Application of Newly Developed Real-time Website-base GIS Monitoring in Tunnelling

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ABSTRACT: In this paper, application of a newly developed real-time website-base GIS (Geographic Information System) automatic monitoring platform in tunnelling is introduced. Some important functions in this platform have included a user-friendly operation interface, automatic generation of induced settlement contour and its impacts on adjacent structures together with presentation of ground profile close to the construction site etc. under a well-recognized GIS, such as Google map. By having these details, potential risk during construction could be categorized and managed. Furthermore, as all data are provided real-time, site condition could be shown immediately and necessary engineering judgement are thus eligible to be made without any delay. The application of this system in three tunnelling case histories are demonstrated; the 1st case is tunnelling in central Kaohsiung which is twin-bored tunnel with depth of tunnel centre is approximately at 15 m to 17 m beneath a 20 m wide main road in the city. The 2nd one is a case in Taipei metro system which has both cut-and-cover and NATM tunnels, attentions were put on its application in follow-up of displacement changes as well as pore pressure during the construction. The 3rd case is TBM tunnelling in a ground consists of very thick clay, occasionally with layers of highly permeable sand and high ground water level in crowded environment city. It aims to completely monitor and control the surface settlement in order to eliminate impacts on adjacent traffic, structures and daily life of residence. By applying this newly developed platform, risk of failures could be minimized, as it provides a clear overall view of geotechnical measurement taken on the site from time to time.

Keywords: real-time website-base GIS automatic monitoring, risk categorized and management, tunneling, settlement

1. INTRODUCTION

Nowadays, due to the fast development of technology for both hardware and software computer, lots of geotechnical monitoring results intended to be presented in more “user-friendly” style, especially using graphical skill and technology to build a monitoring platform to be competent with neighbourhood area, such as Geographic Information System (GIS), used to provide a clear overall view (Player, 2006). In addition, ground profile is always critical to any underground construction activity in urban area, such as deep excavations and tunnelling have a need to present ground condition in the same platform. Therefore, it aims to briefly introduce a newly developed real-time website-base GIS platform which is eligible to present both ground profile along the route of tunnel in the city and displacements induced by tunnel construction activities in this paper. The visualized presentation of monitoring results is also different from traditional one which is capable of showing induced settlement contour. By doing so, it helps the engineers to evaluate risks of adjacent ground and structure during the tunnelling.

2. BACKGROUND OF THE WEBSITE-BASE GIS PLATFORM

As indicated previously, this newly developed website-base GIS platform shall be eligible to has functions as (1) indication of ground profile for any location along the tunnel route as long as borehole log information is available; (2) a “user-friendly” presentation of monitoring data which shall not be a time-history for any single instrument, has to be an overview of the whole construction package at any time, any stage and any location; (3) a self-alert/warning system shall be included and (4) the platform which has to be competent with widely accepted GIS software, such as Google Map or equivalent ones.

Considering four key functions stated above, the platform thus be developed. Following are step-by-step operation of this website-base platform.

Once the user starts to use this platform, the details of all instruments location together with neighborhood environment of the site shall be presented in any GIS system, such as Google Map, as shown in Figure 1. At the same screen, the user is able to see number of each instrument which can be selected later on (also shown in Figure 1). By selecting any one instrument, traditional displacement versus time curve is still eligible to be indicated. In order to maintain data reliability and avoid any man-made error, real-time monitoring instrumentation together with data transmission logs are strongly recommended to be adopted to collect deformation and stresses caused by construction activities. However, it is also possible to use manual instrument to collect data needed in said platform once the project scale is not large enough and the client also has a concern in budget issue.

Figure 1 Instruments installed on site with Google MAP

As shown in Figure 1, it has three options for user to choose which are “Map function”, “Map type” and “Marker List”. Using these options, the user can freely choose the addressed site area, the mode of the map, color and symbol of each instrument associated with actual needs.

