Discussion on Road Reflection Crack and Control

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Abstract. This paper focused on the problems encountered in the road construction of a coal-fired power plant in the Philippines as an example. Some cracks and damage appeared in the roadbed after the road concrete base layer has been built. If the concrete wearing course layer is poured on the old roadbed without dealing with the crack problem, some reflection crack will occur. This paper conducted a series of explorations on how to control the influence of reflection crack on concrete road wearing course layer and provides a variety of solutions to control the occurrence of reflection crack. The paper is expected to provide solutions to control reflection crack on concrete road.

1. Introduction

The coal fired power plant in the Philippines is located at Sitio Dinginin, Barangay Alas-asin, and Municipality of Mariveles in the Province of Bataan. The Facility is located approximately five km southeast from the town of Mariveles which is adjacent to North Channel to Manila Bay. A 2×660MW supercritical coal unit has been built in this area. The landform of the project site is located in the hilly area of island. The original terrain is higher in the north and lower in the south, and the terrain is open. The project is located in the tropical monsoon climate zone, and rainy season (June to October each year) and dry season have clear distinction. The average annual temperature is 25℃~28℃. The bearing layer of the main road in the factory area is silty clay or fully weathered agglomerate. The physical and engineering properties of the whole site strata are suitable for this project.

According to the requirements of the project contract, all facility roads (including sub grades, pavements and structures) shall be designed based on AASHTO『Guide for Design of Pavement Structures』(1993) from American Association of State Highway and Transportation Officials, which is referred to as AASHTO Guide [1]hereinafter. In addition, all roads and pavements shall be designed for a 20-year performance period under the anticipated traffic. Road pavement design shall be in accordance with the Final Geotechnical Report and AASHTO Guide. Facility area roads shall be paved with concrete pavement and designed in accordance with the following criteria: First, operating speed of ten (10) miles per hour (16 kph); Second, Delivery Road Traffic: A. Trucks with 40 tons gross weight. B. CAT 962H Hi-Lift Wheel Loaders with a 3.8 cubic meter bucket, and operating weight (without payload) of 20 tons, or similar large wheel loader. Road Design for the power plant was designed using the methods of AASHTO Guide. The section of road structure is shown in figure 1.

The method of permanent and temporary combination is adopted for the road construction of this project. In the early stage of the construction of the power plant, only the concrete base layer is built, which can meet the requirements during the construction period. The concrete wearing course layer will be completed in the later stage of the project construction, which can meet the requirements during the operation of the power plant.
2. The problems of concrete road pavement

Some cracks and damage appeared in the road base in two years after the construction of power plant, which is shown in refer to figure 2 and figure 3. If the concrete wearing course layer is poured on the old roadbed without dealing with the crack problem, more serious problems will be caused.

First, cracks or damages in the existing concrete base layer make the base vulnerable. If the concrete overlay is directly poured on the road base, reflection cracks could be produced in the wearing course layer in a short time after the construction. Secondly, the construction of the original concrete pavement has been completed for a long time, and the contraction of the base concrete has been completed, but the contraction of the newly poured concrete just started. The contraction of the two layers of pavement does not occur simultaneously, which makes the crack be generated more easily.

3. The reasons of reflection crack

The base material is easily affected by water and temperature, the dry shrinkage and temperature shrinkage cracks are thus produced under the vehicle load, affected by the temperature and humidity and other factors. At the pavement surface layer, the reflective crack formation, integrity and continuity of the pavement structure will cause serious damage on the pavement, it can reduce the strength of the pavement structure, the base layer much softer when immersed in the rain water. If the strength of pavement is reduced, repeated vehicle load may cause rapid structural damage of pavement. How to effectively control the occurrence of road reflection cracks has important practical significance [2].

The causes of cracks in concrete base are illustrated as following. First, after the construction of the rigid base, the internal water evaporation, hydration and other factors will reduce the moisture inside the base continuously, and thus lead to the material volume shrinkage of the rigid base, which
is known as dry shrinkage crack. Second, as the temperature changes, the volume of the rigid base material changes to some extent, which is manifested as thermal expansion and cold contraction. Especially when the temperature drops suddenly, the large temperature stress inside the concrete base is generated, resulting in large deformation of the base and temperature crack. Furthermore, due to the existence of cracks, the overall strength of the concrete base is reduced obviously. During the construction, under the repeated action of traffic load, the displacements of the adjacent plates on both sides of the cracks may be different and a large shear stress will thus be generated in the corresponding position. This shear stress is the cause of cracks in the base. [3] Finally, during the construction of the factory, 80% ~90% of the road base concrete has allowable cracks. Because our drainage system was not completed during the construction of the power plant, and the basement movement is caused by poor drainage, so the cracks are mainly longitudinal, transverse and corner cracks.

Shear stress and longitudinal stress are generated in the rigid base course after cracking. The load generated by these two stresses is the main reason for the surface reflective crack. If no effective measures are adopted to prevent the crack, it is easy to generate a large stress concentration around the cracking area of the base layer, and the stress transfer to the free end of the base layer crack is interrupted, resulting in the increase of surface stress and reflection crack.

4. Code requirements

According to the contract about the design of the road, the rehabilitation methods of road base layer cracks shall be based on part III: Pavement design procedures rehabilitation of existing pavements in the United States AASHTO Guide. As for the road rehabilitation methods with overlay and reflective crack control requirements, there are two methods in the American AASHTO Guide, including bonded concrete overlay and unbonded overlay. The bonded overlay and unbonded overlay method in the AASHTO Guide are shown as Fig. 4 and Fig. 5 respectively.

