

A research for Class II defect Bored Pile's Accept Criteria: A case of Penang Second Marine bridge

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Abstract. The aim of this preliminary research is to study the accept criteria of class II bored pile with subtle defect. According to a detailed comparison of the existed different standards, Chinese ones are more applicable especially for the large diameter bored piles. Through the concrete coring at pile No P25-03 of this case and the comparison to the actual calculation, the Class II pile's defects were very minor. Comparison was also made for the effects on pile structural capacities before and after repair of the defects. the feasible repair proposal may bring forward to more defects to the piles. The Class II piles don't need any further repairation when piles have typical of similar character and sonic logging test result with P25-03's one. For other Class II piles with some differences in characters, verification is needed through further concrete coring on the pile. The recommendation of this research could be adopted for the similar huge marine structures which installed large diameter bored piles.

1. Introduction

The Penang Second marine bridge is approximately 22km in length with a total of 16.5km of bridgeworks of which around 15km is over water. Nowadays, It is the largest and longest bridge structure in the southeast Asia. The bridge is made up of multiple approach span viaducts from both sides with a signature structure featuring longer spans and a higher clearance envelope over the southern navigation channel. The design and built of this project were mainly conducted by Chinese contractors. The general view of the bridge is shown in *Figure 1*.

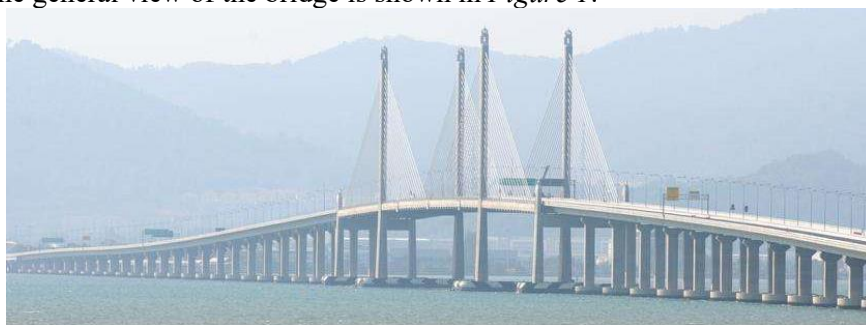


Figure 1. General view of Penang Second Marine Bridge.

The main bridge is one cable-stayed bridge with a single span of 240m. For the main bridge's infrastructure construction, about 50 nos. of bored piles were installed. The diameter of each bored pile is 2.5m. This was the first time that such large diameter bored piles were constructed in the local area. *Crosshole sonic logging* (CSL) method is used for the pile integrity test. The test results were



basically consistent from both the pile inspection team and the local Professional Engineer. The test results revealed that around 20 nos. of piles were Class II based on the present classification criteria. Since Class II piles normally have very minor defects, In order to avoid counter effect caused by unnecessary repairs, the determination would depend on the site verification and comparison with actual further checking calculation.

2. Definition of Defects

2.1. Local & American Standards

Sonic logging for pile integrity test is originated from the United States of America, and this has become internationally accepted method for the determination of bored pile qualities. Its accuracy is higher than the PIT low strain test, but because of the non-homogeneous properties of concrete, standards of different countries have distinct classification of piles from the test results and the corresponding required remedial works are also various. Even in the ASTM standard, there is no clear description.

2.2. China Standard

According to the statistics on the relevant standards, it can be found that in the international standards only the both China Standards have detailed classification on the sonic logging test results. The local Malaysia JKR specifications and ASTM standard do not have the detailed classification of test results, but only mentioned that that significant defects in the pile of conduct should be repaired. The four different standards commonly adopted are shown in below *table1*.

