

Bridging Geological Records to the Past and Engineering Applications to the Future Through the Contemporary Geodetic Technologies

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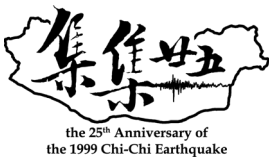
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Since the 1990s, GNSS and leveling networks have been established across Taiwan to monitor the crustal deformation. It has been observed that southwestern Taiwan exhibits a high surface deformation rate. Integrated with the occurrence of several catastrophic earthquakes in this region over the past 200 years, southwestern Taiwan has been inferred to have a high earthquake potential. However, the earthquake catalog shows that the thick mudstone area south of the Hsinhua and Zuozen line is an aseismic zone up to approximately 15 km in depth. Therefore, whether the active faults in the thick mudstone area of southwestern Taiwan present a high earthquake potential is an important question, impacting the design of major infrastructure in the region. Since conventional geological and seismic research methods do not easily clarify the characteristics of structural activity in the aseismic zones, geodetic techniques, including GNSS, leveling, and InSAR, have become essential tools for studying this area. Geological investigation data can provide constraints on near-surface structural geometry and long-term deformation characteristics, while geodetic data can offer constraints on deep structural features and short-term deformation characteristics.

For example, the Chungliao tunnel illustrates the complexities in this region. Before the 2016 Meinong earthquake, the surface velocity field showed a shortening of approximately 44 mm/yr and a left-lateral displacement of 4 mm/yr across the Chegualin fault, and an extension of about 35 mm/yr, a right-lateral displacement of 7 mm/yr, and a vertical velocity difference of approximately 80 mm/yr across the Chishan fault. These results indicate that the Chegualin fault is a thrust fault with a left-lateral component, while the Chishan fault is a high-angle normal fault with a right-lateral component. However, geological investigations suggest that the Chegualin fault is a thrust fault with a right-lateral component, and the Chishan fault is a reverse fault with a left-lateral component. Further two-dimensional fault model shows that the simple fault activities alone cannot adequately fit the horizontal and vertical velocity fields in this area. Therefore, besides fault activities, the movement of mobile shale is another important mechanism controlling the surface deformation in this region and altering its earthquake potential. Additionally, the spatial resolution of less than 10 meters station density in this area allows these surveying results to be successfully compared with other geotechnical monitoring results and applied to subsequent tunnel improvement project planning.

Due to the significant impact of geological activity on major infrastructure projects, as



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highlighted by the Chungliao tunnel study in southwestern Taiwan, we further present the ongoing extension plan of the Expressway 86 as an example to illustrate how geodetic data can assist engineering teams in addressing the impacts of geological activity. The eastern extension corridor of Expressway 86 is expected to cross the Longchuan fault. However, according to existing leveling vertical velocity results, there is a possibility of mobile shale activity in the footwall of the Longchuan fault. Therefore, in this study, we not only collect existing literature but also propose three geological models incorporating mobile shale and reverse faults. These models will be further examined using shallow seismic reflection method to determine which geological model is most probable. Subsequently, we will use geodetic data along the corridor to conduct numerical geological models. This approach will further verify the reliability of the geological models and provide more accurate structural locations. By simulating different periods within the seismic cycle, we can predict surface displacement (strain) patterns. These results are expected to not only inform the design of tunnels and bridges but also provide reference for maintenance planning after construction completion.