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# Proceedings of the 11th Asia Pacific Transportation and the Environment Conference (APTE 2018)

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## Physical and Mechanical Properties of Asphalt Concrete Contain Reclaimed Asphalt Pavement from National Road in East Java Province Indonesia

Ari Widayanti, Ria Soemitro, Januarti Ekaputri, Hitapriya Suprayitno

Reclaimed Asphalt Pavement (RAP) is a paving stripping material with Cold Milling Machine. The RAP accumulation in East Java Province is estimated 50,000 m3 per-year. The RAP usage can decrease RAP accumulation, natural material, damage rate by mining or excavation. RAP mixture produced an optimum performances...

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## Characteristics of Asphalt Concrete Mixed Using Aggregates Coated by Low Density Polyethilene (LDPE) Plastic Waste

Ni Luh Setyarini, Anissa Tajudin

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## Mode Choice Analysis between Bus Rapid Transit and the Alternate Public Transit in Semarang City

Amelia Indriastuti, Djoko Purwanto, Kani Basuki

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Agung Sedayu

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Hera Widyastuti, Ahmad Soimun, Anggit Putri

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Mudjiastuti Handajani, Andi Kuriniawan, Harmini

The Smart City being expedient and reliable is safe, convenient, cheap, regular, scheduled as well as modern city transportation system. The Trans Semarang buses run simultaneously on public roads, there is bound to be inaccurate arrival time information. Consequently, there is the need for a system...

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Sahid Bismantoko, Asep Haryono, Tri Widodo

These the problem of parking systems on the streets is a classic problem that occurs from year to year, many solutions are offered in solving parking problems on the street. The problem is not only related to congestion due to exit and enter the vehicle from the parking lot but also the problem of parking...

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Hadunneththi Pasindu, Kaushan Devasurendra, Pathiraja Udayanga

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Anastasia Sutandi, Wimpy Santosa, Felix Hidayat, Aini Zahiyah

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Okkie Putriani, Sigit Priyanto

The ATTN 2018 data collection process is obtained from the data collection of the sample OD-matrix using cellular data, carried out with the aim of obtaining data on the Origin Destination Matrix (movement) of the mobile phone user movement for a given period to get the sample OD-matrix. Data signals...

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M. Priyadarshanie, H. Pasindu, S. Senevirathne, D. Jayaratne

Urban commercial developments are an integral part of the urban land use which affect the trip generation and attraction pattern in the city. More importantly, these developments increase the demand for parking, which by law should be provided within the development. Lack of adequate parking facilities...

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Hitapriya Suprayitno, Dio Hananda, Jimi Aditya

Good Transportation Planning needs a good and accurate Transport Model. Trip Production Modeling, as the first step, needs to be accurate also. A new Trip Production Accuracy measure, incorporating R2 and Confident Interval values, has been proposed. An experiment to investigate the CI Behavior, due...

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Willy Kriswardhana, Sonya Sulistyono

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Puguh Triwinanto, Tri Handayani, L. Baskoro

Light Rail transportation (LRT) in Indonesia is built first time in 2016. Rail is one of the important components for track at LRT. One of joint of rail for LRT is uses flash butt welding joint. The requirement of flash butt welding joint is based on BS EN 14587-2:2009. Requirements include static...

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Bambang Istiyanto

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Hendro Prabowo, Firda Fatimah, Alia Fauziah, Ira Prabawati, Maria Chrisnatalia

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Iksiroh Husna, Wisnu Handoko, Sarifudin, Anissofiah Wijinurhayati

Work accidents according to Heinrich 88% are caused by human factors so that they can be prevented, so improving the behavior of workers becomes very important. The study was conducted on cadets post-sea practice, against the use of personal protective equipment (PPE). The research method was carried...

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Leksmono Putranto, Dwi Suryana, Sunu Bagakara

This paper is intended to develop Indonesian Driving Anger Scale by adopting several items of driving anger short scale developed by Deffenbacher et al in the USA. The respondents were asked to rate the amount of anger that would be provoked from none at all, a little, some, much and very much if the...

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Avoiding flight delays has become a crucial factor in each airport and airline since a huge economic cost results as consequences. Researches are conducted to measure aviation delay and its economic cost [1] while its environmental cost is sparsely addressed. In this research, the delay of departure...

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Yan Unzilatirrizqi, Bambang Istiyanto, Andrea Maulana

The temperature increasing on earth has triggered drastic climate change. Motor vehicle emissions, especially $CO_2$, are a major source of pollutants in major cities in Indonesia. This greatly affects the transportation sector whose estuary affects the contribution of carbon dioxide ($CO_2$) which is predicted...

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Life cycle analysis (LCA) is a technique to assess the environmental impact of a product or service throughout its life cycle and is used commonly to evaluate transport decisions at the planning level. Well-to-Wheel (WtW) is a subset of LCA that focuses on the efficiency of transport fuels by measuring...

