# REPORT OF RESEARCH RESULTS

**Title** **Durability and traffic-safety functional performance of innovative porous asphalt pavement in Motorway No. 9**

**Primary Researcher** **Assoc. Prof. Dr. Thanongsak IMJAI**,
School of Engineering and Technology, Walailak University

**Co-researchers** **Dr. Chirawat WATTANAPANICH**,
School of Engineering and Technology, Walailak University

**Assis. Prof. Dr. Reyes GARCIA,**
School of Engineering, The University of Warwick, UK

**Summary** Porous Asphalt (PA) pavements are known to reduce aquaplaning and therefore the risk of accidents. However, to date PA pavements have not been used in Southeast Asia. This report summarises results on the performance of PA pavements in tropical weathers through laboratory and full-scale trials. This is the first time PA pavements are built and tested in a real section of a busy motorway in Southeast Asia. The PA pavements were produced using Tafpack Super (TPS) additives. The amount of TPS used in this study was 12% of the total weight of bitumen AC 60/70, with an asphalt content of 4.5%. This led to an air void of 20%, thus meeting the Japanese design guidelines for PA pavements. The results show that the use of TPS-modified binders AC grade 60/70 decreased the penetration value by 30%, increased the softening point by 88%, and increased the viscosity by 400%, which in turn also met the Japanese guidelines. The full-scale tests proved that using TPS additives in the PA mix effectively enhanced traffic safety in rainy weather by increasing skid resistance and permeability by up to 25% and 3%, respectively, over a conventional AC 60/70 pavement. A finite element model investigated the effect of a moving wheel on the performance of PA pavements. The experimental results showed that permanent deformation increases significantly with the number of load cycles, and this was confirmed by the numerical predictions. This large rutting results from the high value of vertical compressive stresses that occurs inside the base layer. This study provides benchmark data for future studies and for consultants/contractors and road managers who want to use PA pavements in tropical weathers. The full-scale test section of Motorway No. 9 also demonstrates real PA pavement applications in urban areas in Southeast Asia. It is expected that by increasing skid resistance and reducing flash flooding after heavy rain, the chance of accidents are reduced and the road users’ experience is improved.

**Aim of Research** This study aims at investigating the properties and performance of PA pavements made with cost-effective Tafpack Super (TPS) additive both in laboratory and real conditions.

**Method of Research & Progression** TPS additives were designed by mix proportioning in the laboratory. The percentages of TPS used in this study vary from 5-15% of the total weight of Hot Mix Asphalts (HMAs), which had bitumen AC grade 60/70. In this study, the experimental programme was divided into two parts.

- Part 1 focuses on “optimising” a mix design of the PA with TPS. Samples were tested in the laboratory to characterise the material and obtain its physical properties. Wheel Tracking tests were carried out to get the dynamic stability of the mix. The results from the latter tests were validated with numerical studies.
- In Part 2, the optimised PA mix design developed in Part 1 was used to build a road section (410 m) of a busy motorway near Bangkok (Motorway no. 9, (Fig. 1a-b) with PA (AC 60/70) mixed with TPS additives and compared to the widely used PA from HMA mixed with Polymer Modified Asphalt (PMA) in Thailand. The section of the motorway was monitored over six years. Performance studies on skid resistance, water permeability, and rutting of the first pilot field test section have been monitored in 2016, 2019 and 2022 (see photo from 2022 in Fig. 1c).

The results of this research are utilised to help develop new optimised PA mix design with TPS additives in order to improve skid resistance and reduce flash floodings after heavy rain, which is expected to enhance traffic safety and reduce traffic jams and travel delays. The results also support shaping the future Department of Highways’ (DOH) road safety policy to reduce accidents and improve the comfort of road users.

**Results of Research**

The PA mixture was designed in the DOH Thailand laboratories and Japanese laboratories. Also, full-scale field tests were conducted to examine the performance of the PA pavements. Based on the test results presented in this study, the following conclusions can be drawn:

- Mixing Tafpack Super additive in asphalt cement 60/70 can improve the performance of PA as the Pen-value decreases, the Softening point value increases, and the viscosity increases. As a result, the PA mixture is more stable (i.e., Marshall stability) and more durable.
- PA that the Tafpack Super polymer mate-rials have modified has the Cantabro loss value following the Japanese standard of PA.
- The PA mix has an average air void of 20%, which meets the Japanese standard of PA.
- From the Wheel Tracking Test, the dynamic stability value is 5775, higher than the Japanese standard of PA specification. Thus, the PA mix has sufficient durability to resist rutting formation.
- The friction test of both PA pavements mixed with TPS and PMA on the test section found that both types of PA have high permeability, thus improving skid resistance. Moreover, the average coefficient of friction is higher than the standard of the Japanese standard of PA.
- Permeability tests on PA pavements mixed with TPS or PMA on the test section found that the performance of both pavements is similar. Therefore, TPS can be considered as an alternative cost-effective additive for PA pavements in Thailand.
- The FEM analysis revealed that as the number of load repetitions increased, there was excessive permanent deformation (XXX mm)

at the surface of flexible pavement. This situation happened because of the high value of vertical compressive stresses that occur inside the base layer.

- Analysis of vehicle speed determines a clogging-prone porous pavement's skid resistance threshold condition. In wet conditions, a highway agency might lower the speed limit to extend the maintenance period of porous pavement.

