The Road Traffic Noise Reduction on the Drainage Pavement

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Abstract: The drainage pavement or porous asphalt has open structure of its gradation. Therefore, the porous asphalt can reduce noise level from road traffic, as well as drains water from the road surface. These behaviors lead to the porous asphalt contribution on road traffic noise reduction and environment. This paper provides an artificial simulation on the road traffic noise reduction when the porous asphalt is applied an urban expressway. The simulation using and adapting ASJ RTN-2008 Model approach. The simulation result shows that the drainage pavement can reduce noise level effectively during its service life.

Keywords: Drainage Pavement, Road Traffic, Noise Reduction, ASJ RTN-2008

1. INTRODUCTION

In recently years, many developed countries has succeed in the implementation of the drainage pavement to give significant contribution in improving safety, reducing erosion, mitigating water pollution, and environment quality such reducing traffic noise. However, there are more discussions among scholars related to its contribution on the road safety.

The porous asphalt also called open-graded asphalt has been use as a wearing course or surface since the 1950s. The first major of its utilization in Australia was about 1973 and in Japan was about 1987. It is a developing in road surfacing technology, as well as an innovative road surfacing technology, which allows water to enter into the asphalt mixes beyond its continuous air voids. The porous asphalt is designed so that after laying and compacting, it forms a surface with a void's more than 20 percent. Then, it is used in wearing courses and always laid on impervious base course. In addition, it is promising and effective in enhancing traffic safety. The use of porous asphalt is also to reduce noise and glare (Sasana and Ismanto, 2003).

Furthermore, the porous pavement is one alternative solution to the problem of storm water drainage from parking and other low traffic density areas (Thomas et al., 2003). In operation actually, this pavement allows incipient rainfall and local runoff to soak through the pavement surface course of open graded asphalt concrete mix and accumulate in a porous base consisting of large open graded gravel, so that the water will percolate into the natural ground below. Then, it would drain laterally to a sump or channel.

Despite the above benefits, the porous asphalt can suffer from problems. Particularly, it can affect both its performance and its service life. The open structure exposes a large surface area to the effects of air and water, leading to rapid aging of the binder. In further, the clogging of the pores can reduce the functionality prematurely (Poulikakos D. L. et al., 2006). In order to reduce the problems addressed to porous asphalt and retain the benefits, the study

of porous asphalt has become an important objective within the more focus of advanced pavement materials research.

Regarding the above experiences, some developing countries including Indonesia have been introducing the drainage pavement as one of alternative solution to overcome the road traffic problems such the increasing road traffic noise. In Indonesia, Sasana and Ismanto (2003) have introduced the utilization of local materials on quality improvement of porous asphalt for Indonesia's roadways. In continuing the efforts, this paper attempts to grasp the contribution of the porous asphalt or drainage pavement in the road traffic noise reduction. Particularly, the paper provides an artificial simulation on the effectiveness of the porous asphalt in reducing road traffic noise. In this study, a case sample when an introducing of the porous pavement on an urban expressway in Makassar, Indonesia is conducted for the simulation.

2. OVERVIEW OF THE ASPHALT POROUS OR DRAINAGE PAVEMENT

The porous asphalt is a pavement layer from standard bituminous asphalt where the fines materials is screened and reduced in order to create void space to make the pavement highly permeable against water. The Iowa Storm Water Management Manual (2009) has given the specification of the void space about 16%, as opposed to 2% or 3% on the conventional asphalt. It is also called the porous asphalt surface course as the Open Graded Friction Course. Furthermore, the manual has emphasized that the porous asphalt has positive characteristics in its ability to blend into the normal urban landscape relatively unnoticed. For instance, it may typically allow a cost reduction of other storm water detention infrastructure through increasing the time of concentration and reducing the peak discharge rates for the larger storms. On the purpose of the porous asphalt in sizing downstream conveyance and structural control system, its surface areas can be assumed to 20% impervious. It is also can be taken for the runoff volume infiltrated from other impervious areas conveyed onto the pervious pavement system.