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Nuri Onat, Murat Kucukvar, Omer Tatari

Adoption of alternative vehicle technologies such as electric vehicles (EVs), plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs) have the potential of reducing some of the environmental impacts and reducing oil-dependency of the U.S transportation sector. However, this potential...

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Achmad Wicaksono, Bagyo Yanuwiadi, Agus Dwiyanto

To manage fishery resources in Indonesia with the principle of sustainability, it is necessary to apply the eco-fishing port concept. This study aims to develop a model for assessment of eco-fishing port with prevailing conditions and regulations in Indonesia. From the model that prepare, the application...

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Andrean Maulana, Oka Purwati

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Juanita Kombaitan, Iwan Kusumantoro, Heru Putro

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Ahmad Utanaka, Hera Widyastuti

There are some methods to determine accident cost, one of which is the willingness-to-pay method. Willingness-to-pay method use in this research because this method more recommended by developed countries than gross output method which is still used in developing countries, especially Indonesia. Road...

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Sasika Ranawaka, Handunneththi Pasindu

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Adhi Muhtadi, Indrasurya Mochtar, Hera Widyastuti

Electric Railway (KRL) is the backbone of public transportation in Jakarta. But KRL share capital is still 4.1%. Therefore this paper seeks to reveal what characteristics play a role for travellers to use KRL regularly or temporarily. The study was conducted in October 2017 at several Jakarta KRL stations....

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Asep Nurhidayat, Djoko Utomo, Rizqon Fajar, Sucipto, Hera Widyastuti

This research was conducted to analyze the model of transportation mode selection between aircraft and high speed train of Jakarta-Surabaya route as an empirical case study, assuming the construction of high speed train infrastructure has been completed and ready to operate connecting Jakarta-Surabaya....

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Anissa Tajudin, Ni Luh Setyarini, Devy Darmawati

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Moe Lwin, Lee Kelvin, Ho Yong, Wang Xuechun

Greenhouse gas emission from the construction of asphalt pavement affect the environment during the production and laying of hot mix asphalt which are carried out at high temperatures. Asphalt mixes be produced and compacted at about 20oC to 40oC lower than the corresponding hot mix asphalt mixes. The...

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Bagus Setiadji, Supriyono, Djoko Purwanto

Road pavement is one of infrastructures that is currently getting most attention due to its important role in accelerating the economic growth rate of an area, opening up isolated regions and improving the connectivity among them. A road infrastructure has a life-cycle which starts from design to reconstruction....

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Arief Setiawan, Latif Suparma, Agus Mulyono

Urban floods are a frequent disaster in Indonesia and cause road damage with the relatively high cost of repairs every year. Durability test of water damage of asphalt mixture on mild temperatures, such as indirect tensile test did not show the weakness of asphalt mixture. Therefore, this study aims...

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Ari Sandhyavitri, Arief Aditya, Muhamad Yusa

This paper objective is to mitigate to what extent the Liddle empirical formula (which the initial power equation of 4th order) may suit in designing road pavement lifespan for overloading vehicle roads. A case study was conducted in the Meredan highway, Siak, Riau, Indonesia. It was identified that...

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Ajay Jagadeesh, Ghim Ong, Yu-Min Su

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H. Pasindu, Lalith Sirisumana, D. Jayaratne

Provincial level and Local roads comprise nearly 50% of the road network in mileage in Sri Lanka. They play a pivotal role in providing access to the local communities especially in rural areas and an essential component of the economic development of those areas. These roads are under the purview of...

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Muhtar, Sri MurniDewi, Wisnumurti, As'ad Munawir

The use of bamboo to replace the steel reinforcement starts from the fact that bamboo has high tensile strength as high as steel. As a renewable material bamboo has much benefit for green construction material. Bridge frame structure is one of structure that can use the bamboo reinforced concrete. The...

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Agus Tjahjono, Vega Andromeda, Afdolludin Tazani

Cylindrical liner is the place of burning to generate power or effort inside the Mother Machine. The size of the oversized diameter will affect the incomplete combustion. The purpose of this study was to determine the causes of broken piston rings and surging, the impact of oversized liners and strategies...

# The 11th Asia Pacific Transportation and the Environment Conference (APTE)

Malang, Indonesia, October 18-20, 2018 http://apte2018.teknik.ub.ac.id

September 14, 2018

To: Anissa N. Tajudin, Ni Luh P.S.E. Setyarini , and Devy S. Darmawati
Department of Civil Engineering, Tarumanagara University,
11470, West Jakarta, Jakarta, Indonesia

Dear: Anissa N. Tajudin, Ni Luh P.S.E. Setyarini , and Devy S. Darmawati

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has been accepted for **full paper presentation** at the 11th Asia Pacific Transportation & the Environment Conference (11th APTE, 2018) on October 18-20, 2018, in Malang, East Java, Indonesia.

