Monitoring Structural Health of Penang Bridge Using Online System

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Summary

Penang Bridge was completed in 1985 as the main linkway between mainland Peninsular Malaysia and the island of Penang. The approach spans are currently being widened from 2-lane dual carriageway to 3-lane dual carriageway including an additional motorcycle lane on each carriageway due to huge increase in traffic volumes since the bridge was originally completed. There is a need to monitor the structural health condition during construction activities for any possible short-term effects and also post-construction for long-term bridge performance. A monitoring system for settlement, tilt and vibration is implemented at Penang Bridge to monitor structural health. Data from sensors positioned along the full-length of the bridge are picked-up and transmitted to the data-logger system via wireless modem and this allows real-time monitoring to be carried out remotely at the control centre. The system has proven to be able to pick-up any major changes in the structural condition of the bridge and provide ample warning, especially during the current construction stage. Once the widening works has been completed, the system will remain as a permanent means of monitoring the long-term structural health of the bridge.

Keywords: Penang Bridge, structural health monitoring, settlement, tilt, construction, widening.

1. Introduction

Penang Bridge was built in 1985 as the main linkway bridging the mainland and the island of Penang. After almost 24 years in operations, the bridge is frequently congested during peak hours due to the increased traffic volumes. The bridge is currently being widened along the low-level viaduct sections to include an additional traffic lane and hard shoulder on each carriageway and would result in the deck width to increase from the present 18.25m to 27.85m. The widening scheme requires installation of additional piles to support the widened deck. The existing pile system consists of a group of 15 Nos. of vertical and raked prestressed concrete spun piles while the newly installed piles consist of a group of either 2 or 3 Nos. of 1000mm diameter bored piles on each side of the bridge. Due to the proximity of the new piles to the existing piles, a strict monitoring regime was required to monitor and ensure that there were no adverse effects on the existing bridge structure.

2. Online Monitoring System

An online monitoring system was found to be essential as it allows the structural health of the bridge to be monitored round-the-clock. Coupled with the construction activities that is occurring along the full length of the bridge at most of the times, the system will be able to provide timely feedback of any possible changes that may affect the structural health.

The parameters monitored were settlement, vibration and tilt. In this first phase of the system, settlement data was devised to be measured and recorded continuously using the online system while tilt was measured manually using portable tiltmeter at set time intervals. Vibration was only measured as and when required.

https://doi.org/10.2749/222137809796067641

The IS-liquid levelling system (IS-LLS) by PROFOUND is used for monitoring of settlements. It is an effective tool for precision monitoring of settlements. The sensors are positioned in pairs on each pier's outmost column above the crosshead. The sensors need to be selected with the appropriate measuring range to ensure accurate settlement measurements; the elevation differences need to be within range, even after the expected settlements.

The IS-LLS system was installed in 6 clusters. All logging PC under each section are interconnected to each other via LAN network cable and finally will reach their own Datum logging PC before being transmitted to the Command Centre at Penang Bridge site office. During installation the sensors are interconnected by means of a pressure line and a digital IS-data cable. The database can be accessed via Local Area Network and viewed in the form of charts and tables.

3. Results

The results from the online monitoring system allowed the Owner and Engineers to verify the structural health of the existing bridge while the on-going construction activities continued on around the clock. The settlement data taken in the initial stages allowed the Contractors and Engineers to agree on the construction methodology as well as the rate of works without having an adverse effect on the bridge foundation system. With the online system, the settlement data during installation of bored piles and final settlement after completion of bored piles and also bridge deck can be verified in real time.

Upon the completion of the widening works, the system will be kept in place and used to monitor the long-term structural health of the bridge. The system will be able to pick-up any effects on the structure due to earthquakes, tsunamis, accidental ship impacts, etc. in the future.

Another main factor to be considered is that there is a considerable cost saving using the online system as compared to conventional methods using manual data reading. As the system is intended to be used on a permanent basis, the amount of labour cost saved over the lifetime of the system justifies the capital costs involved in the installation of this system.

4. Conclusion

The online system for monitoring the structural health of Penang Bridge was found to be a useful tool during the construction activities related to the widening of Penang Bridge. This system will be kept in place as it will continue to be a useful system for the long-term health monitoring of the bridge. At the present moment, the system only caters for real-time monitoring of settlements but with the proven results derived, this will be expanded to cover other relevant information as well. Furthermore, the possibility of this system being expanded and implemented on other bridges is great as it provides updated information related to the real-time performance and health of the bridge.

5. References

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