Geotechnik im Bauwesen
Geotechnical Engineering
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RWTH RHEINISCH-WESTFÄLISCHE TECHNISCHE HOCHSCHULE AACHEN

Potential Ground Subsidence induced by Underground Coal Gasification

Motivation and Objective

With increasing challenges of high prices of oil and gas and uncertainties about political stability in many oil and gas producing countries, coal becomes more and more important in the coming years for its vast reserves and wide distribution all over the world. The technology of Underground Coal Gasification (UCG), converting in-situ, unmined coal into combustible gases (CO, CH_4 and H_2), has continued to attract worldwide interest because of its ability to exploit coal which is otherwise unminable by conventional mining techniques (e.g. longwall mining) due to deep deposit depths, thin seam thickness or low quality, in an economical, safe and environmentally friendly manner. As shown in Fig. 1, the basic operating procedures of UCG involve: construction and linkage of injection and production wells, coal ignition, gas production and decommissioning. Field tests of UCG have shown that as gasification proceeds, an underground cavity is formed gradually and grows both radically outwards and forwards in the axial direction of a gasification channel. Therefore, even though negligible subsidence was predicted and observed in most of field tests worldwide, ground subsidence may be an inevitable consequence induced by a commercial-scale UCG project.

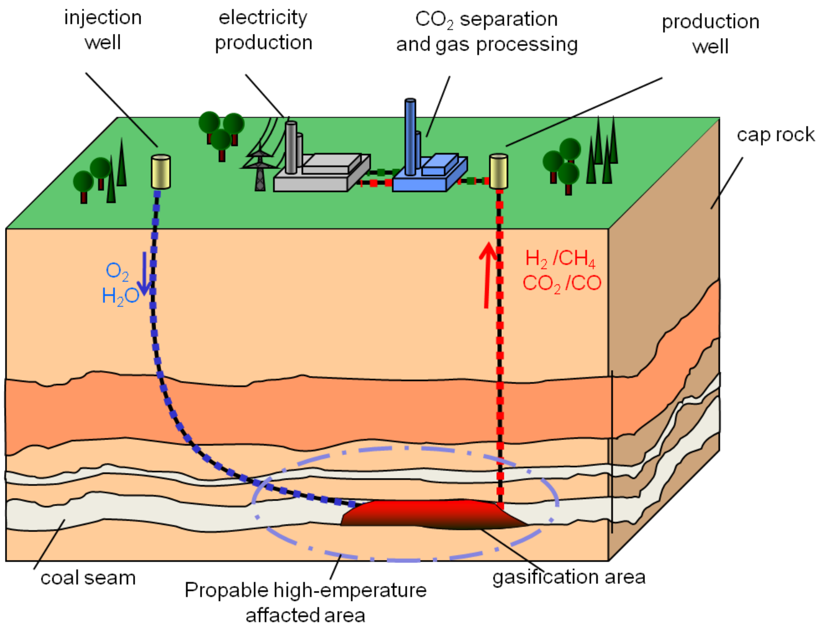


Fig. 1 Principle of UCG.

Methods

Coal combustion and gasification during UCG is conducted at temperatures of 700–900 °C, and it may reach up to 1500 °C. Thus rocks/coal in the vicinity of UCG reactors are exposed to high temperatures (Fig. 1). Plenty of experimental research has indicated that rock strength is dependent on temperature, and usually dramatically decreases above a certain high temperature compared to those at room temperature (e.g. as shown in Fig. 2). In other words, conventional rock failure criteria such as Mohr-Coulomb and Hoek-Brown criteria may not provide a good estimate of rock strength under UCG conditions. Thus, this research proposes new failure criteria which take into account temperature-dependent behavior of rocks, called thermo-mechanical Mohr-Coulomb and Hoek-Brown failure criteria, which are modified on the foundation of conventional Mohr-Coulomb and Hoek-Brown criteria, respectively. Then, ground subsidence induced by UCG is numerically predicted.

