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# Mechanistic Study of Composite Pavement Behavior in Heavy Duty Area

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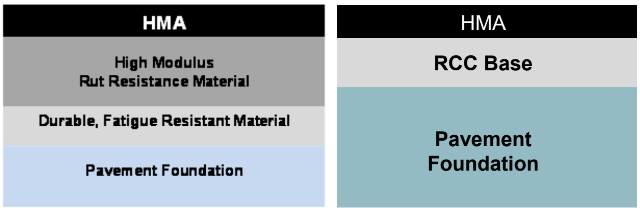
***Abstract*****—**In heavy duty areas, asphalt pavement constructed as entrance roadway may expose distresses such as cracking and rutting during service life. To mitigate these problems, composite pavement with a roller-compacted concrete base may be a good alternative; however, it should be initially investigated. Structural performances such as fatigue cracking and rut depth may be changed due to variation of some design factors. Therefore, this study focuses on the variation effect of material modulus, layer thickness and loading on composite pavement performances. Stress and strain at the critical location are determined and used as the input of transfer function for corresponding distresses to evaluate the pavement performance. Also, composite pavement satisfying the design criteria may be selected as a design section for heavy duty areas. Consequently, this investigation indicates that composite pavement has the ability to eliminate fatigue cracking in asphalt surfaces and significantly reduce rut depth. In addition, a thick or strong rigid base can significantly reduce rut depth and prolong fatigue life of this layer.

***Keywords*****—**Composite pavement, ports, cracking, rutting.

## I. INTRODUCTION

PAVEMENT in heavy duty areas such as a port or container terminal is usually subjected to the heavier loadings of container-handling vehicles than that of a highway. Asphalt pavement is usually constructed at the entrance roadway of a port [8]. Cracks and rutting may be exposed after experiencing traffic and climatic loading, and it may reduce the pavement life and functionality [6], [4], [7]. Perpetual pavement, firs constructed for highways, is interesting for heavy duty areas since it is reported to be a long-life pavement due to the elimination of high horizontal tensile stress or stain at the bottom of the asphalt surface course which induces the bottom-up cracking [1]. This structure generally consists of a high quality asphalt surface, rut resistant material at the intermediate layer, and a fatigue-resistant and durable base layer as shown in Fig. 1 (a) [10]. By the way, Roller-Compacted Concrete (RCC) pavement has been widely used, especially in heavy industrial areas to carry heavy loads [15]. RCC, a zero-slump concrete with final compacted form, has a high strength, high durability and is more economical than those of conventional concrete. RCC may be constructed without joints since it has a high shrinkage resistance [15]. Thus, RCC may be an economical and efficient alternative to replace the intermediate and base layer of a perpetual pavement system, as presented in Fig. 1 (b). This proposed pavement is referred to "RCC-Base Composite Pavement". Composite pavement has been constructed with other rigid base materials such as cement treated material, lean concrete and PCC [12], [16].



(a) (b)

Fig. 1 (a) Perpetual Pavement, (b) RCC-base Composite Pavement

Additionally, typical distresses, as revealed in Fig. 2, are reported in this pavement such as reflective cracking, rutting and fatigue cracking in rigid base [16]. However, this study will not discuss the reflective crack on composite pavement performance since this issue can be effectively controlled by construction methods such as saw-and-seal or immediate seal after crack method [5], [16]. Additionally, SHRP [16] also recommend RCC joint spacing with 3.05 m (10 ft) or less to prevent joint damage when RCC is overlaid with asphalt. Thus, in the present study, the distresses such as fatigue cracking and rutting may represent the performances of RCC-base composite pavement.

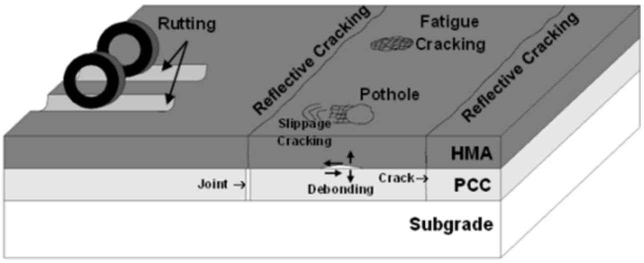


Fig. 2 Typical distresses in composite pavement

Nunez [12] studied the sensitive analysis of composite pavement for highways by investigating the effects of various rigid base materials on pavement performances. This study reported that using composite pavement may reduce surface deflection and minimize or eliminate the high tensile strain or stress at the bottom of the HMA layer. It is also indicated that rut depth within the HMA layer tends to increase as the

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stiffness of base is increased higher than the HMA stiffness. Moreover, Portland Cement Association [14] published a design report by comparing flexible and RCC pavement to RCC-base composite pavement. The results showed that RCC-base composite pavement provides a longer design life than other pavement. With the same traffic level, RCC-base composite pavement has a thinner asphalt thickness than flexible pavement and a thinner RCC layer than RCC pavement.