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If you have any questions, please feel free to contact us through the official e-mail: apte2018@ub.ac.id. Thank you for your interest in the 11th APTE. We look forward to seeing you in Malang in October 2018!

Sincerely,
Chairman of the 11th APTE 2018 Organizing Committee

**Ludfi Djakfar, Ph.D.**
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# The Influence of CBR Value and Overloading on Flexible Pavement Mechanistic Response

Anissa N. Tajudin, Ni Luh P.S.E. Setyarini, and Devy S. Darmawati

***Abstract*— Flexible pavement distresses are often caused by overloading with the combination of other factors, such as subgrade strength. Therefore, this study was conducted to investigate and analyze the effect of subgrade strength on flexible pavement mechanistic response with normal traffic loading and overloading scenario (25% to 100%) using KENPAVE software. CBR was varied from the range 3% to 10% with an increase of every 0,5%. Horizontal tensile strain was then used to estimate pavement fatigue life (Nf) and vertical tensile strain was then used to estimate pavement rutting life (Nr). The results of mechanistic responses reveal that the horizontal tensile strain and vertical compressive strain all decrease with increasing subgrade CBR value. The addition of load will increase the pressure that the vehicle distributes to the pavement, so that the horizontal tensile strain and vertical compressive strain will be higher. Nf and Nd all increase with decreasing of horizontal tensile strain and vertical compressive strain, which implies that higher CBR value will increase Nf and Nd. Rutting occurs at CBR 3% to 7,5% with the overloading of 75% and 100% while fatigue cracking occurs at CBR 3% to 9,5% with the overloading of 50, 75%, and 100%.**

***Index Terms*— CBR, flexible pavement, horizontal tensile strain, overloading, vertical compressive strain.**

## I. Introduction

Pavement quality is one of the most crucial elements in the efficiency of land transportation activities, both in structural and functional. In designing flexible pavement, it is necessary for engineer to consider the specific conditions of a particular location, such as material availability, subgrade strength, rainfall, and traffic load. Differences characteristic of each location will cause differences in calculation result and decision making for choosing the best design. Pavement distress is often caused by overloading with the combination of other factors. Inaccuracy in the design can also cause the road to failure before the expected design life. Therefore, this study is conducted to investigate and analyze the effect of subgrade strength on flexible pavement mechanistic response with normal traffic loading (0% overloaded) and overloading scenario (25%, 50%, 75%, and 100%).

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### *A. Subgrade*

Subgrade takes an important role of pavement's overall structure performance. Subgrade materials should adequately provide a stable platform of road construction, limit progressive settlement as a result of repeated traffic loading, and prevent massive slope failure [1].

The material property used to characterize roadbed soil strength for pavement design in AASHTO 1993 which was then adopted to Bina Marga Pt T-01-2002-B is the resilient modulus ($M_R$). The resilient modulus is a measure of the elastic property of soil recognizing certain nonlinear characteristics. In case that resilient modulus test can't be performed, suitable factors can be used to estimate resilient modulus from standard CBR, R-value, and soil index test results or values [2].

Heukelom and Klomp [3] developed equation to make correlation between CBR value to $M_R$ value which is showed in equation (1) [3].

$$MR = 1500 \times CBR \tag{1}$$

with :

$M_R$ : Resilient modulus (psi)

*CBR* : California Bearing Ratio

### *B. Mechanistic Empirics Response for Layered System*

The basic aim of the structural design process is to combine the different layers in such way as to result in the most cost-effective functional pavement structure. This can be achieved by primarily two different methods, first is by using empirical methods, which is charts and equations developed from experimental studies carried out with a set of traffic, environment, and pavements or second is by using a mechanistic method, in which concepts of mechanics are used to predict responses and performance of the pavement. Such an empirically based specification is unlikely to result in an efficient use of construction equipment or materials and does not allow the use of analytical design procedures. A purely mechanistic approach is not possible at this time because the responses can be predicted by employing concepts of mechanics, but the performance has to be predicted by empirical models. Hence, it is more appropriate to say that pavements can be designed either by using the empirical approach or by using the mechanistic-empirical approach (ME) [4][5].

Flexible pavements are constructed by layered systems with better materials on top and cannot be represented by a homogeneous mass. Burmister first developed solutions for a two-layer system and then extended them to a three-layer system. With the advent of computers, the theory can be applied to a multilayer system with any number of layers by using various software available, such as KENPAVE. The basic assumptions to be satisfied are [6][7]:

1. Each layer is homogeneous, isotropic, and linearly elastic with an elastic modulus E and a Poisson ratio v.
2. The material is weightless and infinite in areal extent.
3. Each layer has a finite thickness h, except that the lowest layer is infinite i n thickness.
4. A uniform pressure q is applied on the surface over a circular area of radius a
5. Continuity conditions are satisfied at the layer interfaces, as indicated by th e same vertical stress, shear stress, vertical displacement, and radial displacement. For frictionless interface, the continuity of shear stress and radial displacement is replaced by zero shear stress at each side of the interface.