Table1.Description of the Standards and Application Level

| No | Country | Title | Application Level | Engineering guidance |
|----|----------|---------------|---|----------------------|
| 1 | Malaysia | JKRSection10 | Technical specification as required in this contract. but not mention CSL. | Low |
| 2 | USA | ASTM_D6760-08 | American technical standard on the CSL test, but focusing on the principles. | Medium |
| 3 | China | JGJ 106-2003 | The common adopted practice in China construction industry for the pile testing, contains all type of detection methods (PIT,PDA,CSL) . | High |
| 4 | China | CECS 21:2000 | Standard in China construction industry focusing on the CSL test, highly professional | Very High |

In the above China Standards, it is clearly specified that Class I and II piles will not require any repair works. There are detailed classifications of the pile test results. In the past decade bored piles have becoming the most popular pile types in China and hundred thousand of bored piles are installed every year. The amount of piles' installing and inspecting are both ranked first in the world. Considering the objective convenient condition, the investigations of defect remedial for bored pile have achieved further progress. In this aspect, All the relevant testing standards are very comprehensive and detailed. The China standards are strong guidance and persuasive. The comparison of each other is shown in *table2*.

Table 2.Criteria for Classification of CSL Pile Integrity Test

| No | Standard Name | Determination and Classification | Treatment Method |
|----|----------------------------|--|---|
| 1 | JKRSection10 | No description | Not mentioned |
| 2 | ASTM_ D6760-08 | No detailed description; 5. Significance and Use 5.1 This method uses data from ultrasonic probes lowered into parallel access ducts, or in a single access duct, in the deep foundation element to assess the homogeneity and integrity of concrete between the probes. The data are used to confirm adequate concrete quality or identify zones of poor quality. | No detailed description; If defects are detected, then further investigations should be made by excavation or coring the concrete as appropriate, or by other testing such as Test Method D 1143, D 4945 or D 5882, and measures taken to remediate the structure if a defect is confirmed. |
| 3 | China (JGJ 106-2003) | With detailed standard for the classification; The relevant defective piles are divided into four classes; The classification adopted in this project is originated from this; | Clearly specified repair for minor defect should be combined other methodes); 10.4.7 For the judgment of pile integrity and classification, other than the use of sonic wave speed, amplitude variation and other auxiliary aid, there are also many complex factors that would govern the result. The followings should be note in the test: 1. The core drilling method can be combined for the sake of result comparison so that a more realistic classification can be reached. |
| 4 | China (CECS 21:2000) | With detailed standard for the classification; The relevant defective piles are divided into four classes; | Clearly specified repair for Class III & IV piles only (relevant extract as follows); Class Result of Integrity Evaluation I Intact, passed. II Basically intact, passed. |

2.3. Application in Project

The sonic logging test in this project was performed based on the "Method Statement for Sonic Logging" prepared by contractor. Adopted Criteria for Classification of CSL is listed In *Table 3*.

Table 3.AdoptedCriteria for Classification of CSL in this Case

| Class | Characteristics |
|-------|---|
| I | The pile is integral. All sonic parameters of all the points in the testing profiles are regular, and there is no sonic velocity less than allowable low limit. |
| II | The pile is with slight flaw. Some of sonic parameters of certain points in one of the testing profiles are irregular, there are no sonic velocity less than allowable low limit. |
| III | The pile can be judged as obviously defective. Sonic parameters of many continuous points in one of the testing profiles are irregular. Sonic parameters of the same depth points in two or more testing profiles are irregular. There are few sonic velocities of concrete less than the allowable low limit. |
| IV | The pile can be judged as seriously defective or with fracture. Sonic parameters of many continuous points in one of the testing profiles are irregular. Sonic parameters of the same depth points in two or more testing profiles are irregular. |

There are many sonic velocities of concrete less than allowable low limit or there is no way of detecting whether the first achieved wave or received signals are seriously defective.

The determination criteria is in line with the foresaid China standard. Meanwhile, for the sake of including the local conventional treatment process, Contractor did not explicitly emphasize that only Class III and IV piles will require repairs as specified in China standard.

3. Method of Treatment

3.1. Local practice

For piles with obvious defects mentioned in Malaysia local practices, such as Class III & IV piles, repairs are needed. For other piles with minor defects, such as Class II in table 3, the consultant is required to combine with other methods (e.g. concrete coring etc.) and decide whether repair is necessary.