Variations of other design factors may also influence on performances of RCC-base composite pavement and it is necessary to investigate their effects. Therefore, this investigation focuses on the variation effect of material modulus, layer thickness and loading on pavement performances such as fatigue cracking and rut depth by applying the heavy wheel loading of handling vehicle used in port areas. In addition, RCC-base composite pavement sections which satisfy the design criteria (i.e. no fatigue cracking in HMA surface and in RCC base, and low rut depth RD<10 mm) may be selected as the pavement design sections for heavy duty areas at a required load repetition.

## II. RESEARCH STRATEGY

### A. Research Procedure

The investigation focuses on the variation of design factor effect on fatigue cracking and rut depth of RCC-base composite pavement. Comparison between conventional flexible and RCC-base composite pavement is firstly discussed to understand their differences. Secondly, RCC base modulus, asphalt thickness and RCC base thickness are changed to investigate their effect. Some design criteria are defined to evaluate these performances. Pavement responses (e.g. stress and strain) at pavement critical locations are computed by using finite element method (FEM) and they are used to evaluate the pavement performance. Moreover, composite pavement section which produces no fatigue cracking in asphalt surface and in RCC base, and produces low rut depth (RD<10 mm) will be selected as a pavement design section for heavy duty area at a required traffic.

### B. Performance Evaluation

Fatigue cracking in the asphalt surface and RCC base, and rut depth are defined as the performances of RCC-base composite pavement. Evaluation of these pavement performances is described in detail in the following.

#### 1) Fatigue Cracking of Asphalt Layer

Bottom-up fatigue cracking of asphalt layer is evaluated by the horizontal tensile strain at the bottom of asphalt surface course [11]. If no tensile strain occurs at this location, the bottom-up fatigue cracking in asphalt may not exist in this pavement system.

#### 2) Fatigue Life of RCC Layer

Fatigue cracking of an RCC base is evaluated by stress ratio (SR) which is the ratio between the tensile stress at the bottom of RCC base and the modulus of rupture of RCC. The fatigue life of RCC can be estimated by the relationship between SR and allowable load repetition developed by Tayabji et al. [17]. This relationship indicates that RCC with SR≤0.4 may have an unlimited life. Thus, composite pavement which produces SR≤0.4 may be selected as a design section for heavy duty areas.

#### 3) Rut Depth of Asphalt Layer

Rutting is a deformation along the wheel path of an asphalt surface due to the repetition of wheel loading. Rut depth is a function of the state of stress or strain in the asphalt layers [16]. In heavy duty areas, rut depth should be less than 10 mm (RD < 10 mm) to secure the changing of lane during the container The WesTrack rut depth prediction model is used and it is shown in (1) [16]. This model is a function of K parameter and the permanent or plastic shear strain $\gamma_P$ at depth of 50 mm beneath the tire edge. Plastic shear strain is determined from (2) and it is based on the shear stress $\tau$ and strain $\gamma_e$ at the corresponding location. The coefficient a, b, and c has a typical value 2.114, 0.04 and 0.124, respectively.

$$RD = K\gamma_p \tag{1}$$

$$\gamma_p = ae^{b\tau}\,\gamma_e N^C \tag{2}$$

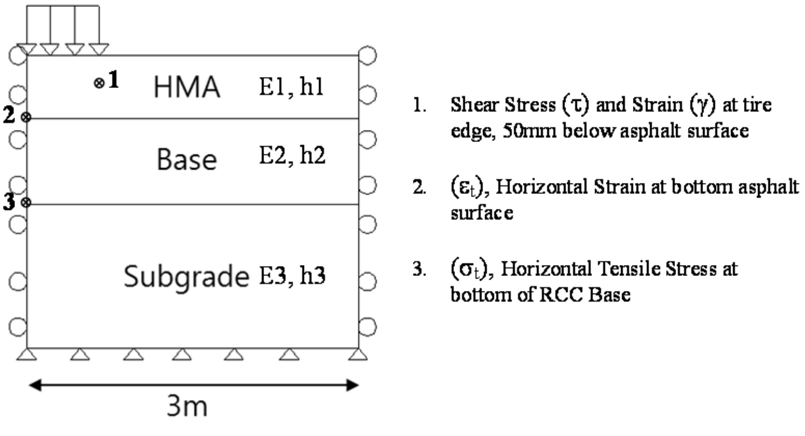


Fig. 3 FEM Axisymmetric Model

## III. FINITE ELEMENT MODEL

### A. *Finite Element Model Description*

Pavement responses such as stress and strain at the critical location of pavement are used to evaluate the performance of composite pavement. In this study, FEM with axisymmetric model is used to compute those responses. Material properties are considered as linear elastic and interface condition are fully bonded. The critical pavement responses corresponding to the considered distresses are: horizontal strain at the bottom of asphalt surface course ($\varepsilon_t$), tensile stress at bottom of RCC base ($\sigma_t$), and shear stress ($\tau$) and strain ($\gamma$) at tire edge below asphalt surface 2 ” (50 mm), as shown in Fig. 3.