*C. Fatigue and Rutting Distress Modelling*

Traffic load working on the surface of flexible pavement is assumed as evenly distributed static load that the material of pavement will give response which is believed to be critical for design purposes are: Horizontal tensile strain (εt) bottom of the asphalt layer and vertical compressive strain value (εc) on the surface of subgrade [8]. Strain is the unit displacement due to stress, usually expressed as a ratio of the change in dimension to the original dimension (mm/mm or in/in). Since the strains in pavements are very small, they are normally expressed in terms of microstrain ($10^{-6}$) [9]. Excessive horizontal tensile strain will create cracking on the surface due to fatigue while excessive vertical compressive strain will make pavement distress occurs due to rutting [10].

Several fatigue and rutting models have been developed to relate the asphalt modulus and/or the measured strains to the number of load repetitions. These models are developed to predict pavement fatigue and rutting life. One of the most common of the fatigue and rutting failure model is developed by Asphalt Institute as equation (2) and (3) [11].

$$Nf = 0{,}0796 \left(\frac{1}{\varepsilon t}\right)^{3{,}291} \left(\frac{1}{E1}\right)^{0{,}854} \quad (2)$$

$$Nd = 1{,}365\, x\, 10^{-9} \left(\frac{1}{\varepsilon c}\right)^{4{,}477} \quad (3)$$

Where horizontal tensile strain on the bottom of asphalt layer (εt) and asphaltic layer modulus (E1) are used to estimate the allowable number of load repetitions to prevent pavement from fatigue cracking failure (Nf) and vertical tensile strain on the surface of subgrade (εc) is used to estimate the allowable number of load repetitions to prevent rutting failure (Nr). Any value lower than the actual number of designed traffic repetitions will cause distress.

## II. Experimental Methods

To study the influence of CBR subgrade values and traffic overloading to flexible pavement mechanistic response, this order of research methodology was carried out:

1. Obtain actual number of design traffic repetitions data from average daily traffic (ADT) on Cipularang Toll Km 97, West Java Indonesia which is then presented by equivalent single axle loads.
2. Determine pavement requirements for KENPAVE input parameters in terms of layer thickness, elastic modulus, resilient modulus, and poison's ratio.
3. Determine load configuration for pavement response analysis in KENPAVE with traffic scenarios of normal loaded (0%) and overloaded (25%, 50%, 75%, 100%).
4. Run KENPAVE to obtain horizontal tensile strain and vertical compressive strain for various CBR values (3% to 10% with an increase of every 0,5%).
5. Calculate pavement fatigue and rutting life using Asphalt Institute failure model to get allowable repetitions to failure.

Analyze the result of pavement response.

## III. Input Parameters

The pavement thickness used in this study is presented in Table I and developed by using Bina Marga 2002 method which is based on AASHTO 1993 with traffic parameters obtained from traffic survey in Cipularang Toll km 97, West Java, Indonesia.

TABLE I
PAVEMENT THICKNESS FOR VARIOUS CBR VALUES

| CBR | Subbase Course Thickness (inch) | Base Course Thickness (inch) | Surface Course Thickness (inch) | Total Thickness (inch) |
|---|---|---|---|---|
| 3 | 16 | 13,5 | 4,5 | 34 |
| 3,5 | 14 | 13,5 | 4,5 | 32 |
| 4 | 12 | 13,5 | 4,5 | 30 |
| 4,5 | 11,5 | 13,5 | 4,5 | 29,5 |
| 5 | 9 | 13,5 | 4,5 | 27 |
| 5,5 | 8 | 13,5 | 4,5 | 26 |
| 6 | 6,5 | 13,5 | 4,5 | 24,5 |
| 6,5 | 6 | 13,5 | 4,5 | 24 |
| 7 | 6 | 13,5 | 4,5 | 24 |
| 7,5 | 6 | 13,5 | 4,5 | 24 |
| 8 | 6 | 13,5 | 4,5 | 24 |
| 8,5 | 6 | 13,5 | 4,5 | 24 |
| 9 | 6 | 13,5 | 4,5 | 24 |
| 9,5 | 6 | 13,5 | 4,5 | 24 |
| 10 | 6 | 13,5 | 4,5 | 24 |

Material characteristics is presented in Table II. Because Poisson ratio has a relatively small effect on pavement responses, it is customary to assume a reasonable value for use in design, rather than to determine it from actual tests [6].