3.2. Other practice

In China standard, it is clearly specified that Class I & II piles identified by Professional Testing Engineer will not require repairs. Even for the large building structures and major bridges in China, this practice was followed and the effect is acceptable. From the China standard, the relevant method of treatment is defined and this was obtained based on the analysis and comparison in hundreds of civil engineering practices and the operation is thus better. This point could also be justified by the comparison calculations in the following sections in this report.

There are not many engineering experiences in Europe, America and other regions and It is difficult to use for reference.

3.3. Adopted practice

The actual treatment process adopted in this project is as followed: After consultation with the local piling inspection consultant for the treatment to piles with minor defects, meanwhile by combining the consultant and supervising engineer opinions, Contractor confirmed to carry out the concrete coring to one of Class II piles which will act as the basis for the judgment at later stage.

4. Concrete Coring on Pile

4.1. Overview to P25-03

Pile No P025-03 is judged to be a Class II pile. Referring to the result of crosshole sonic logging test, it is revealed that there are local defects at positions 0-0.7m and 3.5-5.8m below pile top level. The supervising engineer reckoned that the defects of this pile are relatively obvious as per the curve plot from the test result and believed that the defect is located in the pile core area. From the contractor's reviewing, it is considered that the defect is local void left due to the fast extraction of tremie pipe.

According to the supervising engineer comment, contractor carried out the first core drilling at the pile 25-03 centre area with depth is 0~7m below pile top level. It was found that there are some voids in the concrete but no slurry and sand in core sample. Therefore, It could be determined that the voids were not due to segregation of concrete, which is agreed with the statement that "The defect is local void left by the speedy extraction of tremie concreting pipe ($\phi 27\text{cm}$)". To further verify this statement, two more coring samples at 50cm around the first coring were conducted and the two additional core samples indicated good concrete quality. It could be determined that the defect was only local voids caused by speedy extraction of tremie concreting pipe instead of segregation of concrete.

4.2. Numerical Analysis

4.2.1. Analysis Model

According to the actual coring at P25-03, the following three pile types are determined based on their characteristics. The worldwide adopted 3D software *ANSYS* is used to simulate the pile structural behaviour. The analysis loading conditions are listed in *table4*.

Table 4. Description to Analysis Loading Conditions

| Type | Characteristic | Specific description |
|--------|---------------------|---|
| Type 1 | Pile without defect | Assume without any integrity problem in the pile |
| Type 2 | Pile with defect | Based on the coring result on P25-03, the defect in the centre of pile is simulated as hollow which will not use for resistance of forces. Assumed DIA of defect is 30cm.the location and depth is the same as the testing report. |
| Type 3 | Pile with repairs | According to the routine method to repair the bored pile with cement grout to fill up the voids at defected zone. Cement grout is hard to work with original concrete Together,its effect could be ignored during cal. |

4.2.2. Calculation modeling

For simplifying the calculation, the pile lengths in three models are taken as 14m which is same as the actual pile free length after the scouring. The boundary conditions in each model are the same, that is the ends are restrained in the model. Although this simulation is not exactly the same as the actual condition, the analysis results will not affect the comparison required and conclusion.

The external loadings the same with actual condition are applied at the top of piles in each model, the analysis results are indicated in *Figure2* and *Figure3*. The *Figure2* is showing that the largest stress is located at the outer face of pile. The *Figure3* is showing that the stress distributions are basically the same in three types of models at the pile core region.

