International Journal of Engineering & Technology, 8 (1.1) (2019) 190-200

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Analysis of Casting Time on Jointed Plain Concrete Pavement

Rusandi Noor[1]*, Feri Muhammad[2], Isnaini Zulkarnain[3]

[1] *Structural Engineering Research Group, Departement of Civil Engineering, Universitas Muhammadiyah Kalimantan Timur, Jalan Ir. H Juanda No. 15, Samarinda 75124 Indonesia*
[2]*Master Program Study of Civil Engineering, Faculty of Civil and Environmental Engineering, Institut Teknologi Bandung, Jalan Ganesha 10, Bandung 40132, Indonesia*
[3]*Infrastructure Project Management Research Group, Departement of Civil Engineering, Universitas Muhammadiyah Kalimantan Timur, Jalan Ir. H Juanda No. 15, Samarinda 75124 Indonesia*
**Corresponding author E-mail: rn903@umkt.ac.id*

Abstract

The purpose of this study is to focus on numerical procedures for the best timing of jointed plain concrete pavement casting, which has resulted in an effective length and thicknees ratio of pavement. The aim of the study can be achieved by developing a computer simulation model that can estimate pavement strength of the actual state with loads such as shrinkage, creep, and vehicle load. The research develop of each creep coefficient and shrinkage strain based on observed data in the early age. This research will be varied input of soil parameter in the form of subgrade reaction (k), value of subbase stabilized cement with thicknees 15 cm is 4826,33 MPa. Combination simulation result shown, the comparison of concrete thicknees (H) and concrete length (L) for nigth casting k=13MPa/m, minimum thickness (H)=L/9.94; for k=27MPa/m, minimum thickness (H)=L/10.08; k=55MPa/m, minimum thikness (H)=L/10.08; k=83MPa/m, minimum thickness (H)=L/10.38 for daytime casting k=13MPa/m, minimum thickness (H)=L/8.62; k=27MPa/m, minimum thickness (H)=L/9.99; k=55MPa/m, minimum thickness (H)=L/9.15; k=83MPa/m minimum thickness (H)=L/9.33. Casting time is an important factor affecting the dimensional and shape accuracy concrete pavement. This paper can provide a theoritical basis for developing jointed plain concrete casting procedure.

Keywords: *JPCP, Construction Time, Pavement Ratio,*

1. Introduction

Jointed plain concrete pavement (JPCP) are the most common type of rigid pavement due to their cost and simplicity. In JPCP, no slab reinforcment is used except for dowel bars placed at transverse joints and allow the joints or tie bars at longitudinal joints. Performing JPCP that has good performance and long service life require complex processes that integrate the appropriate material design combinations. One of the most influential processes of pavement quality is the timing of construction [1]. Jointed plain concrete pavement (JPCP) using normal strength concrete, which is compressed using a vibrator. The compressive and tensile strength of the JPCP has a significant difference, on short-term loads, pavement material is considered to be still elastic to the occurrence of structural cracks on rigid pavements can be predicted using elastic analysis. Stress on this JPCP can be retained by concrete itself and the dowel connection. Due to occurrence of volume changes, the horizontal movement of the pavement can be still allowed. The relative-vertical movement along the connection is restrained by dowel and the continutity of the concrete slab. The critical stresses on the concrete pavement may occur below or above the pavement. It depends on the gradient temperature gradient assumed to be at the end time of construction. Commonly this happens if pavement construction work is done in the morning or afternoon. It will cause the concrete pavement cooler, then there will be bending up (curling up) on concrete pavement. For example over 30 years of service, pavement slab will experience approxiamtely 10950 fatigue cycles due to temperature effects [2]. Location of research in Samarinda

2. Parameter Determination

The design of pavement requires more than “thickness design” for carrying flexural stresses. The pavement is subject to range of loads and stresses induced by traffic loading, climate, and environmental factors [3]. The design process balances a large number of interacting factor and constraints to produce pavement system that are functional, sustainable, cost effective, and long lasting.