TABLE II
PAVEMENT THICKNESS FOR VARIOUS CBR VALUES

| Layer | Material | Elastic Modulus (psi) | Poisson's Ratio |
|---|---|---|---|
| Surface | Asphalt concrete | 350.000 | 0,35 |
| Base | Bituminous treated | 230.000 | 0,35 |
| Subbase | Granular | 16.000 | 0,4 |
| Subgrade | Soil | Based on each CBR | 0,45 |

Load characteristics is presented in Table III. Actual number of design traffic repetitions data from average daily traffic (ADT) on Cipularang Toll Km 97, West Java Indonesia which is then presented by equivalent single axle loads (ESAL). Thus, load characteristics used in this study is based on standard axle load which is single axle dual wheels.

TABLE III
PAVEMENT THICKNESS FOR VARIOUS CBR VALUES

| Parameters | Units | Values |
|---|---|---|
| Contact radius | inch | 4,51 |
| Contact pressure | psi | 70 for normal load (0%), 87,5 for overloading of 25%; 105 for 50%, 122,5 for 75%, and 140 for 100% |
| Inter wheel spacing | inch | 16.000 |
| ESAL | repetitions | 23.947.797 |
| ESAL | repetitions | 23.947.797 |

## IV. RESULTS AND DISCUSSION

CBR values are varied from the range 3% to 10% with an increase of every 0.5%, thus create 15 pavement variations. Pavement structure consists of asphalt concrete surface course, bituminous treated base, and granular subbase. Loading scenarios are represented by contact pressure which is one of the input parameters in KENPAVE. Normal loading indicates standard pressure from standard axle and overloading scenarios are carried out by increasing the amount of that contact pressure. Vertical compressive strains, horizontal tensile strains, and predicted life for rutting and fatigue resulted due to variation of subgrade CBR values and loading scenarios from normal, over 25%, 50%, 75%, and 100% are presented in Table IV to Table VII.

TABLE IV
VERTICAL COMPRESSIVE STRAIN FOR VARIOUS CBR VALUES AND LOADING SCENARIOS

| CBR | Vertical Compressive Strain | | | | |
|---|---|---|---|---|---|
| (%) | Normal | +25% | +50% | +75% | +100% |
| 3 | 1,52E-04 | 1,90E-04 | 2,28E-04 | 2,65E-04 | 3,03E-04 |
| 3,5 | 1,50E-04 | 1,87E-04 | 2,25E-04 | 2,62E-04 | 3,00E-04 |
| 4 | 1,50E-04 | 1,87E-04 | 2,24E-04 | 2,62E-04 | 2,99E-04 |
| 4,5 | 1,44E-04 | 1,80E-04 | 2,16E-04 | 2,52E-04 | 2,88E-04 |
| 5 | 1,47E-04 | 1,84E-04 | 2,21E-04 | 2,58E-04 | 2,95E-04 |
| 5,5 | 1,46E-04 | 1,82E-04 | 2,18E-04 | 2,55E-04 | 2,91E-04 |
| 6 | 1,47E-04 | 1,84E-04 | 2,16E-04 | 2,57E-04 | 2,94E-04 |
| 6,5 | 1,44E-04 | 1,80E-04 | 2,16E-04 | 2,51E-04 | 2,87E-04 |
| 7 | 1,39E-04 | 1,73E-04 | 2,08E-04 | 2,42E-04 | 2,77E-04 |
| 7,5 | 1,35E-04 | 1,69E-04 | 2,02E-04 | 2,36E-04 | 2,70E-04 |
| 8 | 1,29E-04 | 1,62E-04 | 1,94E-04 | 2,26E-04 | 2,58E-04 |
| 8,5 | 1,26E-04 | 1,57E-04 | 1,88E-04 | 2,20E-04 | 2,51E-04 |
| 9 | 1,22E-04 | 1,52E-04 | 1,83E-04 | 2,13E-04 | 2,44E-04 |
| 9,5 | 1,18E-04 | 1,48E-04 | 1,77E-04 | 2,07E-04 | 2,36E-04 |
| 10 | 1,14E-04 | 1,43E-04 | 1,71E-04 | 2,00E-04 | 2,29E-04 |