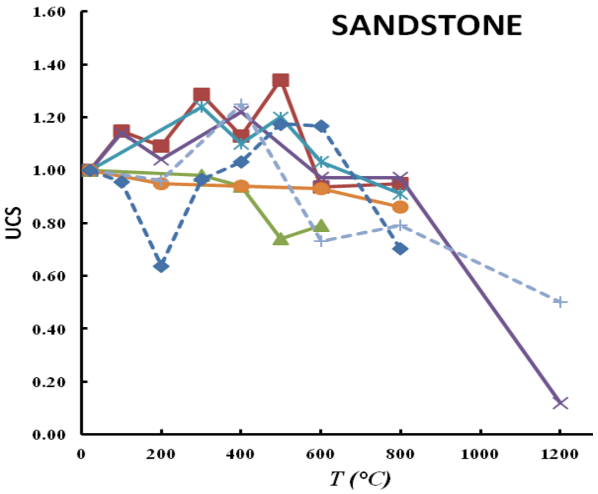


Fig. 2 Unconfined compressive strength (UCS) of sandstones versus temperature.

Since most of the research on high-temperature rock strength focuses on granite, marble, sandstone and limestone, limited results are available for argillaceous rocks. In order to extend the knowledge of temperature influences on rock strength, the claystone material was selected and performed a suite of laboratory testing including thermal treatment, uniaxial and triaxial compression tests to study physical and mechanical properties of the specimens after different high-temperature treatment. The procedure of thermal treatment is as shown in Fig. 3. The results of the testing were used to parameterize the models for numerical study hereafter.

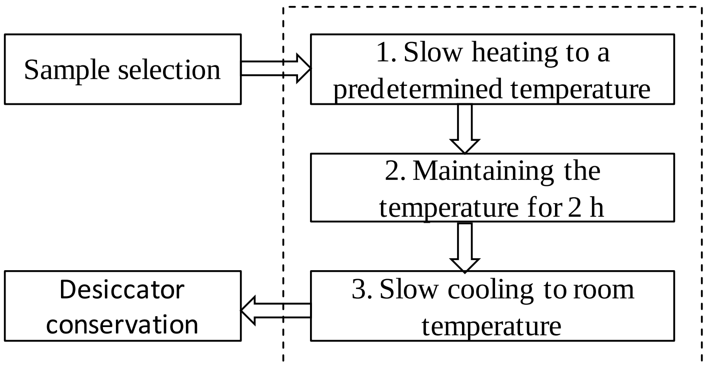
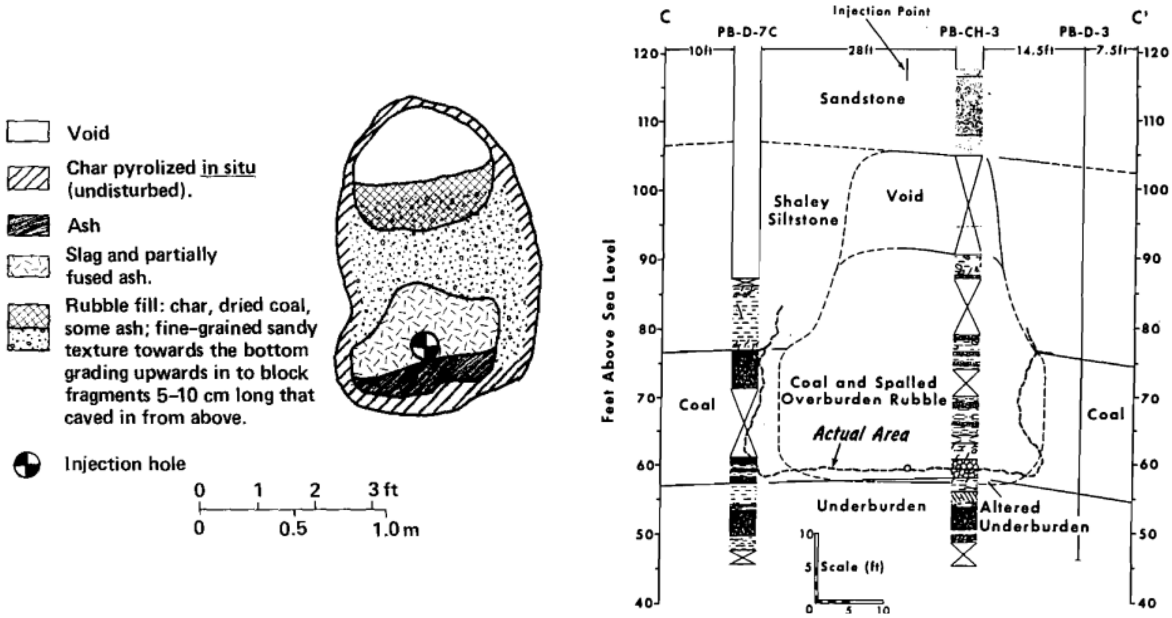