2.1.Rainfall Data

It is necessary to understand some hydrologic concept before starting the design of pavement concrete structure. Precipitation, in the form of rain, may result in accumulation of water on the surface and find its way through joints and cracks inside a pavement structure [3]. The effect of rain on concrete pavement will be very influential when the pavement is submerged in a certain period of time. Water will easily enter micro cracks which will cause greater cracks. Rain data presented in Figure 1, this rain data derived technical report located in Samarinda in the year 2016. From data, it can be seen that average rainfall is 18 mm, with the peak of the rain occurring in Desember of 25.6 mm and the lowest in February of 10.2 cm/hr. Rainfall data is used to pavement designer to select dry or wet periods for sensitivity analysis of pavement design using mechanistic-empirical design methods. Correspondingly, increases in surface texture decreased water depths; whereas, increases in rainfall intensity and drainage length increased water depths. The oever-all experimentaly obtained equation 1, shown below [4]

$$d = [3.38x10^{-3}(1/T)^{-0.11}(L)^{0.43}(I)^{0.59}(1/S)^{0.42}] - T \tag{1}$$

where

d = average water depth above top of texture (in)
T = average texture depth (in)
L = drainage-path length (ft)
I = rainfall intensity (in/hr)
S = cross slope (ft/ft)

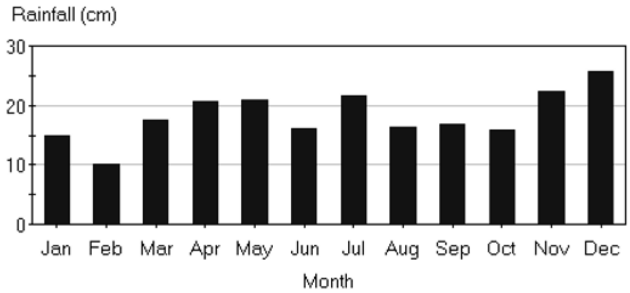


Fig. 1: Monthly Rainfall Data Samarinda in 2016

2.2 Concrete Strength Variation

Assesing the concrete strength at an early age is a good indicator for concrete quality and the potential for carrying load. Concrete strength however should not be taken as a guarantee for durability and long-term performance.[4] A concrete with adequate strength may not have the correct entrained air volume and air bubble size distribution and would perform poorly under freeze-thaw condition. Mix design in this study determined the variation of concrete strength *(fc')* starting from 25MPa, 28MPa, 30MPa, 35MPa. Composition the concrete mixture is determined as shown in table 1 [4].

Table 1: Mix Design Specifications

fc' (*MPa*)	*w/c*	Water (kg/m^3)	Cement Type 1 (kg/m^3)	Coarse Aggregat (kg/m^3)	Fine Aggregat (kg/m^3)
25	0.52	181	348.08	1136	648.92
28	0.49	181	369.39	1136	663.61
30	0.45	181	402.22	1136	630.78
33	0.42	181	430.95	1136	602.05
35	0.39	181	464.10	1136	568.90

The purpose of the concrete strength variations given in order to understand the most effective scheme during pavement construction and the aggregate type is the siliceous gravel. Cement type 1 used for general construction purposes which do not use specific requirement for hydration heat and initial compressive strength, suitable for use on soil and water containing sulfate 0 % -0,10 %. [4]

2.3 Temperature

A concrete slab will undergo volume changes and develop due to changes in temperature and moisture. During the day, as the air temperature and sun increase the surface temperature of concrete slab, the top of the slab will tend to expand relative to the nutral axis and the bottom of the slab will tend to contract as it is insulated by the soil in the base [5]. However, the weigth of the slab will prevent it from contraction expansion, and compressive stresses will be induced in the top layer of the slab, while tensile stresses will be induced in bottom layer. The opposite will occur at night where te air temperature will be cooler coMPares to the base of the slab since it is insulated by the base. A similar effect is observed with moisture changes. As moisture is removed from the concrete slab, and specifically the hydrated cement paste, the concrete will shrink. The empirical formula appears to be the most suitable for determining surface coefficient of heat transfer h_c shown below [5]

$$h_c = 698.24[0.00144T_m^{0.3}U^{0.7} + 0.00097(T_s - T_{air})^{0.3}] \tag{2}$$

where
h_c = surface coefficient of heat transfer
T_m = average of the surface and air temperature
U = average daily wind velocity
T_s = surface temperature

T_{air} = air temperature

The location of the temperature under consideration is the area of Samarinda, in 2016 with formula 2 and the value of air temperature by using formula 3, as seen in Figure 2 below.