#### 1) Loading Parameters

Generally, pavement in ports is subjected to heavier wheel load than on highways. Wheel load is a combination of vehicle and container weight distributed to each wheel. Handling vehicles such as truck, trailer, straddle carrier, sidelifter or sideloaders, reach stacker, and front lift truck and rubber tire gantry cranes (RTG), have a very different wheel configuration to that of highway vehicles [3]. The contact radius of these vehicles is typically ranged from 136 mm to 272 mm and the average contact radius is about 223 mm [9].

Therefore, in this study, single wheel load is used for the axisymmetric problem analysis and it is assumed to have a constant contact radius 223 mm. Two cases of loading, 100 kN and 30 0kN with contact pressure 0.64 MPa and 1.92 MPa, respectively, are applied in the pavement analysis.

### B. *Thickness and Material Input*

Thickness and material inputs for the analysis are listed in Table I. Typical elastic modulus of asphalt concrete (E1=3.5 GPa) is constantly used for all case of study. Elastic moduli of RCC (E2=19-30 GPa) are the typical value used for heavy duty or industrial area [13]. Elastic modulus of subgrade E3 is assumed and it corresponds to the soil with CBR 10%.

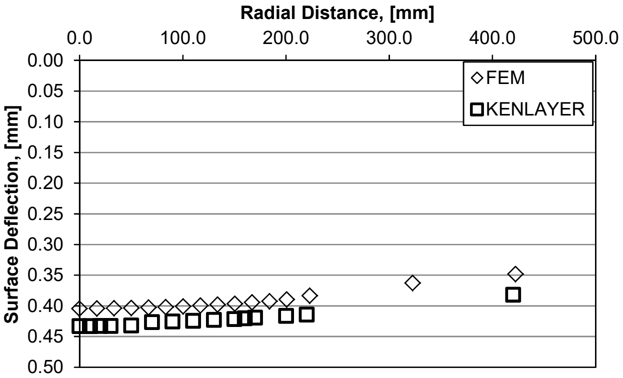
TABLE I
MATERIAL AND THICKNESS PROPERTIES FOR AXISYMMETRIC ANALYSIS

| Description | Elastic & Rupture Modulus, [GPa] (Poisson’s Ratio) | Thickness, [mm] |
|---|---|---|
| Comparison of Composite and Flexible Pavement | E1 = 3.5 (0.35)<br>$E2_{RCC}$ = 19, 21, 25, 28, 30 (0.15)<br>$M_{R,RCC}$ = 3, 3.1, 3.94, 4.42, 4.73<br>$E2_{Granular}$ = 3.5, 2.3, 1.75, 1.4, 0.35 (0.38)<br>E3 = 0.1 (0.45) | h1 = 100<br>h2 = 200<br>h3 = 1200 |
| Effect of Asphalt Thickness | E1 = 3.5 (0.35)<br>$E2_{RCC}$ = 19, 21, 25, 28, 30 (0.15)<br>$M_{R,RCC}$ = 3, 3.1, 3.94, 4.42, 4.73<br>E3 = 0.1 (0.45) | h1 = 50, 100, 200, 300<br>h2 = 200<br>h3 = 1200 |
| Effect of RCC Base Thickness | E1 = 3.5 (0.35)<br>$E2_{RCC}$ = 19, 21, 25, 28, 30 (0.15)<br>$M_{R,RCC}$ = 3, 3.1, 3.94, 4.42, 4.73<br>E3 = 0.1 (0.45) | h1 = 100<br>h2 = 200, 400, 600<br>h3 = 1200 |

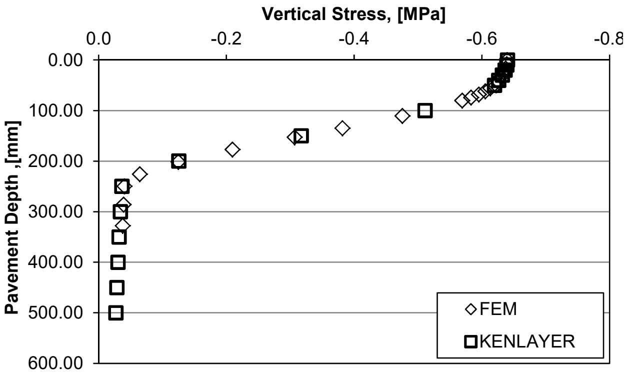
### C. *Model Verification*

The accuracy of FE solution is evaluated by comparing with the result from multi-layer elastic software KENLAYER. Surface deflection, vertical stress profile along the pavement depth and at interface are used for this verification. Pavement model is composed of 50 mm-Asphalt surface (with EHMA=3.5 GPa) and 200 mm-RCC base (with EBase=0.35 GPa), respectively. Elastic modulus of subgrade is 100 MPa. Interface between each layer is considered as fully-bonded condition.