Regarding the above functions, the porous pavement is generally composed of four layers (Diniz, 1980) i.e. the sub base course, the reservoir base course, the reservoir top stabilizing course, and the open graded asphalt concrete surface course, respectively from bottom to up layers. The cross-section typically of the four layers adapted from Thelen and Howe (1978) is shown in Figure1.
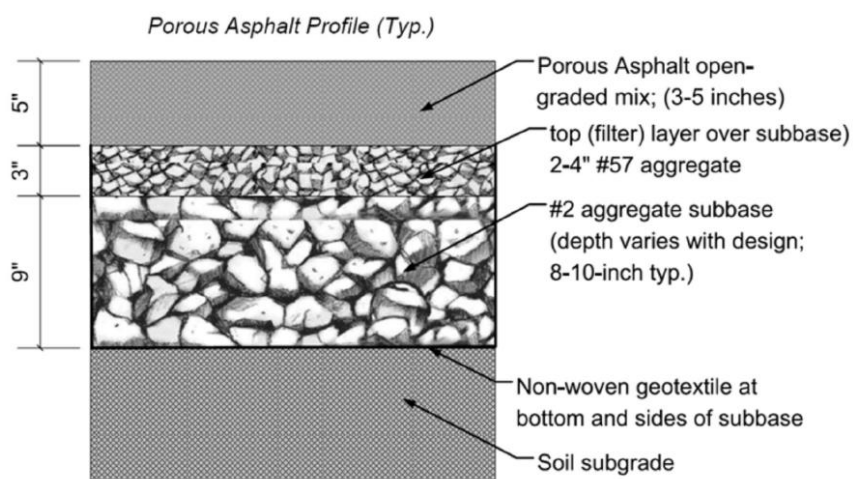

Figure 1 The cross-section typically of a porous pavement (Thelen and Howe, 1978)

Figure 1 shows that the bottom layer is minimally compacted sub-base consisting of undisturbed existing soil or, in the case of unsuitable base soils, an imported and prepared base course. This course may also require an auxiliary drainage structures such as French drains, pipe drains, etc. The reservoir base course consists of crushed stone aggregate having 1-2 inches (2.54-5.08 cm) diameter. The thickness of this course is obtained from runoff storage needs and frost depth considerations. The reservoir base course surface is stabilized by two inches (5.08 cm) of ½-inch (1.27 cm) crushed stone aggregate. The up-layer is the porous asphalt concrete surface course which its thickness is based on bearing strength and pavement design requirements. Mostly applications have used 2½ inches (6.35 cm) to be sufficient.

3. THE ROAD TRAFFIC NOISE PREDICTION BY ASJ RTN-2008 MODEL

In predicting road traffic noise, ASJ have developed a recently model, namely ASJ RTN-2008 Model. This sub section provides the construction of the model regarding the purpose of this paper.

The ASJ RTN-2008 have developed the equivalent continuous A-weighted sound pressure level as follow equation (ASJ, 2008):

$$L_{Aeq,T} = 10 \log \left(10^{L_{AE}/10} \cdot \frac{N_T}{T} \right) = L_{AE} + 10 \log \frac{N_T}{T} \tag{1}$$

where,

N_T : number of vehicles) during the time interval T [s],

L_{AE} : the single-event sound exposure level,

$L_{Aeq,T}$: the equivalent continuous A-weighted sound pressure level, and

Tables must be numbered sequentially and have a reasonably explanatory title centered over the table.

$$L_{AE} = 10 \log \left(\frac{1}{T_o} \sum_i 10^{L_{A,i}/10} \cdot \Delta t_i \right) \tag{2}$$

The A-weighted sound pressure level $L_{A,i}$ [dB] for noise propagation from the ith source position to the prediction point is calculated considering attenuation due to various factors in the sound propagation from an omni-directional point source in a hemi-free field as expressed as follows (ASJ, 2008).

$$L_{A,i} = L_{WA,i} - 8 - 20 \log r_i + \Delta L_{cor,i} \tag{3}$$

Where $L_{WA,i}$ is the A-weighted sound power level of a single running vehicle at the ith source position [dB] and r_i is the direct distance from the ith source position to the prediction point [m]. $\Delta L_{cor,i}$ denotes the correction related to various attenuation factors in the sound propagation from the ith source position to the prediction point [dB], and is given by following equation (ASJ, 2008):

$$\Delta L_{cor,i} = \Delta L_{dif,i} + \Delta L_{grnd,i} + \Delta L_{air,i} \tag{4}$$

Where $\Delta L_{dif,i}$ is the correction for diffraction [dB], $\Delta L_{grnd,i}$ is the correction for the ground effect [dB] and $\Delta L_{air,i}$ is the correction for atmospheric absorption [dB]. The suffix i for the source position is hereafter omitted for simplicity of notation.

The A-weighted sound power level of a road vehicle, L_{WA} is given by following equation (ASJ, 2008):

$$L_{WA} = a + b \log V + C \tag{5}$$

Where V is the vehicle speed [km/h], a and b are regression coefficients, and C is the correction term from a reference value (the power level when the vehicle runs on a dense asphalt pavement constructed within the last several years).

L_{WA} varies with the road conditions such as the pavement type and road gradient. Because there are various sound sources in the road vehicle and the noise generated from these sources is influenced by the body shape, the vehicle noise has the directivity. To consider the change in the noise radiation caused by these factors, the correction term C is given by following equation (ASJ, 2008):

$$C = \Delta L_{surf} + \Delta L_{grad} + \Delta L_{dir} + + \Delta L_{etc} \tag{6}$$

Where ΔL_{surf} is the correction for a drainage asphalt pavement [dB], ΔL_{grad} is the correction for road gradient [dB], ΔL_{dir} is the correction for sound radiation directivity [dB] and ΔL_{etc} is the correction for other factors [dB]. Due to this paper is only concern to the drainage asphalt effect, then we only consider ΔL_{surf} in the simulation.