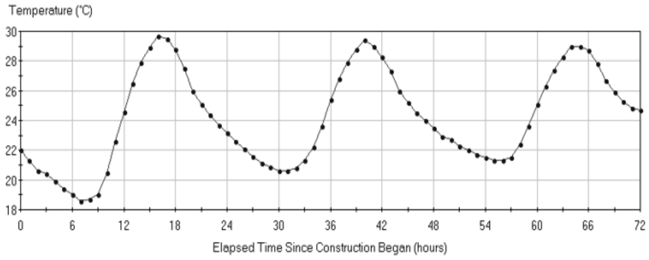


Fig. 2: Daily Temperature for Samarinda in 2016

The minimum pavement temperature occurs mostly during early morning. From Figure 2 average daily temperature in samarinda is 26 degree celcius. It is possible to approximate the temperature variation with depth once the surface temperature is known. The equation can be written in the following form [6].

$$T = T_s(1 - 0.063d + 0.007d^2 - 0.0004d^3) \quad (3)$$

where

d = depth (in)

T_d = temperature at depth *d* (°F) and

T_s = the surface teMParature (°F)

This formula was developed for degree Fahrenheit and conversion in needed to get result in degrees Celcius.

2.4 Vehicle Load

Damage is defined as the deterioration happens as a result of changes in the engineering propertise of the pavement layer material. This damage does not happen altogether at the sma time, but rather progressively-or, more preciesly, in increment-with the passage of every vehicle or, if expressed in time, every hour during its service[6]. Therefore, the most rational approach is to consider and compute the damage in each and every increment by considering the relevant traffic (class of vehicle) and the pavement material propertise. The damage at any increment can be expressed as follows Miner's rule :

$$D = \sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{o}\frac{n_{ijk}}{N_{ijk}} \quad (4)$$

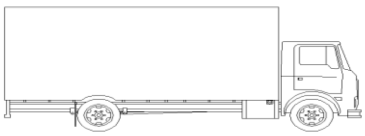
where

D = Damages

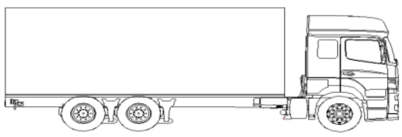
n = calculated laod applications

N = allowable number of load applications

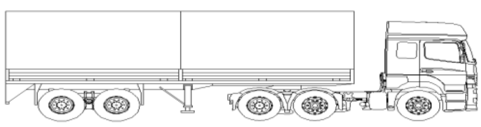
Where i, j, and k are different categories over which the summation of the damage is made. This total damage over time can then be related to distress, and finally the distress can be expressed as a function of time [7]. For any specific type of distress, when total damage referred to as the cumulative damage factor reaches 1. Because it was desirable to maximize use of all available data, the veehicle types selected for investigation included singel axle load (a) , tandem axle load (b) and tridem axle load (c). These represented all major vehicle types for which data had been accumulated in Samarinda during 2 year study period of 2014-2016 . Figure 3 shows 3 vehicle types.[7]



(a)



(b)



(c)

Fig. 3: Type of Vehilce

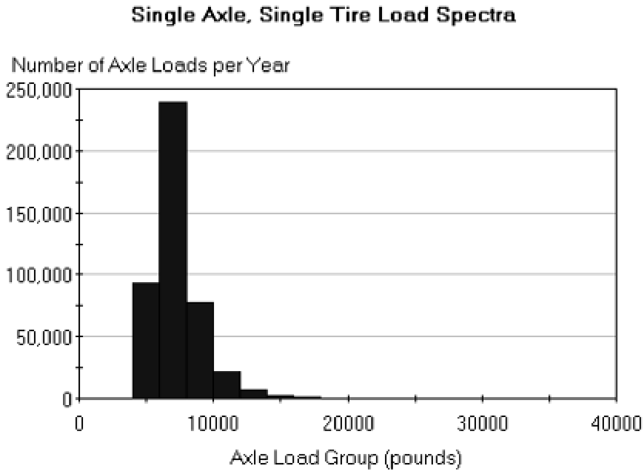
The parameter selected to represent the vehicle weight data. This selection wase based primarily on the creation of simplicity, since alternate parameters such as axle load distributions are much more difficult to treat statistically and handle computationally. These trafic parameters and ADT were used to compute the design as follows [7].