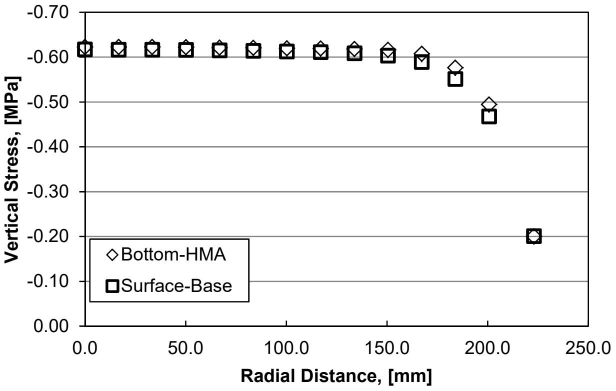
Figs. 4 (a) and (b) show the comparison of surface deflection and vertical stress, respectively, from FEM and KENLAYER calculation. Calculated surface deflection of the two methods is not significantly different (about 6%). Moreover, vertical stress along pavement depth is coincided between the FEM and KENLAYER results. This good agreement between the two methods gives the sufficient of geometry, boundary condition and mesh of FEM in this present study. Furthermore, Bathe’s criterion [2] also suggested that FEM mesh is adequately fine when jumps in stress across inter-element boundaries become negligible. Fig. 4 (c) shows that jump stresses across interface between asphalt surface and base are insignificant. Thus, this FEM model provides a sufficient fine mesh for the calculation of pavement responses.



(a)



(b)



(c)

Fig. 4 FEM Verification: (a) Surface Deflection, (b) Vertical Stress, (c) Jumps of Vertical Stress at Interface

## IV. Results and Discussion

### *A. Comparison between Composite and Flexible Pavement Performances*

Performances of composite and flexible pavement (i.e. fatigue cracking and rut depth) are compared. Pavement structure is constantly composed of 100 mm and 200 mm of asphalt surface course (h1) and base layer (h2), respectively. With asphalt modulus (E1=3.5 GPa) and base moduli (E2=0.35 to 30 GPa), pavement which can satisfy the design criteria (i.e. no fatigue cracking and RD<10mm) are selected as a design section for heavy duty area at a required load repetition. RCC-base composite pavement is identified by modulus ratio (E1/E2 <1) and others are flexible pavement.

#### 1) Fatigue Cracking of Asphalt Surface in Composite and Flexible Pavement

Horizontal strain at the bottom of asphalt surface course is used to evaluate the bottom-up fatigue cracking of asphalt surface in composite and flexible pavement. If horizontal compressive strain occurs, this crack may not exist. Fig. 5 illustrates the comparison of horizontal strain at the bottom of asphalt surfaces in composite and conventional flexible pavement systems. Here, 100 kN and 300 kN of single wheel loading are applied on each pavement.

Fig. 5 indicates that all RCC-base composite pavements (E1/E2<1) produce horizontal compressive strain at the bottom of asphalt surface and thus this pavement has ability to eliminate the bottom-up fatigue cracking in asphalt. For conventional flexible pavement, only sections with modulus ratio (1≤E1/E2≤1.24) that produce compressive strain. Therefore, for both loading cases, pavement structures with modulus ratio (E1/E2<1.24) satisfy a design criterion (i.e. no fatigue cracking in asphalt surface), and consequently, they are used to evaluate the rut depth in the next section.

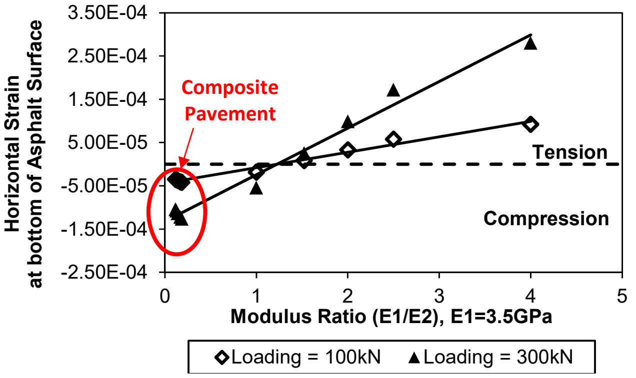


Fig. 5 Horizontal Strain at Bottom of Asphalt Surface in Composite and Flexible Pavement

#### 2) Rut Depth of Asphalt Surface in Composite and Flexible Pavement

Pavements (E1/E2<1.24) are analysed to compute rut depth at one million repetitions which is evaluated with criterion 10 mm. Shear stress and strain at critical location, as shown in Fig. 3, are determined from FEM and used as the input of transfer function (1) and (2). Computed rut depths in pavements (E1/E2<1.24) are shown in Fig. 6 for both case of loading.