Furthermore, the noise reduction effect due to a drainage asphalt pavement depends on the vehicle type, and also on the number of years since pavement was constructed. The correction formula is based on measurement data. The correction value for noise reduction due to a drainage asphalt pavement ΔL_{surf} for an expressway is calculated as follows.

ASJ RTN Model (2008) have given for running speeds of vehicle at less than 60 km/h, ΔL_{surf} for light vehicle and heavy vehicle are calculated using Equation (7) and Equation (8), respectively.

$$\Delta L_{surf} = -5.7 + 6.4 \log(y+1) \tag{7}$$

$$\Delta L_{surf} = -3.9 + 3.6 \log(y+1) \tag{8}$$

While the running speeds of vehicle at equal or more than 60 km/h, ΔL_{surf} for light vehicle and heavy vehicle are calculated using Equation (9) and Equation (10), respectively.

$$\Delta L_{surf} = -5.7 + 6.4 \log(y+1) \tag{9}$$

$$\Delta L_{surf} = -3.9 + 3.6 \log(y+1) \tag{10}$$

While the running speeds of vehicle at equal or more than 60 km/h, ΔL_{surf} for light vehicle and heavy vehicle are calculated using Equation (9) and Equation (10), respectively.

4. THE SIMULATION RESULTS

Regarding the adapted ASJ RTN Model, we tried to simulate the road traffic noise reduction on the expressway when the porous asphalt is introduced on the roadway. The simulation applied the service life of the porous asphalt during fifteen years. The simulation result is shown in Figure 2.

Figure 2 shows that the porous asphalt can effectively reduce traffic noise during the first year of its construction until the fifth or the sixth year of its service live. The noise reduction is remaining until the tenth year. In this regard, the porous asphalt can reduce the traffic noise until 4 dB at the first years after its construction. Unfortunately, the porous asphalt may produce increasing traffic noise when its service live more than ten years.

The above simulation result indicates that the porous asphalt needs a maintenance effort at least each five years in order to maintain its ability in reducing traffic noise effectively. This is no difference in comparing to the conventional asphalt mixes in maintenance efforts.
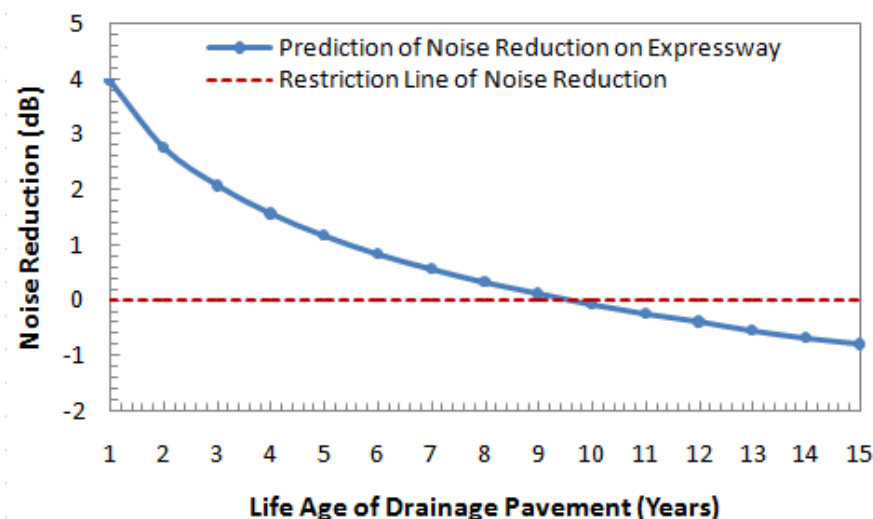

Figure 2 The simulation result on noise reduction of the porous asphalt during 15 years

5. CONCLUSIONS

The contribution of the drainage pavement on road traffic noise reduction has been elaborated in this paper. Particularly, an artificial simulation has been conducted in order to grasp the effectiveness of the porous pavement in reducing the road traffic noise on an urban expressway in Makassar, Indonesia. The simulation is based on an adopting and adapting of the ASJ RTN-2008 Model approach.

The simulation results show the effectiveness of the porous pavement in reducing the noise level until 4 dB during the first year of its service live. However, the pavement needs a routine maintenance effort each five years in order to maintain the noise reduction ability. In addition, a periodically maintenance effort has to have be conducted after its service live achieve ten years.

The porous asphalt seems promising in implementation for a certain roadway in developing countries such in Indonesia. However, the construction cost of the pavement construction changing from the conventional mixes to the porous asphalt still need more consideration.

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