$$DesignEAL = 365(N)(ADT_{eff})\sum_{i}(P_i)(UEAL_i) \tag{5}$$

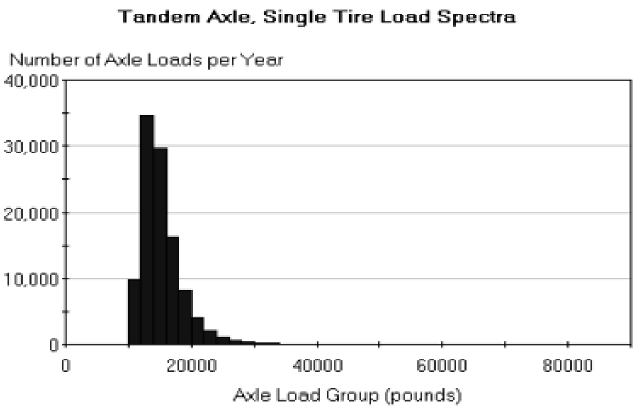
where

N = Design period in years
ADT_{eff} = Average or effective ADT during the design period
P_i = Predicted fraction of the total traffic stream
$UAEL_i$ = Corresponding average unit EAL’s

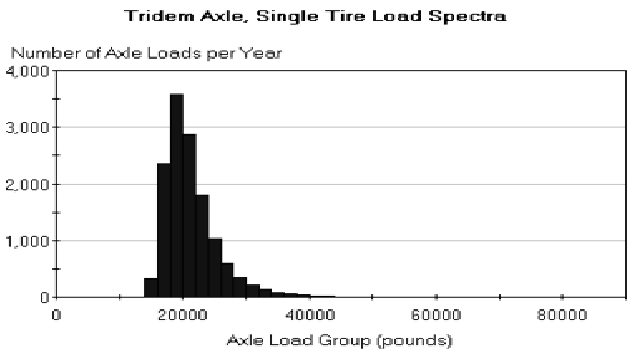
Vehicle weight data were available from the operation of loadmeter station. These eaquation 5 provide much of weight data for low-volume facilities. During the study period, approxiamtely 239821 single axle, 34566 tandem axle, 3586 tridem axle were counted [7]. The dependent variables in the analysis were treated as continuous variable. Because of this method for data representation an the plausibility of strong interaction among many of local condition. With this method the avalaible data are grouped into catageroies representating each feasible combination of independent variable and the averages of the dependent variables within each combination of local conditions was excessive. For the precentage of each vehicle load distribution can be seen in the Figure 4 below.



(a)



(b)



(c)

Fig 4: Number of Axle Load Per Year 2014-2016 (a) Single Axle; (b) Tandem Axle; (c) Tridem Axle

The criteration of reasonableness dictates that the sum of predicted precentages must equal 100 percent. Because the percentages of each vehicle type is predicted independently, the initial estimate is multiplied by 100 and divided by the sum of initial predictions, was adopted.

3. Early Age Method

The design of a quality concrete mixture should satisfy a number of competing desirable performance requirements for construction such as workability, ease of placement, consolidation and finishing, early age propertise such as setting time; should not bleed excessively but just enough to avoid drying shrinkage cracking; appropriate strength gain; volume stability to minimize curling and warping; bond strength to reinforcement and tiebars [8]. During the early age, temperature and moisture fluctuation induce volume changes in the concrete. Assesing the concrete strength at an early age is a good indicator for concrete quality and the potential for carrying stress. Concrete strength however should not be taken as a guarantee for durability and long-term performance [8]. A concrete with adequate strength, for example, may not have the correct entrained air volume and air bubble size distribution. Several studies have developed thermal models to predict transient temperature evolution in pavement section exposed to the outdoor environment. These models have been developed for both mature concrete section as well as for early age concrete, for time periods following concrete placement until seven days, when heat generation resulting from cement hydration reaction is a significant contributor to thermal behavior. Since the subgrade can serve as a heat-sink, such models describe transient temperature evolution both within the pavement section, and within an underlying soil layer. In general, this quantity depends on both time and temperature history at a given location. Hansen and Pederson proposed that the effect of both time and temperature can be accounted for via an "equivalent age" $t_{eq}(x,t)$ defined as, [8]

$$t_{eq}(x,t) = \int_0^t \exp\left[-\frac{E_a}{R}\left(\frac{1}{T(x,t)} - \frac{1}{T_{ref}}\right)\right] dt \tag{6}$$

where

E_a = Activation energy
R = Ideal gas constant (8.314 J/mol K)
T_{ref} = Refrence Temperature