As the platform has a function of self-alert/warning, values of alert/action levels shall be given before the start of the project and warning message shall be shown once any instrument reaches alert/warning level, as shown in Figure 2. Since none of instrument indicates any measured deformation/stress currently beyond alert level, “no available data in table” is therefore presented.

Since the platform has to be user–friendly, the output can be possibly presented in the platform directly (refer to Figure 3) or into formats of EXCEL, CSV or PDF. In Figure 3, it shows name and number of instrument, last measured value and related date as well as alert level etc.

As explained previously, the platform has a function of contour interpretation which can possibly categorize influence zone induced by tunnel construction. Further details will be presented in later section.

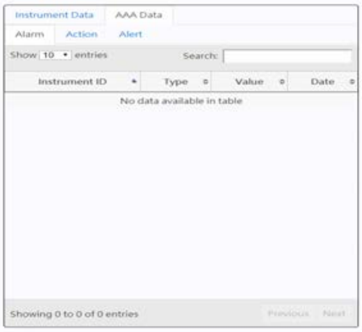

Figure 2 Warning message from the system

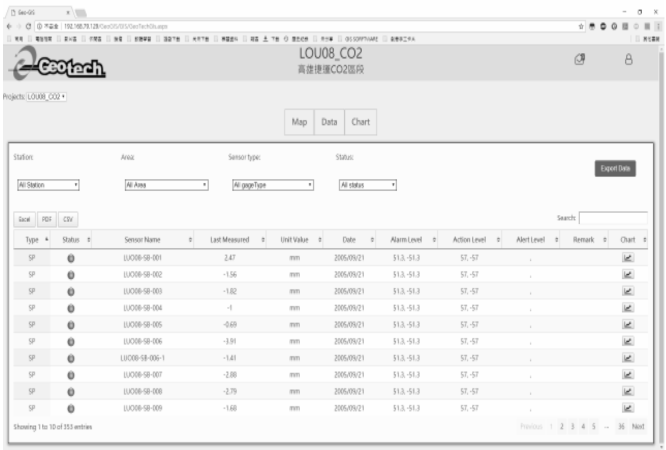

Figure 3 Details of instruments and measurements shown in the platform

3. APPLICATIONS

Several examples are presented in this paper in order to demonstrate the performance of newly developed website-based platform.

3.1 Tunnelling in Kaohsiung

A 5.6 m of internal diameter twin-bored tunnel was constructed in central Kaohsiung, Taiwan and centre-to-centre distance is approximately 12 m at west end of the tunnel and gradually increases to 14 m at east end of the tunnel. 25 cm thick, 1.2 m width reinforcement concrete tunnel segments were used to construct the tunnel and depth of tunnel centre is approximately at 15 m to 17 m beneath a 20 m wide main road in the city. The length of a single tunnel is approximately 300 m.

Soil logs taken from locations close to tunnel site were presented in Figure 4 (Hsiung et al., 2016). As shown in Figure 4, the main soil strata at tunnel depth has *SPT-N* value less than 20 and sand content of soils is very high, up to 70 to 80%. Groundwater level is also high, approximately 3 to 4 m below surface level.

In order to generate a full view of ground profile, a full ground profile was generated by the platform automatically instead of manually. By doing so, the opportunity of man-made bias or error should be eligible to be reduced. In addition, potential ground risks could also be predicted and prevented in advance. Figure 5 shows generated ground profile (light colour means “silty sand” and dark colour means “silty clay”), it is aware that more reliable and intensive site investigation program as well as data should assist to help to generate a more reliable ground profile. Limited and poor quality site investigation would not be able to achieve the purpose stated above in the aspect of risk assessment.

