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Review

Review on asphalt plug joints: Performance, materials, testing and installation

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HIGHLIGHTS

- Asphalt plug joints are damaged and failed due to different mechanisms.
- Joint structure optimization reduces stress concentration.
- Binder properties are related to joint performance.
- Performance based material specifications can be developed.

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ABSTRACT

Asphalt plug joints (APJs) have been used worldwide because of its low cost, ease of installation and repair, low instance of snowplow damage, low traffic noise and ride comfort. The service life of APJs is relatively short. Extending the service life is thus becoming necessary by considering improved materials, structure design and performance testing. This paper provides a review on the field performance, materials used, testing methods and installation procedures of APJs. The literature review shows that the performance of APJs varies significantly worldwide. APJs are damaged and failed due to different mechanisms and performance based material specifications are needed to develop in accordance with the failure mechanisms. The joint structure can be optimized to reduce the concentrated stress and strain at the critical locations based on finite element analysis. APJs are simple but require careful construction, installation and quality control to ensure the good performance. It indicates that APJs can perform satisfactorily by taking into account proper joint design and material selection, suitable testing evaluation and careful field installation.

Contents

1. Introduction

An expansion joint on a concrete bridge deck is a relatively small and cheap component in a bridge. This usually results in insufficient attentions on joint design, material selection and

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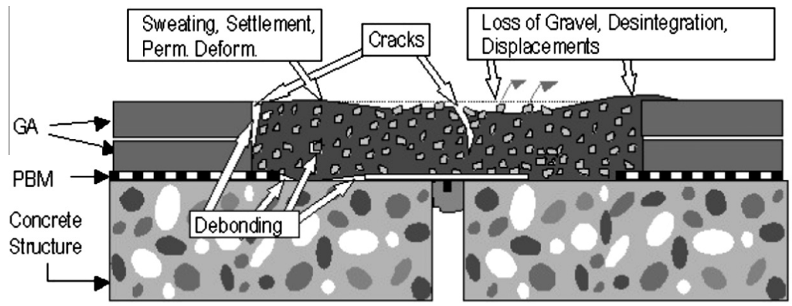

Fig. 1. Typical distress types of APJ reported by Partl (GA: gussasphalt; PBM: polymer–bitumen menbrance).

installation. The service life of expansion joints in road bridges is usually much lower than expected. Many maintenance problems caused by faulty joints are frequently reported [1–4]. Bridge joints can be the bridge elements that lead to the greatest deterioration and the highest repair costs. The maintaining work also results in a great influence on traffic unblocking and safety. It was reported that the cost of maintaining expansion joints could reach 7–25% of the global maintenance costs of bridges [3].

Various joint materials and systems have been used to obtain the maximum benefit like watertightness, maximum movements in both horizontal and vertical directions, ride quality and durability [1–4]. APJs have gained more attentions because of their advantages of noise reduction and driving comfort [5,6]. Other benefits of APJ application are their low cost, easy construction, maintenance and repair. APJs are very common for small ranges of joint movement, typically smaller than 50 mm [7–10]. They are also becoming popular for replacing or rehabilitating joints [3,4].

A typical APJ system consists of a backer rod in the gap, a steel plate on top of the gap, a block-out, and a special asphalt mixture that consists of polymer modified bitumen and aggregates [5,7,8,10]. The structure of APJs seems simple, but their service behaviors are complex. APJs may be damaged and failed due to different mechanisms. Typical types of damage include low temperature and fatigue cracking, rutting and permanent deformation, and debonding of the joint-pavement interface [3,11,12]. Because the joint filling material is a bitumen-rich mixture, the joint performance is strongly dependent on the type of asphalt binder. The binder properties including flow/creep resistance at high temperatures, relaxation and tension elongation at low temperatures are directly related to the field performance of APJs. Finite element analysis and laboratory validation tests confirmed that only a small length of APJ was effectively developing the strain field with bridge motion. Strain/stress concentrations occurred at the edge of the gap plate and the joint-pavement interface [11,13,14]. It indicated that the improved joint design can also lead to a better joint performance and longer service life [15–18]. Research done by EMPA indicated that the introduction of movement aids allowed developing APJs with larger joint movements of 70–100 mm [19–22]. Laboratory tests and field trials confirmed that the embedment of the springs in joint materials enforced a more homogeneous longitudinal strain distribution within the material during joint movements.

The goal of this paper is to provide a review on the aspects associated with APJs including application and field performance, constituent materials and testing, installation and structure design. The focus is to provide useful information to develop engineering-based design guidelines and performance based material specifications.

2. Application and performance

APJ has become popular in many countries for accommodating bridge joint movements less than 50 mm because of its low cost, ease of installation and repair, low instance of snowplow damage. The benefits of noise reduction and driving comfort also become interesting especially in the Netherlands [6,23,24]. However, the field performance of APJs worldwide varies significantly. Fig. 1 gives an illustration of typical distress types of APJ reported by Part l [20].

A survey of 250 joints on UK highway bridges done by Johnson indicated that half of bridge expansion joints were installed by APJs [1]. 50% of the APJs surveyed were leaking and tracking was common, especially in heavily trafficked nearside lanes. Cracking and debonding were found more on lightly trafficked road, particularly in winter. An inspection survey of 150 expansion joints done by Lima indicated that the joints used more frequently included reinforced elastomeric cushion joints (51%), elastomeric flexible strips (22%), and asphaltic plug joints (9%) in Brisa, Portugal. APJs were very suitable for small ranges of movement, particularly replacing joints in old bridges. For bridges older than 25 years, about 28% of the bridges have been installed by APJs [3,25]. The average life of APJ was 7.7 years in Portugal. In the Netherlands, the APJ systems only have an average service life of about 3 years. In order to improve the joint performance and reduce the traffic noise caused by defected joints, the Dutch Ministry of Transport, Public Works and Water Management have started a large research project on the application of innovative silent joint systems [6].

APJs are successfully used in Switzerland even on heavy traffic motorways [5,20]. New Swiss guidelines on APJ were released by the Swiss Guidelines of the Swiss Federal Road Office (ASTRA) in 2005 [26]. In 1996 and 1997, 18 APJs were installed on seven different test sites for in field performance observation using the four most commonly applied APJ systems in Switzerland. Most of these APJ systems showed satisfactory performance. Three joints were replaced in the 5-year monitoring period. Cracking and debonding were the most common defects detected during visual inspections. Lateral debonding in bridge parapet or footway zones happened in 70% of the investigated joints. Recent researches done by EMPA showed that the performance of APJs could be improved significantly on the basis of material selection and on-site construction [27,28]. APJs have been widely used in Germany since 1980s because of the low cost of maintaining and cleaning as well as high travel comfort. Federal Institute for Materials Research and Testing (BAM) has developed test criteria and methodologies for quality assurance as well as rules for the approval of APJ.

A survey done by Umass Dartmouth showed that 25% of the Departments of transportation (DOTs) in USA used APJs. Only a few DOTs followed a specification or guideline for joint design purpose. No DOT had any guidelines for evaluation of joint performance [11]. Bramel and Dolan carried out a survey of 50 state departments of transportation in USA to assess the use and installation guidelines [9,11]. The survey data showed that APJs were used successfully in many states but not all. Splitting in cold weather and track out in warm weather were the causes that leaded to a poor performance. Chang and Lee reported a statistics of 7763 bridge joints in Indiana, USA [2]. The percentage of APJ