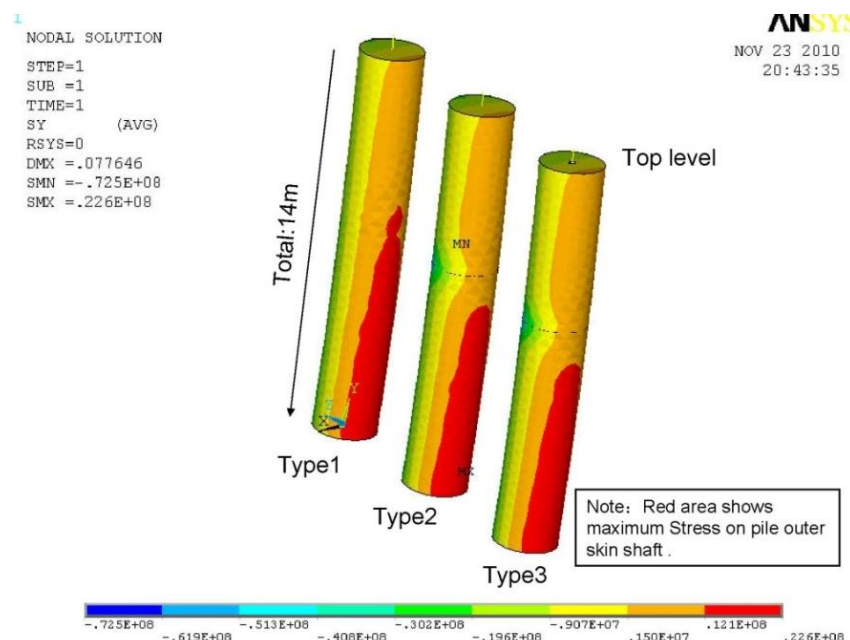


Figure 2. Stress contour at the outer face of pile based on 3D Analysis

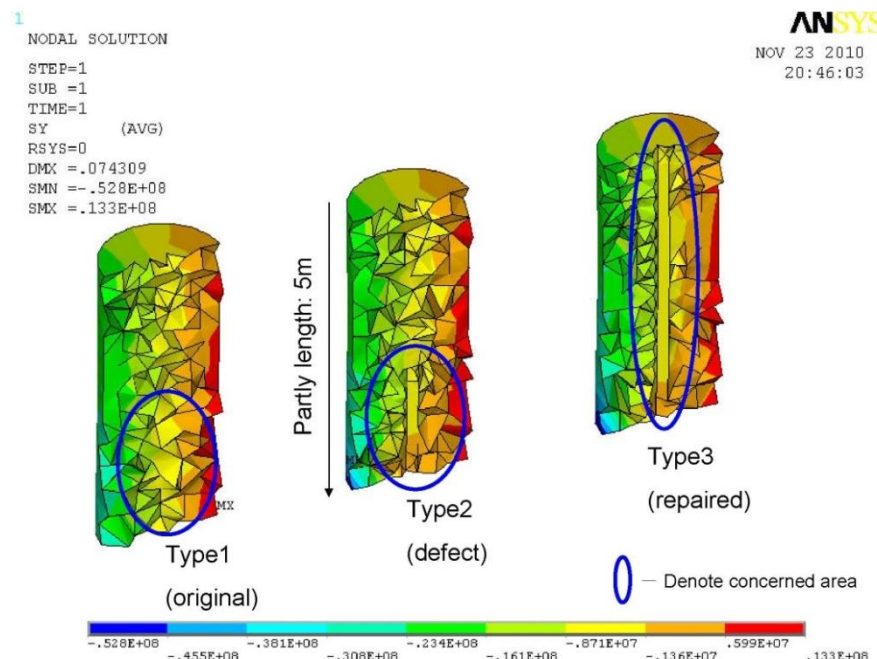


Figure 3. Stress contour at the cross section of pile internal based on 3D Analysis

5. Conclusion

The conclusions of this research could be listed as followed:

- The quality of class II bored pile is commonly defined by sonic logging test. The relevant remedial works is generally not required. This approach is also highlighted in the relevant two China professional standards.
- The two China standards have more detailed and clearer pile classification and method of treatment for defective piles in comparison to the standards of other countries.
- Basing on numerical simulation, if coring drilling is carried out and followed by grouting for the class II piles, the weakening is even greater than the ones without any remedy.
- Considering the existing of the steel casing and the thickness of pile shaft itself, the durability of piling could not be weakened by the minor defect of Class II.

The recommendation could be adopted for the similar marine structures which installed large diameter bored piles.

6. References

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