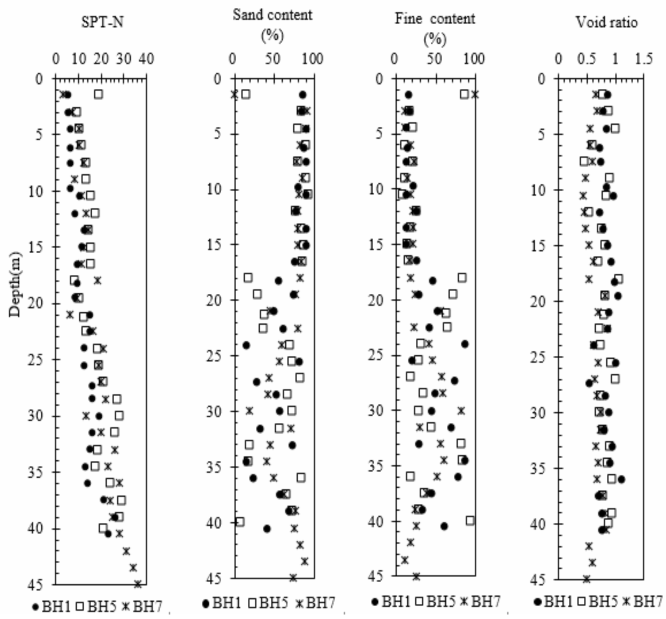

Figure 4 Soil logs from boreholes close to the site

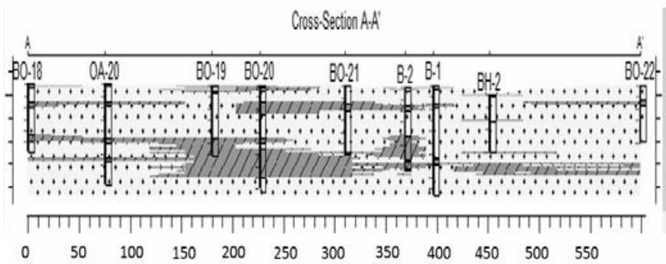

Figure 5 Generated ground profile

Deformation induced by tunnel construction was further examined. Different from previous product, the newly developed platform not only provides the function showing a conventional time versus displacement curve of a single instrument, as shown in Figure 6, but also could provide an overall deformation contour to directly indicate the impacts on adjacent ground and structures (refer to Figure 7; buildings with dark colour mean those has more than 10 mm of observed building settlement). Although settlement of several buildings are more than 10 mm, the maximum tilting of the building is only 3.3/10000, much less than the alert level (1/500) so no immediate risk is seen and no additional protection measure should be undertaken under this situation. Tunnel construction here only induces limited displacement and actually the road is quite wide so located buildings are a little bit away from the tunnel.

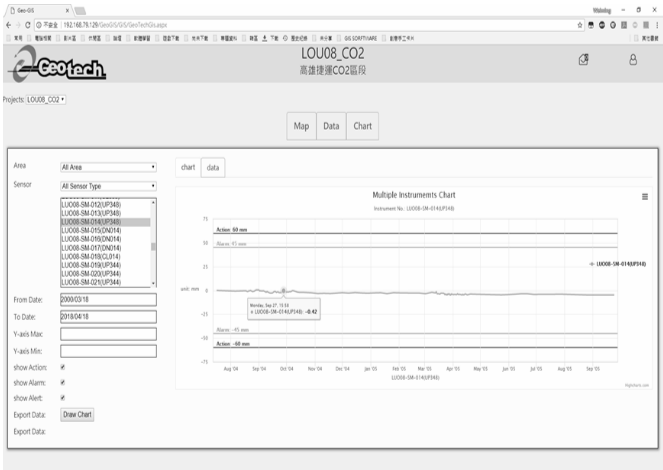

Figure 6 Conventional presentation of monitoring record

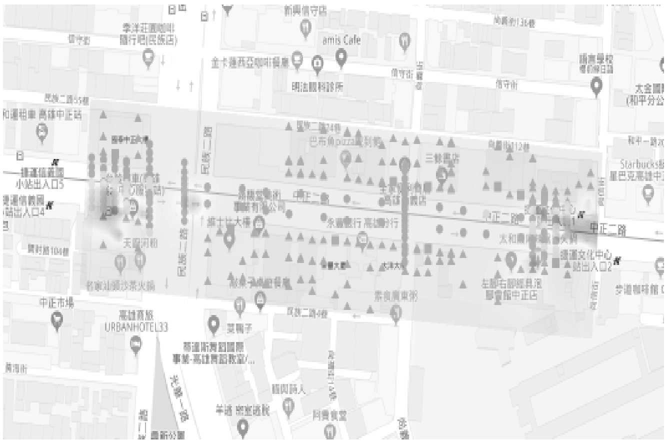

Figure 7 Presentation of monitoring record using newly develop website-based platform

