Application of multi-hazard knowledge base for underground infrastructure based on iS3 platform

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Abstract. The underground infrastructure is faced with progressive diseases such as deformation, leakage, crack and sudden disasters such as fire, explosion and earthquake during its service period, and the interaction of multiple disasters leads to multi-field coupling and disaster chain. The multiple disasters knowledge base of underground infrastructure is based on iS3 platform, including static case database, static knowledge base, model method base and scenario base. The multi-disaster knowledge base combs the real disaster cases in the last hundred years according to the unified disaster data standard, which can realize the inquiry and statistical analysis of multi-disaster cases. By summarizing the key parameters of multiple disasters, the quantitative models between the characteristics of underground infrastructure operation safety state and the measurable state parameters are established. Some of the input parameters for the multiple disasters models are from the static database, and these models are automatically updated according to the characteristics of the underground infrastructure service life. The independent concurrent and interlocking multi-disaster chain scenarios and patterns are established by numerical simulations, real-scale tests and model-scale experiments. A case study of the Shanghai Century Avenue subway station is performed. A variety of disaster numerical simulations are carried out based on the unified BIM model, and knowledge base is used to carry out inversion, prediction and analysis of key parameters.

1. Introduction
Fighting against disasters is an eternal subject of human survival and development. With the increase of climate change and unstable factors, how to ensure the ability of underground infrastructure to withstand extreme multiple disasters (earthquakes, fires, explosions, etc.) and extreme environments (high ground temperature, high ground pressure, strong aging, etc.) is a major urgent issue at present demand[1][2][3]. As the scale of urban development becomes larger and more complex, the potential safety risks of urban underground infrastructure and buildings are huge, security is facing serious challenges, and the multi-disaster prevention of underground infrastructure is extremely urgent. Multi-hazard prevention and control is the hotspot and frontier of international disaster prevention and mitigation research, as well as the future development trend and development direction of civil engineering infrastructure disaster prevention[4]. The location, climate, geology and other conditions of the underground infrastructure and its own spatial form and operating state are complex and changeable, and weak links and vulnerable nodes are prone to appear under the action of progressive diseases (such as deformation, leakage, damage, etc.). Inducing catastrophic accidents; under sudden disasters (such as fires, explosions, earthquakes, etc.), the underground infrastructure and the internal...
environment often produce multi-hazard coupling and chain accidents, resulting in further expansion of accidents. The huge amount of civil engineering infrastructure built by human society is gradually degrading over time, and its potential safety risks are also an issue of urgent concern. Disasters faced by civil engineering infrastructure generally do not occur in isolation. For example, earthquakes are accompanied by fires, and the damage and destruction of civil engineering infrastructures often occur under the combined effects of multiple disasters. Post-earthquake fire ignition events constitute a secondary consequence of an earthquake and may result in the loss of life and substantial property damage, especially in urban areas where the potential for fire spread and conflagration exists[5] [6] [7] [8].

Figure 1. Multi-hazard scenario of underground infrastructure and deduction of disaster chain model.

This paper aims to introduce the basic framework and the application of the multi-hazard knowledge base. The knowledge base integrates all information, knowledge and data of underground infrastructure multi-disaster action scenarios and disaster chain modes, multi-disaster response characteristics and performance spatiotemporal evolution rules, and intelligent emergency coordination and post-disaster recovery linkage mechanism

2. Framework of the multi-hazard knowledge base

2.1. Basic information of system application

The multi-hazard knowledge base of underground infrastructure is based on iS3 platform, including static case database, static knowledge base, model method base and scenario base as shown in Figure. 2. The multi-hazard knowledge base is available on website: http://ifire.is3.org.cn/.
2.2. Multi-hazard static case database

The multi-hazard static database sorts out the underground space fire accident cases that have occurred in the past 60 years at home and abroad. The scenes cover tunnels, underground complexes and subways, etc., and establish a fire history case database, as shown in Figure 3. The database covers the name of underground space, basic information, fire time, cause and overview of fire, fire duration and casualties, structural and equipment damage, related photos, videos, and news reports. Establish a database to facilitate digital management and query historical fire cases, summarize the causes of accidents through real accident case analysis, and formulate operation management plans and emergency evacuation and rescue plans.