TABLE V
HORIZONTAL TENSILE STRAIN FOR VARIOUS CBR VALUES AND LOADING SCENARIOS

| CBR | Horizontal Tensile Strain | | | | |
|---|---|---|---|---|---|
| (%) | Normal | +25% | +50% | +75% | +100% |
| 3 | 7,32E-05 | 9,15E-05 | 1,10E-04 | 1,28E-04 | 1,46E-04 |
| 3,5 | 7,28E-05 | 9,10E-05 | 1,09E-04 | 1,27E-04 | 1,46E-04 |
| 4 | 7,24E-05 | 9,06E-05 | 1,09E-04 | 1,27E-04 | 1,45E-04 |
| 4,5 | 7,15E-05 | 8,94E-05 | 1,07E-04 | 1,25E-04 | 1,43E-04 |
| 5 | 7,12E-05 | 8,90E-05 | 1,07E-04 | 1,25E-04 | 1,42E-04 |
| 5,5 | 7,06E-05 | 8,82E-05 | 1,06E-04 | 1,24E-04 | 1,41E-04 |
| 6 | 7,02E-05 | 8,77E-05 | 1,05E-04 | 1,23E-04 | 1,40E-04 |
| 6,5 | 6,94E-05 | 8,68E-05 | 1,04E-04 | 1,22E-04 | 1,39E-04 |
| 7 | 6,85E-05 | 8,56E-05 | 1,03E-04 | 1,20E-04 | 1,37E-04 |
| 7,5 | 6,82E-05 | 8,53E-05 | 1,02E-04 | 1,19E-04 | 1,36E-04 |
| 8 | 6,69E-05 | 8,36E-05 | 1,00E-04 | 1,17E-04 | 1,34E-04 |
| 8,5 | 6,64E-05 | 8,30E-05 | 9,97E-05 | 1,16E-04 | 1,33E-04 |
| 9 | 6,58E-05 | 8,22E-05 | 9,86E-05 | 1,15E-04 | 1,32E-04 |
| 9,5 | 6,51E-05 | 8,14E-05 | 9,77E-05 | 1,14E-04 | 1,30E-04 |
| 10 | 6,43E-05 | 8,04E-05 | 9,64E-05 | 1,13E-04 | 1,29E-04 |

TABLE VI
PREDICTED RUTTING LIFE FOR VARIOUS CBR VALUES AND LOADING SCENARIOS

| CBR (%) | Nd | | | | |
|---|---|---|---|---|---|
| | Normal | +25% | +50% | +75% | +100% |
| 3 | 171.451.910 | 63.135.874 | 27.856.524 | 13.974.241 | 7.687.584 |
| 3,5 | 180.330.315 | 66.365.629 | 29.386.008 | 14.728.981 | 8.097.621 |
| 4 | 181.954.964 | 67.003.545 | 29.621.247 | 14.855.339 | 8.170.575 |
| 4,5 | 217.193.147 | 80.079.418 | 35.357.826 | 17.748.070 | 9.768.120 |
| 5 | 195.024.401 | 71.685.447 | 31.716.733 | 15.887.845 | 8.744.154 |
| 5,5 | 206.060.633 | 76.020.523 | 33.579.943 | 16.830.794 | 9.253.025 |
| 6 | 198.015.917 | 72.917.870 | 35.504.974 | 16.166.602 | 8.891.782 |
| 6,5 | 217.870.636 | 80.279.231 | 35.504.974 | 17.811.370 | 9.798.601 |
| 7 | 256.957.925 | 94.684.018 | 41.876.411 | 21.007.889 | 11.557.204 |
| 7,5 | 290.075.470 | 106.818.107 | 47.222.659 | 23.682.615 | 13.004.051 |
| 8 | 350.760.255 | 129.164.822 | 57.101.802 | 28.637.100 | 15.750.672 |
| 8,5 | 398.066.872 | 146.585.127 | 64.803.053 | 32.499.351 | 17.843.123 |
| 9 | 456.761.764 | 168.446.601 | 74.540.738 | 37.330.564 | 20.548.342 |
| 9,5 | 524.408.666 | 192.670.921 | 85.262.996 | 42.791.089 | 23.503.664 |
| 10 | 609.482.870 | 224.085.867 | 99.220.392 | 49.704.278 | 27.314.869 |

TABLE VII
PREDICTED FATIGUE LIFE (NF) FOR VARIOUS CBR VALUES AND LOADING SCENARIOS

| CBR (%) | Nf | | | | |
|---|---|---|---|---|---|
| | Normal | +25% | +50% | +75% | +100% |
| 3 | 59.834.852 | 28.709.351 | 15.774.621 | 9.494.038 | 6.115.893 |
| 3,5 | 60.896.691 | 29.232.049 | 16.061.929 | 9.666.932 | 6.227.258 |
| 4 | 61.814.435 | 29.659.174 | 16.257.267 | 9.792.949 | 6.312.522 |
| 4,5 | 64.529.422 | 30.967.552 | 17.017.976 | 10.237.765 | 6.592.772 |
| 5 | 65.489.072 | 31.416.490 | 17.228.639 | 10.373.590 | 6.684.633 |
| 5,5 | 67.433.433 | 32.352.206 | 17.770.376 | 10.680.781 | 6.889.466 |
| 6 | 68.610.531 | 32.913.833 | 18.049.584 | 10.882.461 | 7.003.156 |
| 6,5 | 71.181.140 | 34.153.411 | 18.743.410 | 11.270.377 | 7.272.358 |
| 7 | 74.341.266 | 35.686.816 | 19.597.498 | 11.805.315 | 7.591.569 |
| 7,5 | 75.313.964 | 36.143.354 | 19.850.811 | 11.935.970 | 7.702.024 |
| 8 | 80.434.557 | 38.604.690 | 21.183.494 | 12.760.841 | 8.225.845 |
| 8,5 | 82.201.209 | 39.437.041 | 21.641.639 | 13.015.358 | 8.389.928 |
| 9 | 84.989.771 | 40.778.928 | 22.379.497 | 13.467.286 | 8.687.490 |
| 9,5 | 87.725.415 | 42.078.758 | 23.095.956 | 13.899.689 | 8.953.583 |
| 10 | 91.601.224 | 43.951.168 | 24.120.424 | 14.518.977 | 9.349.038 |