By comparing details of cross section of tunnels (refer to Figure 8) and suggestions shown in Figure 9 made by Clough and Schmit (1981), the influence zone shall be less than 8 m away from boundary of the tunnel which is consistent with results shown in website-based platform.

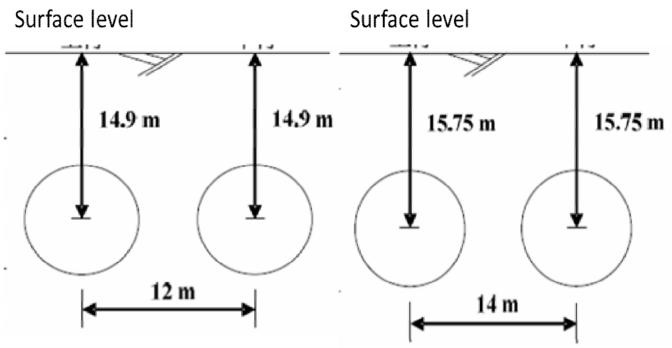

Figure 8 Details of cross sections of tunnels in transverse direction

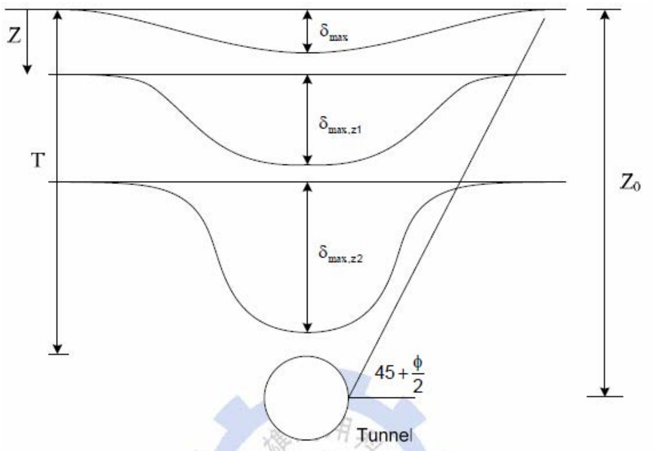

Figure 9 Influence zone made recommended by Clough and Schmit (1991)

3.2 NATM and Cut-&-Cover Tunnel in Taipei

In order to construct an above-ground depot for metro system in Taipei, a cut-&-cover tunnel plus one NATM tunnel has to be constructed for the use of cross-over and storage track of the depot. Further, a historical building is located on top of slope close to the tunnel and necessary slope-cut has to be conducted in order to construct the cut-&-cover tunnel so the website-based platform is considered to be adopted to control site activities, induced deformations, pore pressure and stress as well as potential risks.

Figure 10 shows the site condition and earth anchors were installed as additional support at the section for cut-&-cover tunnel close to the portal of NATM tunnel. However, conventional horizontal strutting system was applied for the rest section of cut-&-cover tunnel.

Figure 10 Site condition of NATM and cut-&-cover tunnel

As indicated previously, several modes can be selected in this newly developed platform; Figure 11 thus presented those locations of instruments with various backgrounds, such as road, terrain and hybrid etc. so the user can choose anyone suitable.