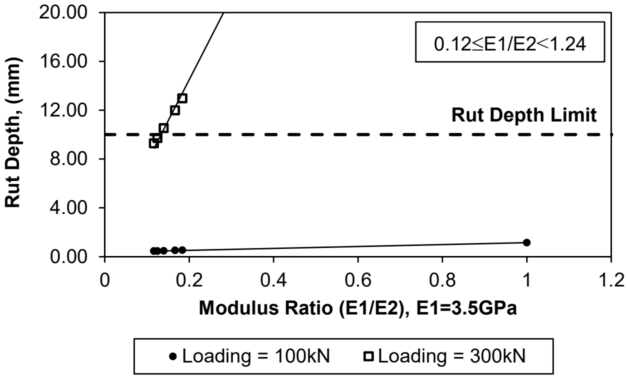


Fig. 6 Rut Depth in Composite and Flexible Pavement

Fig. 6 shows that, for both loadings, rut depths in composite pavements (E1/E2<1) are very small comparing to that of flexible pavement since shear stress at the critical location of composite pavement is shifted to the bottom of the asphalt layer, as shown in Fig. 7. For 100 kN loading, rut depths in composite pavements are smaller than 1mm and are ranged from 0.44 mm to 0.52 mm. For flexible pavement (E1/E2=1), computed rut depth is about 1.14 mm. In the case of 300 kN loading, rut depths in composite pavement (0.12≤E1/E2≤0.18) are increased and they are ranged between 9.27 mm to 12.96 mm and pavements (E1/E2<0.13) produce small rut depth (RD<10 mm). However, rut depth in flexible pavement is higher than the limitation. Thus, composite pavements (0.12≤E1/E2≤0.18) and (E1/E2<0.13) verify the rut depth criterion (RD<10 mm) for 100 kN and 300 kN loading, respectively, and these pavements are used to evaluate fatigue cracking in RCC base in the following section.

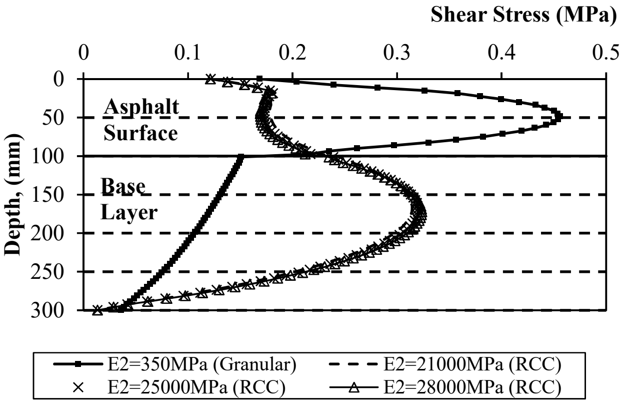


Fig. 7 Shear Stress Distribution at the Tire Edge in Composite and Flexible Pavement

3) Fatigue Cracking of RCC Base in Composite Pavement

SR, ratio of horizontal tensile stress at bottom of RCC base and modulus of rupture, is used to evaluate fatigue cracking of RCC layer. Composite pavement with SR<0.4 may produce no fatigue cracking in RCC base and these pavements are selected as the design section for heavy duty area. Composite pavements (0.12≤E1/E2≤0.18) are analyzed to compute stress ratio SR and to evaluate fatigue cracking of RCC base. Stress Ratio SR, for both loading cases, are computed and shown in Fig. 8.

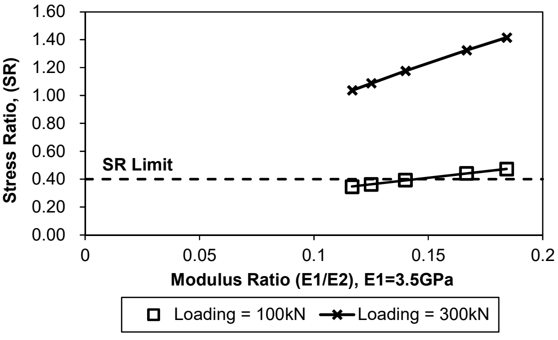


Fig. 8 Stress Ratio of RCC Base in Composite Pavement

Fig. 8 indicates that stress ratio of RCC base is increased for both cases of loading since E1/E2 is increased (or E2 is reduced). This means that fatigue life of RCC will be extended due to the augmenting of RCC base modulus. In the case of 100 kN loading, composite pavements (0.12≤E1/E2≤0.14) satisfy the fatigue cracking criterion (i.e. no fatigue cracking in RCC base) due to SR<0.4. However, in the case of 300 kN loading, all pavements produce high stress ratio SR>0.4, and thus, they are rejected for the design section in heavy duty areas.

In summary, composite pavement (E1/E2=0.14, h1=100 mm, h2=200 mm) is selected as the design section for heavy duty areas in the case of 100 kN loading because this structure satisfies the three design criteria (i.e. no fatigue cracking in asphalt surface course and RCC base and low rut depth RD<10mm after one million load repetitions). In the case of 300 kN loading, all composite pavements cannot verify these three design criteria.

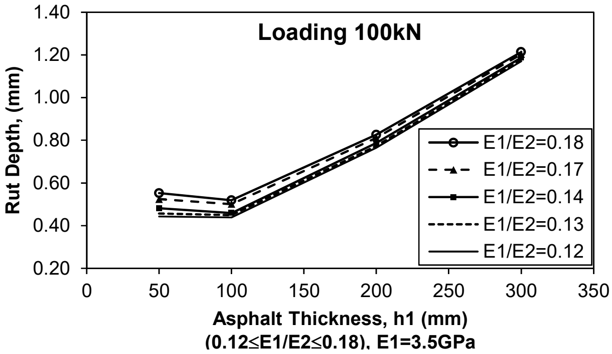
### *B. Effect of Asphalt Thickness on Composite Pavement Performances*

According to the findings in the previous section, fatigue cracking in asphalt surfaces may not exist in composite pavement, and thus, its performances may be discussed only on rut depth and fatigue cracking in RCC bases. Asphalt thickness effect is investigated by changing h1 from 50 mm to 300 mm with a constant RCC base thickness (h2=200 mm). Composite pavements (0.12≤E1/E2≤0.18) are analysed in this investigation. Additionally, for both cases of loading (i.e. 100 and 300 kN), composite pavements that verify the design criteria (i.e. no fatigue cracking in RCC base, SR<0.4 and low rut depth RD<10 mm at one million load repetitions) may be selected as the design section for heavy duty areas.