2.3. Multi-hazard static knowledge base and model base

Through literature survey of classic literature and books in the field of disaster prevention at home and abroad, the key physical parameters of various disasters under the action of progressive diseases and sudden disasters of underground infrastructure are analysed. Establish a multi-hazard static knowledge base for underground infrastructure, covering the time-random process model and spatial distribution random field model of multi-hazard coupling. Integrating the underground infrastructure disaster prevention domain algorithm into the cloud service of the is3 platform, the algorithm can be called in the system in real time, and the algorithm in the cloud platform can be called in real time. In order to improve the predictability of smoke temperature of tunnel fires and address problems of model correction and uncertainties, a forecasting method of Ensemble Kalman Filter is presented by doing data assimilation. The results of the numerical simulation with and without the EnKF algorithm are
compared to the experimental data as shown in Figure 4. Results show that the EnKF method improves the accuracy of the smoke layer temperature.

![Figure 4. Fire temperature prediction algorithm for underground infrastructure.](image)

2.4. Multi-hazard scenario base

Based on the unified BIM model, the numerical simulation models of fire, earthquake and explosion disasters were established respectively, and the response behaviour and disaster mechanism of underground infrastructure under various working conditions were carried out.

![Figure 5. Numerical Simulation of Evacuation of Shanghai Century Avenue Station.](image)

The core parameters in the method library and the scene library in the underground infrastructure multi-hazard knowledge base come from the static database and the static knowledge base. The update of the static database and knowledge base makes the model method in the method library also update accordingly. The applicability of the knowledge base is consistent with the characteristics of the underground infrastructure during the service period in real time.

3. The application of the multi-hazard knowledge base in Shanghai Century Avenue Station

3.1. Basic information of Shanghai Century Avenue Station

Century Avenue Station is located on Shanghai Metro Transportation Lines 2, 4, 6, and 9. Century Avenue Station runs from northwest to southeast. There are 12 entrances and exits in the station. Century Avenue Station is a three-story underground station with an average daily passenger flow of 120,000. Prepare separate plans for evacuation of large passenger flows, on-site treatment of station fires, on-site treatment of train fires, and earthquake emergency response.
3.2. Numerical Simulation of fire disaster at Century Avenue Station

Taking the sudden fire disaster chain as an example, the algorithms of fire risk identification, rapid-fire warning, fire scenarios reconstruction and dynamic evacuation are established, which have been applied in many underground roads and spaces in Shanghai. Combined with the BIM model of the Shanghai Century Avenue Station, the key underground infrastructure in the comprehensive demonstration area, a numerical model for fire disaster analysis is established, and the change law of key behaviour indicators in the knowledge base is analysed, and a database is established, which is integrated in the underground infrastructure knowledge base software scene library Show in the module. The BIM model of the Century Avenue subway station group was imported into the fire FDS software, and a numerical model of the Century Avenue subway station group was established using the FDS software. The entire subway station group has three floors. With reference to the FDS manual and previous fire numerical analysis experience, the grid size is determined to be 0.2-0.4m, and a relatively fine grid is set near the fire source, with a total of 4986560 grids. The structural parameters and environmental parameters (such as ambient temperature, ambient pressure and humidity) of the FDS model were consistent with the real subway station. The heat release rate per unit area (HRRPUA) method was considered in the fire simulation. HRR is set as 20MW according to the static knowledge base, the burning area is set as 2m², and the environmental velocity in the station is set as 0.3m/s. The building material in the station is set as "concrete". The ambient pressure and the ambient temperature are set as 100.01kPa and 20 °C, respectively. The simulation time is set as 600s. 

The visualization of the numerical simulation of the fire in the Century Avenue Station is of great significance for guiding the subway operation management department to deal with sudden disasters, operation accidents and emergencies. In terms of emergency rescue and evacuation, the rescue and evacuation decision support module can provide auxiliary decision support from the convenience of fire emergency ventilation and smoke exhaust, fire development trend prediction, personnel self-
rescue escape guidance, intelligent rescue response and multi-departmental linkage coordination guidance.

4. Conclusions
Established underground infrastructure multi-hazard knowledge base software, which can realize multi-hazard case query, statistics and analysis; multi-hazard action scenarios and disaster chain pattern analysis; multi-hazard risk identification and other functions, covering 3 disaster types and 6 disaster effects Scenarios, according to data standards, sort out tens of thousands of disaster data for nearly a hundred years. Demonstration application of underground infrastructure multi-hazard knowledge base based on Century Avenue Station. Based on the Century Avenue System BIM model, a multi-hazard simulation analysis method for underground infrastructure is established, covering fire, earthquake and explosion sudden disasters. The multi-disaster knowledge base of underground infrastructure covers the whole linkage process of risk identification, intelligent response and post-disaster recovery, providing scientific technical support for multi-disaster prevention and rescue.

5. References
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