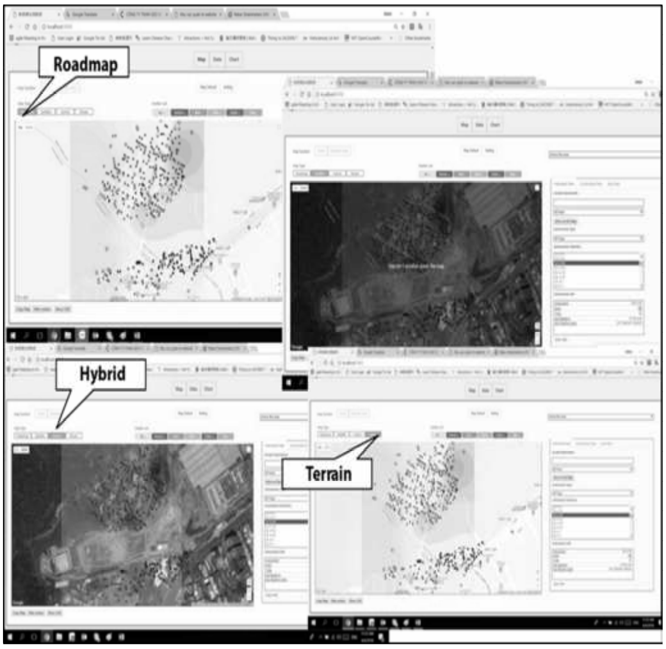

Figure 11 Instruments with various backgrounds

As mentioned earlier, in this tunnel project, the monitoring of historical building on top of the slope close to the tunnel is a key issue in this project, it thus seen from Figure 12 that many settlement points were installed on slope where immediately close to the place that located historical building. A combination of Real–time monitoring and manual monitoring were applied for the measurements of these instruments so any movement or potential risk of said historical building is thus eligible to be indicated in advance and necessary protection or patch could be delivered on time. Except settlement markers, instruments installed on site include piezometer, inclinometer, tiltmeter, load cells, observational wells and crack meters on structures.

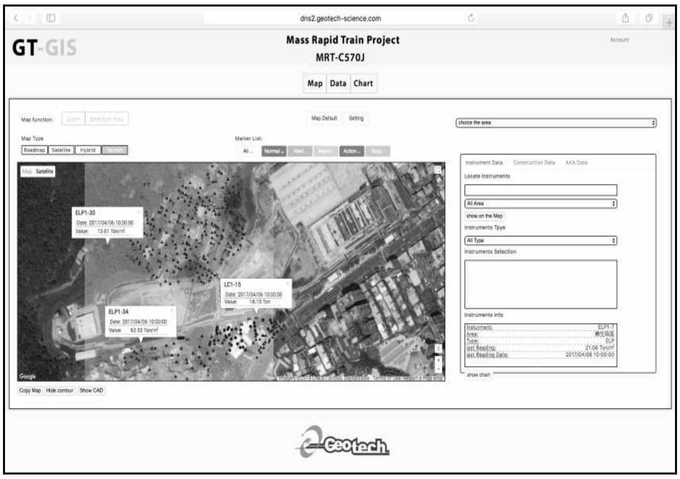

Figure 12 Instruments installed on the site

3.3 Accident Caused by Tunnelling in Taipei

As shown in Figure 13, an unexpected collapse was caused by tunnel construction in urban area of Taipei city and the depth of tunnel centre is approximately 40 m (refer to Figure 13). In order to fully understand any change of ground and adjacent structures, real-time monitoring instrumentation were installed on site immediately, as presented in Figure 14. Once this newly developed platform can be applied in the beginning of the project, it shall be much easier for all parties involved to realise what happens on site at any specific time and specific area which can assist to follow up and then decide protection measures shall be undertaken immediately.


Figure 13 Accident caused by tunnel collapse


Figure 14 Real-time monitoring instrument installed on site

4. CONCLUSION

Application of a newly developed real-time website-base GIS (Geographic Information System) automatic monitoring platform in some tunnelling projects is discussed. By applying this newly developed platform, the risk of failures could be minimized, as it provides a clear overall view of geotechnical measurement taken on the site from time to time.

5. REFERENCES

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