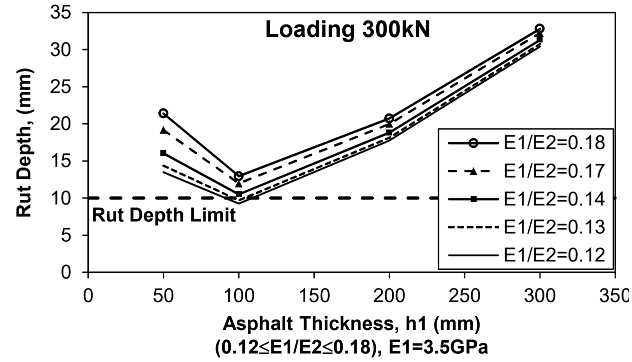
1) Effect of Asphalt Thickness on Rut Depth

Computed rut depth at one million load repetitions, 100 kN and 300 kN, are illustrated in Fig. 9 (a) and Fig. 9 (b), respectively. Fig. 9 shows that, in both loading cases, composite pavements with low E1/E2 (or high E2) can produce a small rut depth in all of asphalt thickness study. Moreover, increasing of asphalt thickness from 50 mm to 100 mm will slightly reduce rut depth since critical shear stress and strain is shifted from the critical location (i.e. 50 mm under asphalt surface at tire edge) for computing rut depth. However, this rut depth will be significantly increased due to the increase of asphalt thickness from 100 mm to 300 mm. When thick asphalt is used, this structure may resemble the pavement composed of asphalt surfaces on other asphalt intermediate layers above the RCC base layer. Thus, rut depth may be developed in both asphalt surfaces and the asphalt intermediate layer.

Fig. 9 (a), 100kN loading case, shows that rut depths of all case are smaller than the design criterion (RD<10 mm). Therefore, pavements (0.12≤E1/E2≤0.18, 50 mm≤h1≤100 mm, h2=200 mm) satisfy the rutting criterion and will be used to evaluate fatigue cracking of RCC base in the next section. In the case of 300 kN loading, as shown in Fig. 9 (b), only pavement (E1/E2≤0.12, h1=100 mm, h2=200 mm) that verifies the rut depth criterion (RD<10 mm).



(a) 100kN Loading Case

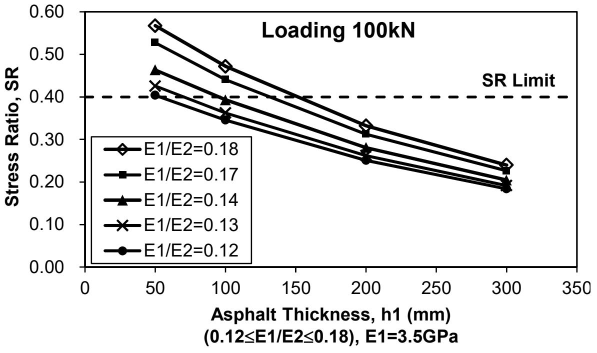


(b) 300kN Loading Case

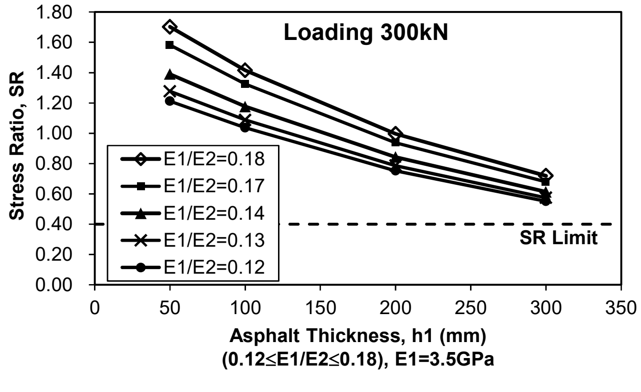
Fig. 9 Effect of Asphalt Thickness on Rut Depth of Composite Pavement

2) Effect of Asphalt Thickness on Fatigue Cracking of RCC Base

Fatigue cracking of RCC base is evaluated by stress ratio SR, ratio between tensile stress at the bottom of RCC base and rupture modulus of RCC. Composite pavements with SR<0.4 satisfy the design criterion (i.e. no fatigue cracking RCC base) and they are selected as the design section for heavy duty areas. Stress ratios are computed and illustrated in Fig. 10.