5.8.2 Pre-overlay Repair

The following types of distress should be repaired prior to placement of the bonded PCC overlay

| Distress Type     | Repair Type          |
|-------------------|----------------------|
| Working cracks    | Full-depth repair or slab replacement |
| Punchouts         | Full-depth repair     |
| Spalled joints    | Full- or partial-depth repair |
| Deteriorated patches | Full-depth repair    |
| Pumping/faulting  | Edge drains          |
| Settlements/heaves | Slab jack or reconstruct area |

Figure 4. The 5.8.2 in AASHTO Guide about bonded overlay.

5.9.2 Pre-overlay Repair

One major advantage of an unbonded overlay is that the amount of repairs to the existing pavement are greatly reduced. However, unbonded overlays are not intended to bridge localized areas of nonuniform support. The following types of distress (on the next page) should be repaired prior to placement of the overlay to prevent reflection cracks that may reduce its service life.

Guidelines on repairs are provided in References 1 and 3. Other forms of pre-overlay treatment for badly deteriorated pavements include slab fracturing (break/seat, crack/seat, or rubbing) the existing PCC slab prior to placement of the separation layer fracturing and seating the existing slab may provide more uniform support for the overlay.

Figure 5. The 5.9.2 in AASHTO Guide about unbonded overlay.

According to the Chapter 5.8.2 of AASHTO Guide, the bonded overlay can be used for the design scheme. This is prone to cause reflective cracking if we retain the cracks in the base surface as shown in figure 4. If there are local serious Cracks, perhaps “remove and replace by block” is the most ideal approach. AASHTO Guide requires slab replacement for cracks.

According to the Chapter 5.9.2 of AASHTO Guide, unbonded overlay can be used for the design scheme. One major advantage of an unbonded overlay is that the work of repairs to the existing pavement are greatly reduced. However, unbonded overlays are not suitable to bridge localized areas of non-uniform support. The types of distress (Fig.3) should be repaired prior to placement of the overlay to prevent reflection cracks that may reduce its service life. Other forms of pre-overlay treatment for badly deteriorated pavements include slab fracturing (break/seat, crack/seat, or rubbing) the existing slab prior to placement of the separation layer fracturing and seating the existing slab may provide more uniform support for the overlay.
Based on the problems encountered and the suggestions in the code, the appropriate solution is proposed to control reflection crack next.

5. The solution to control the reflective cracks

According to the extensive research data and code requirements, there are several methods to control the reflection crack.

The first method to control the reflection crack is the bonded concrete overlay scheme. When the damaged conditions and joint load transfer of the old concrete pavement are rated as excellent, the base layer should milling, or high-pressure water jetting. Other methods shall be adopted to trim and clean old concrete pavement surface and apply adhesive on the surface after cleaning, so that the top overlay and the old concrete pavement can be combined together as a whole. If there are local serious cracks, these distress should be full-depth repaired or use slab replacement method as shown in Fig. 3.

Another method to control the reflection crack is the unbonded concrete overlay scheme. When there is a lot of surface damage of concrete pavement, but the subgrade is stable, the base layer is basically not required to repair on deteriorated areas. Then we place a separation layer to act as reflection crack control and leveling course. The separation layer is usually asphalt mixes [4]. For the asphalt overlay, single-layer or double-layer asphalt pavement can be arranged, and at least one layer uses dense graded asphalt mixture; the leveling layer can be placed as required. We shall reasonably select the following measures to slow down reflection crack according to temperature, load, bearing capacity of old concrete pavement, joint load transfer ability, etc. [5]:

- Increase the thickness of asphalt overlay.
- Mix fibers, rubber and other modifiers in the overlay asphalt mixture.
- Place stress absorbing layer, polyester fiberglass cloth or geotextile interlayer on the top face of the old concrete slab or overlay.
- Use large particle size asphalt macadam in the sub layer of asphalt overlay.
- Install asphalt felt to block crack propagation

According to Chapter 5.9.2 of AASHTO Guide, when the old concrete pavement is damaged seriously, crack and seat scheme can be used to treat old concrete pavement. The treated old pavement is used for the base or sub base of the rebuilt pavement. This method requires to crack the concrete into pieces, typically 1 to 3 feet in size and seat the pieces firmly. Seating consists of several passes of 35 to 50-ton rubber-tired roller over a racked or broken slab. The purpose of the technique is to reduce the size of PCC pieces to minimize the differential movements at existing cracks and joints, thereby minimizing the occurrence and severity of reflection cracks. The crack and seat scheme is shown in Fig. 6.

According to the current crack situation of the road base, this project is suitable to adopt the unbonded concrete overlay scheme. When the concrete base layer is damaged seriously, crack and seat scheme can be used to treat old concrete pavement. When there is only surface damage of concrete pavement and the subgrade is stable, a separation layer is placed to act as reflection crack control and leveling course. The power plant project in the Philippines needs to consider the actual situation of local material procurement, machinery use and schedule requirements. According to the construction unit, in the local power plant in the Philippines, the purchase of asphalt mixture is difficult and the construction period is long, so it is an appropriate method to use asphalt felt as the separation layer (Figure 7). Asphalt felt is paved as crack interlining between old concrete base layer and concrete wearing course layer, it can alleviate the level of strain and the effect of vertical load, thus delay the reflective crack. After the reconstruction, the flatness, anti-skid and deflection of the road surface in this section were tested and the results indicate that all the road surface indexes could meet the code and display excellent driving performance [6].
6. Conclusion
In this paper, for the Philippines power plant road concrete cracks in the base concrete layer, the methods of how to control the reflection crack in concrete wearing course layer was explored, the formation mechanism of reflection crack and reasons were analyzed, and the methods to control reflection crack were proposed. These will provide references for solving similar problems of road reflection crack.

References
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