Concrete tensile strength, depending on time, the strength of concrete will almost reach its maximum at 28 days of concrete. The strength of concrete is parabolic over time, while the stress that occurs on the pavement is very dependent on ambient air temperature and time. Relationship betwen creep and pavement thickness shown in Figure 5. By using formula 6 then then generated correlation coefficient water cement ratio on each thickness of concrete by representing it in coefficient creep

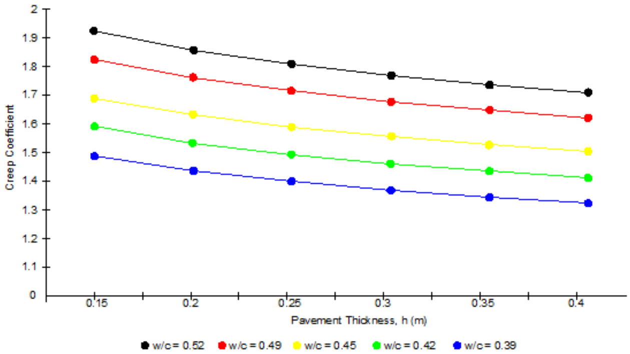


Fig. 5: Creep Coefficient Relationship Graph with Pavement Thickness

The stress caused by the creep effect is inversely proportional to the crepp coefficient. The creep coefficient is also inversely proportional to the pavement thickness. If the pavement thickens the creep coefficient gets smaller and the stress also decrease, but this is inversely proportional to the cement water ratio factor the creep coefficient increases, seen in Figure 5. While the influence of concrete compressive strength against shrinkage strain is straight proportional, higher compressive strength made more shrinkage strain, this indicates the bigger stress caused by shrinkage strain seen in Figure 6.

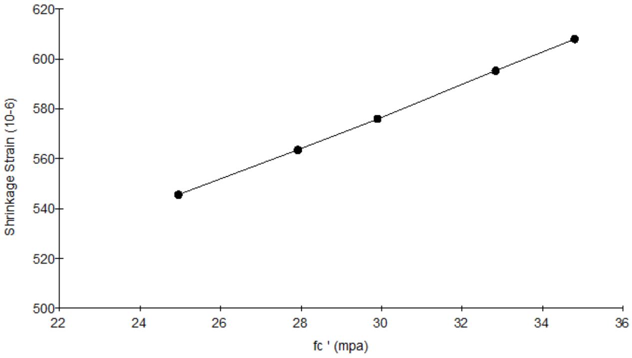


Fig. 6: The Shrinkage Strain Relationship Graph with *fc'* (MPa)

4. Pavement Modeling

A rigid pavement is basically a slab resting on a subgrade or base. The slab is much stiffer than the supporting base or foundation material, and therefore carries a significant portion of induced stresses [9]. The load-carrying mechanism is similar to beam action, although a concrete slab is much wider than the beam and should be considered as a plate. Westergaard developed stress equation for rigid pavement slabs supported on a liquid foundation, which is a conceptual model that consider the foundation as a series of spring [10]. When the slab is loaded vertically down, the springs tend to push back; when the environment-related loads are pulling up on the slab, the springs tend to pull down toward the foundation (Figure 7)

