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Structural response of RC frame under surface curvature and differential settlement in mining areas

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ABSTRACT

Ground subsidence caused by coal mining can lead to various forms of surface deformation, which endanger the safety of the buildings. To assess the influence of the surface curvature of the mining area on the dynamic performance and damage of surface buildings, the reinforced concrete (RC) frame structures with various differential settlement types are investigated using SAP2000 software. These structures' structural vibration property and damage characteristics are analyzed separately through the modal analysis method, theoretical derivation, and nonlinear static analysis. The result shows that the RC frame structure's natural vibration property and damage degree in the subsidence area vary with negative and positive surface curvature and should not be treated equally. The impact of surface curvatures in mining areas on natural vibration property is the change of structural mass distribution and the stiffness degradation caused by structural damage. The damage caused by the differential settlement will inevitably degrade the seismic performance of the structures located in the subsidence area.

1. Introduction

Extensive mining of underground mineral resources has caused various surface deformation and subsidence in mining areas which endanger the safety of surface buildings (Boroń et al., 2020). By determining the surface deformation and response of building structures in the mining areas, the exploring method can ensure the structure's safety, which is an important research work (Müller et al., 2018; Li et al., 2019; Maddah and Soroush, 2020). The surface deformation caused by underground mining or tunneling is a long-term time-varying process. In this process, the structures located in the subsidence area will experience a series of different force states as the strata and surface deformation varies and finally reaches a relatively new balance state force. Furthermore, the surface deformation mainly includes vertical displacement or subsidence, horizontal displacement, slope, and curvature in the mining subsidence area. Recently, several research works are focusing on the surface deformation in the mining areas (Mayoral et al., 2019; Gong et al., 2020; Sanmiquel et al., 2018; Wang et al., 2019; Zhang et al., 2018). A recent study found that curvature deformation can cause the building's most extensive and uncertain damage than other surface deformation forms (Liu et al., 2019; Bao et al., 2021). However, it is not clear enough about the structural performance of the building when subjected to surface curvature deformation. In addition, the influence of curvature deformation on the building depends not only on the characteristic of the structure itself but also on the features and positions of surface curvature (Deck and Singh, 2012; Can et al., 2012; Shabha and Kuhwald, 1995), as shown in Fig. 1. Some researchers have conducted a few studies regarding the complex influence of tunneling and mining-induced curvature deformation on building structures. Liu et al. (2019) had pointed out that the structural damage had occurred to the buildings near the door and windows in rural areas of China under the surface curvature deformation because of the additional stresses.

Moreover, Il'ichev and Nikiforova (Il'ichev and Nikiforova, 2018) had proposed a method to determine the curvatures and the difference between the slopes of foundations according to the data obtained by clinometric measurements of the slope angles of the foundations.

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