**Future Areas to Take Note of, and Going Forward**

During the first year after the construction of the PA pavement on the field test section, it was found that the permeability and the skid resistance met the standard of the Department of Highways. In further studies, a long-term performance test should be conducted to provide data on the design of the PA mix developed for the DOH Thailand. Alternative maintenance methods should also be explored to ensure the permeability of the PA pavements remain sufficiently high.

**Means of Official Announcement of Research Results**

The use of Porous Asphalt (PA) pavements offers a sustainable method to cut down traffic noise, while at the same time providing stormwater management systems that encourage infiltration and reduce detention pools and road floodings. However, because PA pavements are prone to early deterioration (ravelling, filling of air gaps/voids), it is not a material commonly used as road surfacing in motorways. A novel mix design process for PA pavements with TFS additives proposed in this study could be adopted to encourage construction of PA pavements in Southeast Asia. The mix design leads to PA with TPS additives with enhanced permeability and durability, and with high percentage of air spaces (with a design air void of 20%). The improved permeability and clogging resistance also leads to a mix with aggregate gaps between 2.36 mm and 4.75 mm. Using the TPS modifier considerably improves the bonding between aggregate particles, producing a binder grade roughly equivalent to PG82. High mechanical, effective anti-stripping, and anti-aging properties define the improved binder. As a result, one may conclude that the rutting development can be avoided by using a PAP treated with a TPS concentration of 12%.

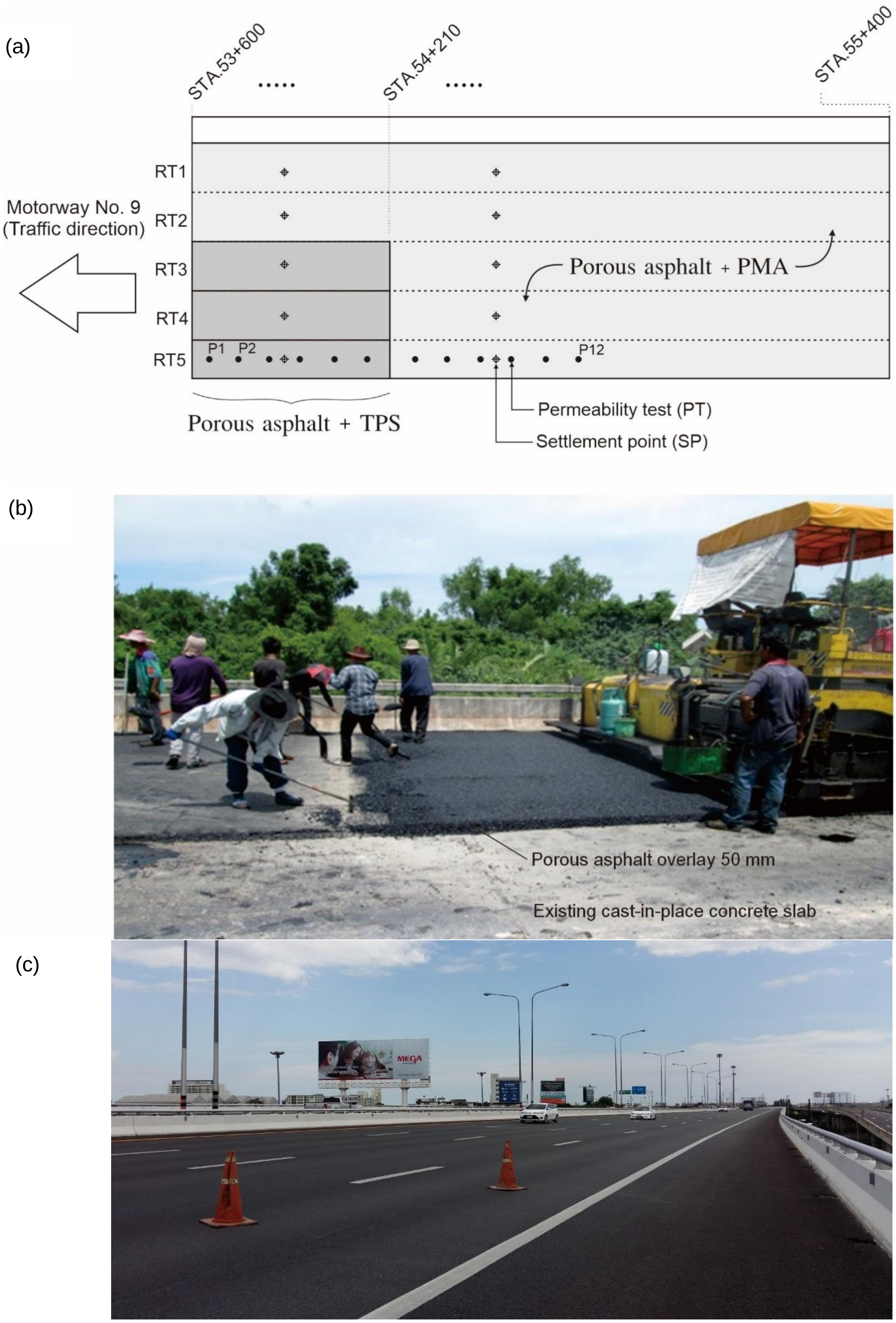


**Fig. 1** Photo of Construction of the pilot test section: (a) key plan for the section and field test positions, (b) construction of the PA and (c) overview of the current porous pavement (photo taken in December 2022).