(a) 100kN Loading Case



(b) 300kN Loading Case

Fig. 10 Effect of Asphalt Thickness on Stress Ratio of RCC Base

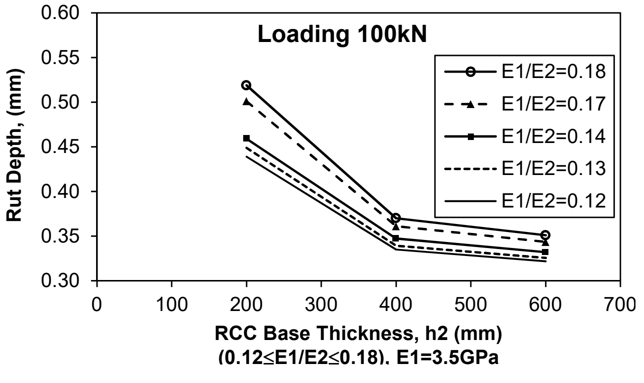
Fig. 10 shows that the stress ratio tends to be decreased when E1/E2 are reduced (or E2 is increased). Moreover, as h1 is increased, the stress ratio is significantly reduced. Therefore, a thick asphalt surface may delay the development of fatigue cracking in RCC base. In the case of 100 kN loading, as shown in Fig. 10 (a), composite pavements (E1/E2=0.14, h1≤100 mm, h2=200 mm), (E1/E2=0.13, h1>75 mm, h2=200 mm), (E1/E2= 0.14, h1≤100 mm, h2=200 mm), (E1/E2=0.17, h1≤130 mm, h2=200 mm) and (E1/E2=0.18, h1>150 mm, h2=200 mm) may create small stress ratio SR<0.4, and thus, these pavements verify the design criteria (i.e. no fatigue cracking in RCC base and low rut depth RD<10 mm). In the case of 300 kN, as shown in Fig. 10 (b), all pavements produced SR>0.4, and thus, they may not verify the RCC fatigue cracking design criterion.

In summary, in the case of 100 kN loading, composite pavement (E1/E2=0.14, h1=100 mm, h2=200 mm) is a required design section for heavy duty areas due to its verification in the design criteria (i.e. no fatigue cracking in RCC base and low rut depth at one million load repetition) and also, the need of a low application of asphalt material. In the case of 300 kN, no composite pavement can achieve the requirements of the design criteria.

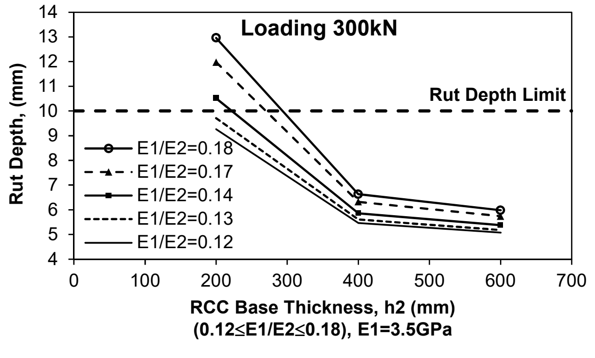
### C. *Effect of RCC Base Thickness on Composite Pavement Performances*

The effect of RCC base thickness on rut depth and fatigue cracking of an RCC base in composite pavement is investigated by changing the RCC thickness h2 from 200 mm to 600 mm. With a constant asphalt thickness h1=100 mm, composite pavements (0.12≤E1/E2≤0.18) are analyzed.

1) Effect of RCC Base Thickness on Rut Depth



(a) 100kN Loading Case



(b) 300kN Loading Case

Fig. 11 Effect of RCC Base Thickness on Rut Depth

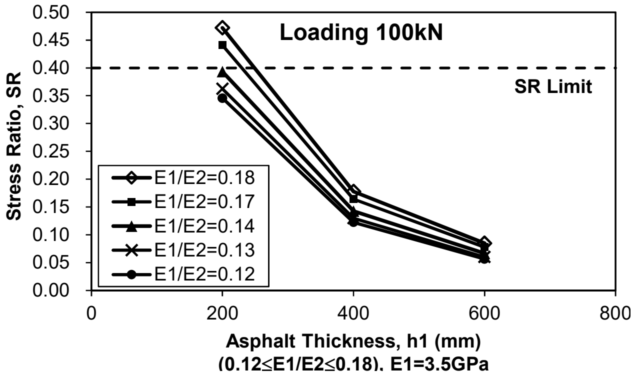
Computed rut depths at one million repetitions of 100 kN and 300 kN loading are shown in Figs. 11 (a) and (b), respectively. In both loading cases, composite pavement with low E1/E2 (or high E2) can produce a small rut depth in all cases of the RCC base thickness study. Moreover, increasing the RCC base thickness from 200 mm to 600 mm will significantly reduce rut depth in the asphalt layer.

For 100 kN loading, as shown in Fig. 11 (a), rut depths of all cases are smaller than the rut depth criterion (10 mm). Thus, composite pavements (0.12≤E1/E2≤0.18, h1=100 mm, 200 mm≤h2≤600 mm) verify the design criterion (RD<10 mm) and they are used to evaluate the fatigue cracking of RCC base in the next section. In the case of 300 kN loading, as shown in Fig. 11 (b), composite pavements (E1/E2≤0.13, h1=100 mm, h2≤200 mm), (E1/E2≤0.14, h1=100 mm, h2≤250 mm), and (E1/E2≤0.18, h1=100 mm, h2≤300 mm) produce a low rut depth that satisfy the rutting criterion. Thus, these pavements are analyzed in the next section to evaluate the fatigue cracking in the RCC base.