The highlighted values in Table VI and Table VII shows the repetitions value are below actual number of design traffic repetitions which is 23.947.797.

### *A. Subgrade CBR and Strain Response Relationship*

The outputs calculated by KENPAVE used in this study are horizontal tensile strain at the bottom of asphalt layer which will give critical value to cause fatigue cracking and vertical compressive strain at the top of the subgrade which will give critical value to cause rutting distress. The relationship between CBR value and vertical compressive strain is shown in Fig. 1 and the relationship between CBR value and horizontal tensile strain is shown in Fig. 2.

Fig. 1 shows that for normal traffic loading scenario, as the CBR value increased from 3% to 10%, the vertical compressive strain decrease from 1,52 x 10-4 to 1,14 x 10-4 while for 100% of traffic overloading scenario, the vertical compressive strain decrease from 3,03 x 10-4 to 2,09 x 10-4. For all traffic loading scenarios, every 0,5% increase of CBR value will reduce the horizontal tensile strain around 1,986%. The slightly horizontal tensile strain escalation from CBR value of 4,5% to 5% may occurs due to the difference of each pavement thickness. What can also be seen from Fig. 1 is that higher CBR value will lower vertical compressive strain which is occurred on subgrade. The result is also implied that higher traffic load will increase vertical compressive strain as much as the increase of traffic load percentage which shows the linear relationship between vertical compressive strain and overloading traffic.

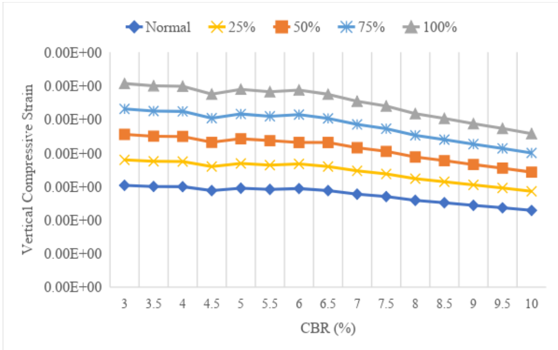


Fig. 1. CBR value and vertical compressive strain relationship

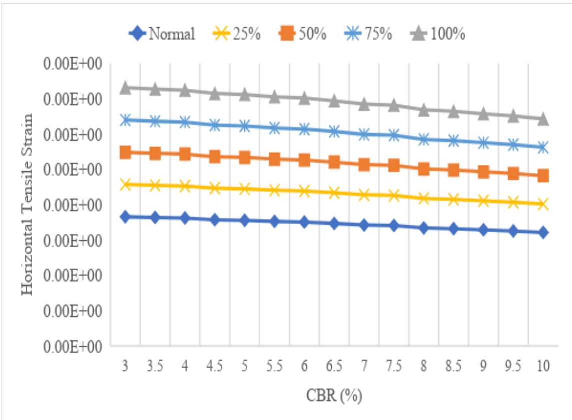


Fig. 2. CBR value and horizontal tensile strain relationship

Fig. 2 shows that for normal traffic loading scenario, as the CBR value increased from 3% to 10%, the horizontal tensile strain decrease from 7,32 x 10-5 to 6,43 x 10-5 while for 100% of traffic overloading scenario, the vertical compressive strain decrease from 1,46 x 10-4 to 1,29 x 10-4. For all traffic loading scenarios, every 0.5% increase of CBR value will reduce the horizontal tensile strain around 0,917%, lower than the percentage resulted in vertical compressive strain. What can also be seen from Fig. 2 is that higher CBR value will lower horizontal tensile strain which is occurred below the asphaltic layer. The result is also implied that higher traffic load will increase horizontal tensile strain as much as the increase of traffic loads percentage which shows the linear relationship between horizontal tensile strain and overloading traffic.

