports of abandoned underground coal mine data
3. Management of abandoned underground coal mining-related damages :
- managing the mining-related damages data and prevention work results
 - searching and viewing the individual survey and prospecting data

Fig. 2 shows the windows for the management of the database related with ground subsidence area and work of forest restoration.

4. Making the thematic maps :
- Making the various complex map of mining layers
5. Analysis of 3-D mining tunnel map :
- Visual analysis between underground tunnel and surface facilities

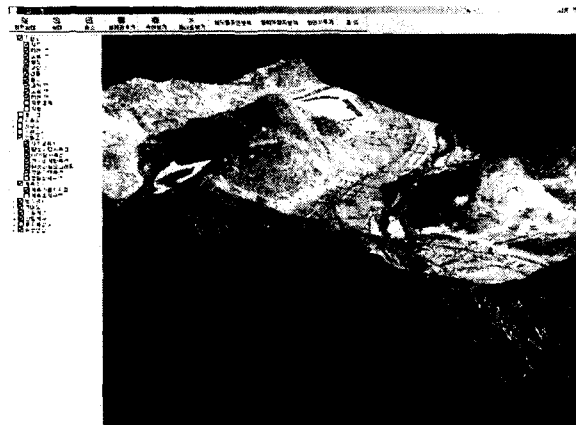


Fig. 3. 3-D satellite image and mining tunnel map

Fig. 3 shows the window where satellite image, mining tunnel map and some topographical elements built 3 dimensionally were overlaid.

6. Analysis of the possibility of ground subsidence :
- 2-D and 3-D cell-based analysis by calculating distance between tunnels and each cell

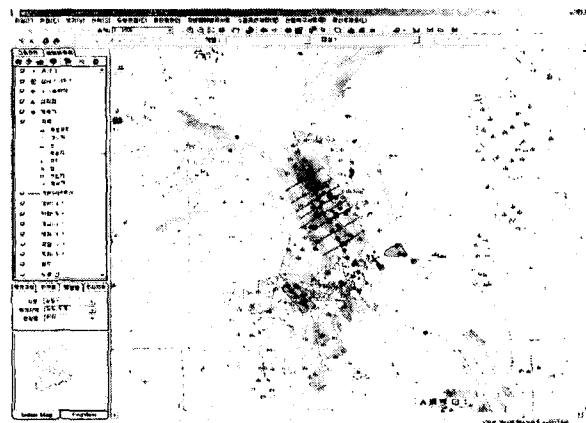


Fig. 4. (a) 2-D cell-based analysis of ground subsidence

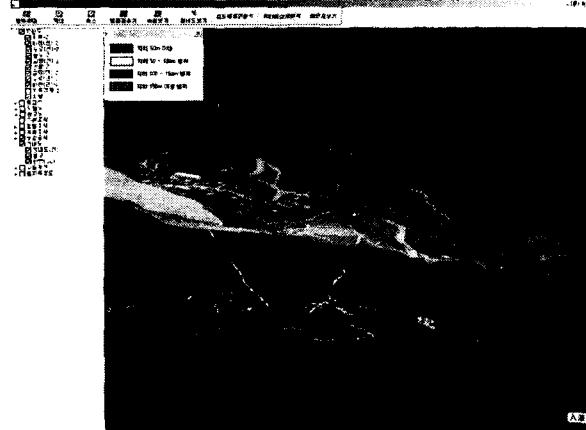


Fig. 4. (b) 3-D cell-based analysis ground subsidence

Fig. 4. (a) 2-D analysis represents that the distances from surface to drifts are divided into 3 grades (red-yellow-green). The red areas have high possibilities of ground subsidence. Fig. 4. (b) shows the ground surface and the virtual surfaces of 50m (red), 100m (green), 150m (blue) depth from the ground surface respectively. And white lines represent the shafts and drifts.

4. Discussion and Conclusion

AMGIS is the first implementation to analytically manage problems associated with abandoned underground coal mines and mining-related damages in Korea.

Through building database for 8 abandoned underground coal mines and developing application programs to support internal business of CIPB in the pilot project, it is shown that GIS is very effective tool for managing mining-related damages. Also, we can have foundation to develop an expert system such as estimation and trend analysis of ground subsidence and verification of remediation of AMD, etc.

The second year (2004. 9 ~ 2005. 8) of the AMGIS project is now under way for 44 abandoned underground coal mines in the Taebaek City, and the application programs will be improved as more valuable, analytical and visualized system.

In the future, database for all 336 abandoned underground coal mines in South Korea will be built and AMGIS will be expanded and stabilized. The client application will be extended for all sections related with mining-related damages in CIPB. And the expert system that can analyze the possibility of ground subsidence and AMD will be developed. Also, the web GIS system for offering general information to the public will be built by the year 2009.

The contents of database and application programs in AMGIS can be applicable not only to coal mines but also to metalliferous and non-metallic mines. AMGIS will be a supporting system to propose the most effective solution of mining-related damages.