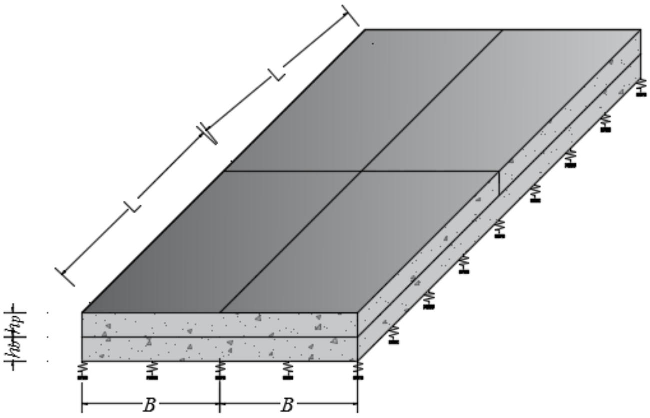


Fig. 7: JPCP Pavement Modeling

Modelling of JPCP in HIPERPAV III, pavement length (L), pavement widht (B), pavement height (h_{av}) dan subbase height (h_s). The level of reliability used in this study is 90%. The dimension of the cross section include the width and length as well as the height of the rigid pavement being filled in the geometry input. This research planned rigid pavement width of 2.75 m. This rigid pavement width is taken from the requirements of SNI Pd-T-14-2003 on rigid pavement design width of 5.5 m for two lanes. So each lane is taken value of 0.5 (5.5) = 2.75 m. The pavement height is varied starting from 15cm, 20cm, 25cm, 30cm, 35cm, and 40cm. As for the variation of pavement length starting from B, 1.25B,....2.5B.

5. Result and Discussion

5.1 The Effect of Casting Time

The initial and peak stresses on the concrete that occur at night, are less than the stress during the day. This difference in casting temperature has a great influence on the stresses that occur in concrete pavement. At day casting on concrete will experience a significant temperature change, this increase the thermal stresses on the pavemnet. Therefore, consideration of the time and temperature of this concrete pavement, so that the initial crack in the pavement can be prevented and the service life of the pavement is longer, can be seen in Figure 8. The risk of cracking on concrete pavement will occur when casting time begins at the begiining of day to mid day. The risk increase will start from 5^{th} to 11^{th} hour. The peak is a crack ratio of 120% from stress to strength versus elapsed time. Referring to the numerical model of the various input data on the previous sub then get the best time in casting is at 23^{th} hours or midnight, the ratio obtained seen in Figure 8 that is 70% crack ratio.