Fig. 3 Flow chart of the procedure of thermal treatment.

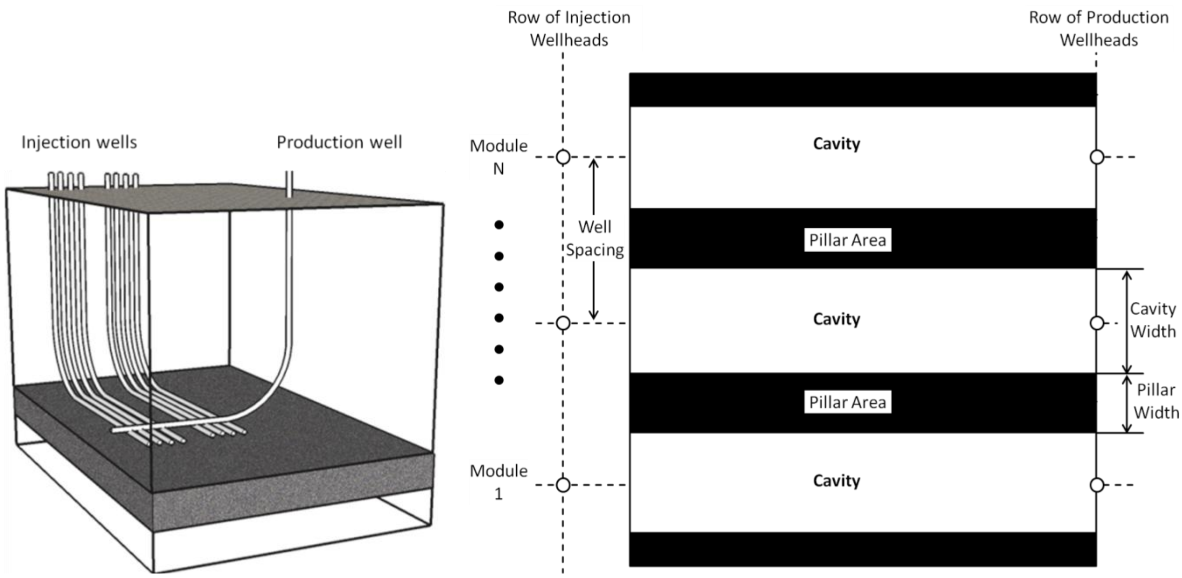
Numerical Modeling

Major features of a UCG cavity are an approximately rectangular cross-sectional shape with dome-shaped roof and bow-shaped bottom, a porous bed of mainly ash, char and coal overlying the bottom of the cavity, and a void space between these zones and cavity roof (Fig. 4). Thus to account for a worst-case assumption, cavities simulated are rectangular and not filled with rubble and ash. A commercial-scale UCG project may be arranged as shown in Fig. 5. 2D Models were constructed according to Fig. 5b. Based on the proposed thermo-mechanical Mohr-Coulomb failure criterion, hundreds of numerical calculations were carried out to study temperature distribution in the vicinity of the cavities, the relation between cavity width and subsidence/cavity height, potential subsidence induced by different number of cavities in one coal seam as well as in multi-seams.



(a) (b)

Fig. 4 Cross sections of UCG cavities from the Large Block Tests, Centralia, Washington (a) and Tono I (CRIP) test near Centralia (b).



a) b)

Fig. 5 Possible layout of a commercial scale UCG application. a) 3D Schematic view, and b) plan view.