The results of mechanistic response reveal that the horizontal tensile strain and vertical compressive strain all decrease with increasing subgrade CBR value. Higher CBR value represents stronger subgrade, thus the subgrade will receive lower strain value. The addition of load will increase the pressure that the vehicle distributes to the pavement, so

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that the horizontal tensile strain and vertical compressive strain will be higher.

*B. Subgrade CBR and Pavement Life Relationship*

Horizontal tensile strain is then used to estimate the allowable number of load repetitions to prevent fatigue cracking failure, which called by pavement fatigue life (Nf) while vertical tensile strain is then used to estimate the allowable number of load repetitions to prevent rutting failure, which called by pavement rutting life (Nr). The relationship between CBR value and Nd is shown in Fig. 3 and the relationship between CBR value and Nf is shown in Fig. 4.

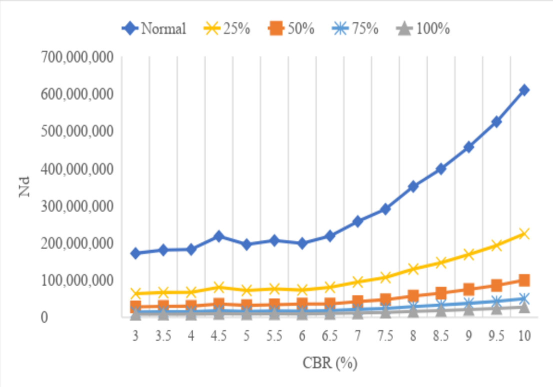


Fig.3. CBR value and Nd relationship

Fig. 3 shows that for normal traffic loading scenario, as the CBR value increased from 3% to 10%, the allowable repetitions to prevent rutting (Nd) is also increase from 171.451.910 to 609.482.870 while for 100% of traffic overloading scenario, the Nd values increase from 7.687.584 to 27.314.869.

The result is also implied that higher traffic load will lower Nd values which means rutting will occur faster because allowable repetitions will be less than those with lower traffic load. Nd decrease significantly in overloading scenarios compared to normal traffic loading with the values of 63%, 227%, 565%, and 1172% for 25%, 50%, 75%, and 100% of overloading respectively.

Any value lower than the actual number of designed traffic repetitions will cause distress. It can be implied that rutting occurs at CBR 3% to 7,5% with the overloading of 75% and 100%.

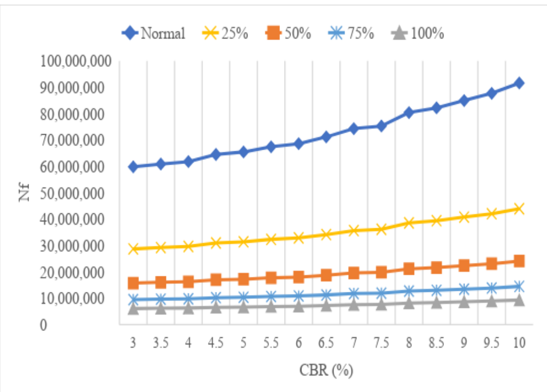


Fig. 4. CBR value and Nf relationship

Fig. 3 shows that for normal traffic loading scenario, as the CBR value increased from 3% to 10%, the allowable repetitions to prevent fatigue (Nf) is also increase from 59.834.852 to 91.601.224 while for 100% of traffic overloading scenario, the Nd values increase from 6.115.893 to 9.349.038.

The result is also implied that higher traffic load will lower Nf values which means fatigue cracking will occur faster because allowable repetitions will be less than those with lower traffic load. Nf decrease significantly in overloading scenarios compared to normal traffic loading with the values of 52%, 153%, 319%, and 566% for 25%, 50%, 75%, and 100% of overloading respectively but less significant than those in Nd values.

Any value lower than the actual number of designed traffic repetitions will cause distress. It can be implied fatigue cracking occurs at CBR 3% to 9,5% with the overloading of 50, 75%, and 100%.

## V. Conclusions

The findings of this study are important for pavement designer and regulator to consider the sensitivity of pavement mechanistic response to the variations of subgrade strength and overloaded traffic for the pavement design and code.

According to the result and analysis in this study, the following conclusions are drawn:

1. The results of mechanistic response reveal that the horizontal tensile strain and vertical compressive strain all decrease with increasing subgrade CBR value. Higher CBR value represents stronger subgrade, thus the subgrade will receive lower strain value.
2. The addition of load will increase the pressure that the vehicle distributes to the pavement, so that the horizontal tensile strain and vertical compressive strain will be higher.
3. Nf and Nd all increase with decreasing of horizontal tensile strain and vertical compressive strain, which implies that higher CBR value will increase Nf and Nd.
4. Rutting occurs at CBR 3% to 7,5% with the overloading of 75% and 100% while fatigue cracking occurs at CBR 3% to 9,5% with the overloading of 50, 75%, and 100%.

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