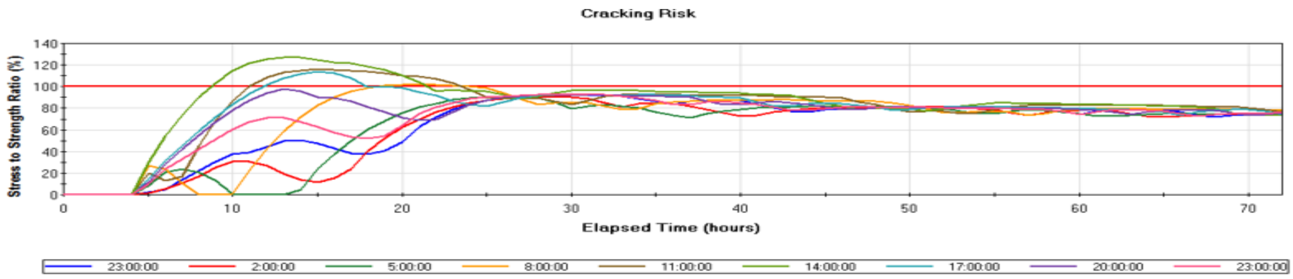


Fig 8 : Cracking Risk Ratio of Concrete Pavement

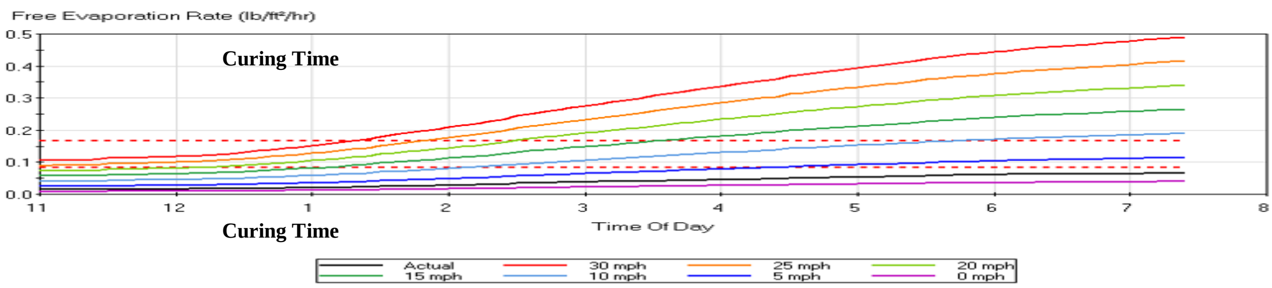


Fig 9 : Determination of Curing Time

5.2 Evaporation Rate

The evaporation rate in concrete is a function of air temperature, concrete temperature, relative humidity and wind speed. In this study obtained a comparison of these thing [11]. The actual wind speed in this analysis is about 2mph. When the load is combined as shown in Figure 9, it will get critical time for curring. If the the evaporation rate exceeds the bleed rate, then the potential for plastic shrinkage increases. On the graph when wind occurs at a speed of 30mph then concrete must be cured at 3 hoours after casting, this also applies to other wind loads. The evaporation rate can be easily computed using an equation computing device with numerical equation by T.Poole (2005).[12]

$$ER = 4.88\left[0.1113 + 0.04224\frac{WS}{0.447}\right](0.0443)(e^{0.0302(CT*1.8)+32}) - \left[\left(\frac{RH}{100}\right)\left(e^{0.0302(AT*1.8)+32}\right)\right] \quad (7)$$

where
ER = the evaporation rate
WS = the wind speed
CT = concrete temperature
AT = air temperature
RH = relative humidity

5.3 Various Ratio of JPCP

The stress that occurs on the pavement exceeds the tensile stress then it is stated that the concrete has cracked, this means the ratio of stress and strength of the concrete has been greater than one. Cracks in the concrete can also occur at the time of early age, although the concrete has not experienced a vehicle load. This is due to the stress caused by the temperature difference on the pavement. stress working at early age of concrete is strongly influenced by the time of concrete hardening (t) and the quality of concrete (fc '). At the time of curing process, with the concrete hydration process and the temperature gradient, the concrete stress will increase in the early age. Similarly, the stress ratio that occurs at the time this early age. It depends on time. The higher the service life of concrete the higher the concrete tension ratio. And this is inversely proportional to the quality of concrete. Better quality of concrete (fc ') could make smaller concrete tension ratio. While the difference in stress and strength ratio caused by variation of concrete thickness is inversely proportional. Thicker the concretecould made smaller the force ratio obtained during the early age of concrete. For the ratio of stress and strength to cement water, Smaller the ratio of cement water the ratio could made stress and strength decreases.

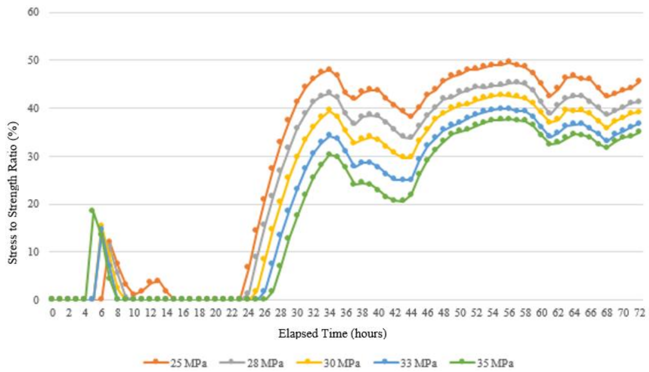


Fig. 10 : The relationship between the start time and the stress - strength ratio of concrete (%) for various concrete (fc ') and nighttime construction, subgrade of soil reaction (k) 27 MPa / m, thick (h) 25 cm and length (L) 3.44 m

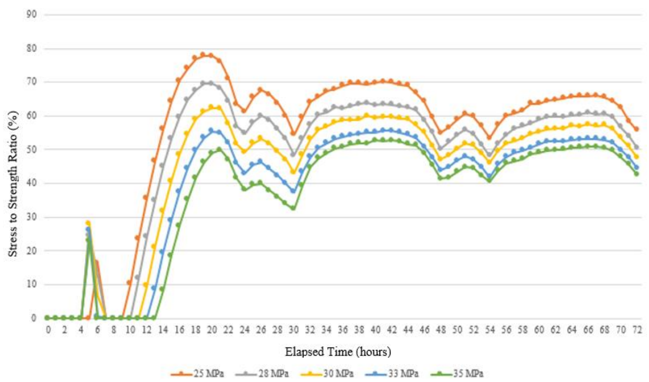


Fig. 11 : The relationship between the start time and the stress - strength ratio of concrete (%) for various concrete (fc ') and daytime construction, subgrade of soil reaction (k) 27 MPa / m, thick (h) 25 cm and length (L) 3.44 m