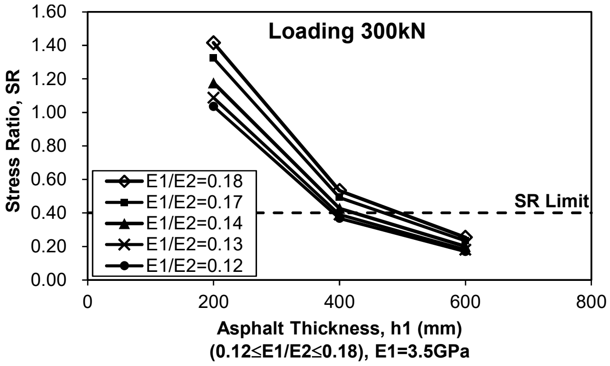
### 2) Effect of RCC Base Thickness on Fatigue Cracking of RCC Base

The fatigue cracking of the RCC base is evaluated by stress ratio SR, ratio between tensile stress at the bottom of the RCC base and modulus of rupture. Composite pavements with SR<0.4 are selected as the design section for heavy duty areas. Stress ratio SR are determined and shown in Figs. 12 (a) and (b) for loading 100 kN and 300 kN, respectively. Fig. 12 indicates that stress ratio tends to decrease when modulus ratio E1/E2 is reduced (or E2 is increased). Moreover, as h2 is increased, the stress ratio is significantly reduced. Therefore, thick RCC base may extend the fatigue life of RCC.

For 100kN loading as shown in Fig. 12 (a), composite pavements (0.12≤E1/E2≤0.14, h1=100 mm, h2>200 mm), (E1/E2=0.17, h1=100 mm, h2>240 mm) and (E1/E2=0.18, h1=100 mm, h2>260 mm) produce SR<0.4, and thus, they achieve the design criteria (i.e. no fatigue cracking in RCC base). For 300 kN loading, as shown in Fig. 12 (b), composite pavements (E1/E2≤0.13, h1=100 mm, h2≤400 mm), (E1/E2=0.14, h1=100 mm, h2>440 mm), (E1/E2=0.17, h1=100 mm, h2>475 mm) and (E1/E2=0.18, h1=100 mm, h2>500 mm) produce stress ratio SR<0.4, and thus, these pavements verify the design criterion (i.e. no fatigue cracking RCC base).



(a) 100kN Loading Case



(b) 300kN Loading Case

Fig. 12 Effect of RCC Base Thickness on Stress Ratio of RCC Base

According to the sensitive analysis in the previous section, composite pavement sections summarized in Fig. 13 are the required design section for heavy duty area that can produce no fatigue cracking in the asphalt surface, no fatigue cracking in the RCC base and low rut depth at one million repetitions of both 100 kN and 300 kN loading.

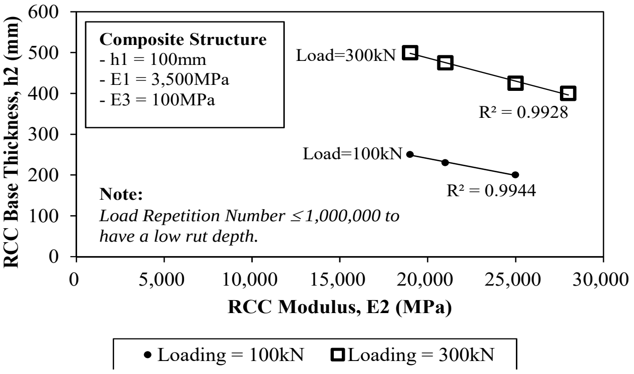


Fig. 13 Required Composite Pavement Section for Heavy Duty Areas

## V. CONCLUSION

RCC-base composite pavements in heavy duty areas are sensitively analyzed with the heavy wheel loading of container-handling vehicles to investigate the effect of some design factors on fatigue cracking and rutting by changing the material modulus, layer thickness and loading. Many results have been derived from this investigation as:

- RCC-base composite pavement can eliminate the critical horizontal tensile strain at the bottom of an asphalt surface course that induces the bottom-up fatigue cracking in this surface layer. Thus, the fatigue cracking of asphalt can be neglected during the design process.
- Rut depth in RCC-base composite pavement is excessively reduced because the critical shear stress and strain is shifted to the bottom of the asphalt layer. However, these predicted rut depth may be overestimated or underestimated due to the application of transfer function without post calibration of the equation.
- High modulus of the RCC base can significantly reduce the rut depth developed in the asphalt layer and extend the

fatigue life of the RCC base layer.

- Thick asphalt surfaces may increase rut depth and extend the fatigue life of the RCC base. However, in terms of economics, thick asphalt may not be a good alternative to prolong the life of the RCC base.
- Increasing the RCC base thickness may significantly reduce rut depth and extend the fatigue life of the RCC base.

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