As for the variation of pavement length. The longer of pavement The ratio of stress-strength of the concrete is also increasing. This is due to the greater the ratio between the length of concrete pavement with the relative length of stiffness in the concrete. In addition, with the increasing length of road pavement, the thermal and shrinkage stress are also getting bigger[13]. From the graph it is shown that for pavement widths with spans of more than 3.44 meters with the same (*fc'*) 30 MPa concrete. The ratio of stress to strength of concrete has been exceeded. This will result in an initial crack in this concrete. So that the concrete does not crack the concrete length should be limited and the quality of the concrete (fc ') must also be increased, and the timing of the concrete must also be considered. From Figure 10, 11, 12, 13 and 14, also seen casting time effect on the ratio of stresses and strength of concrete.

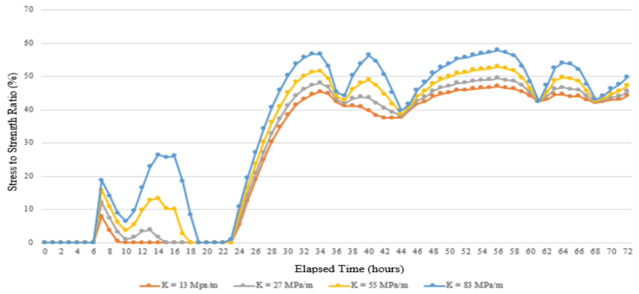


Fig. 12 : The relationship between the start time and the stress - strength ratio of concrete (%) for various subgrade reaction of soil (k') nighttime construction, subgrade of soil reaction (k) 25 MPa / m, thick (h) 30 cm and length (L) 3.44 m

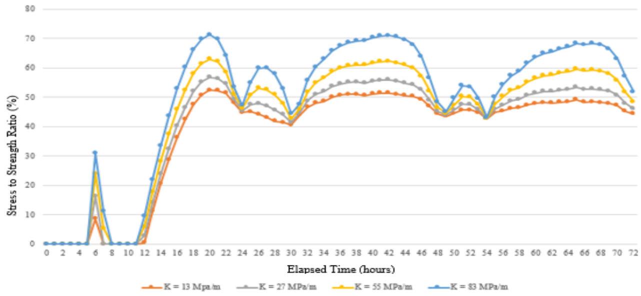


Fig. 13 : The relationship between the start time and the stress - strength ratio of concrete (%) for various subgrade rection soil (k) and daytime construction, subgrade of soil reaction (k) 25 MPa / m, thick (h) 30 cm and length (L) 3.44 m

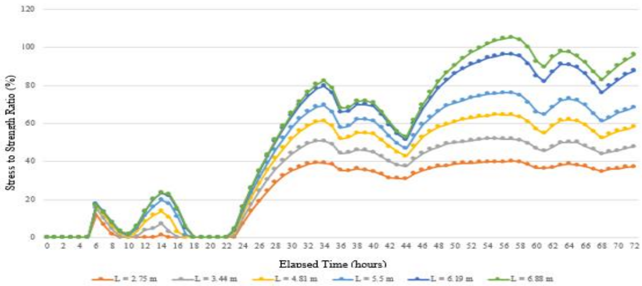


Fig. 14 : The relationship between the start time and the stress - strength ratio of concrete (%) for various concrete (fc ') and daytime construction, subgrade of soil reaction (k) 30 MPa / m, thick (h) 25 cm and length (L) 3.44 m

Casting at night is more likely to have the ratio of stress and strength in early age is smaller when coMPared to foundry at night. In order for the JPCP pavement can be used maximally it is necessary to consider the strength of concrete, thickness of pavement, length and subgrade reaction of soil to be used. From the results of modeling that has been done for the condition of casting at night. The length of concrete and the quality of the concrete should be limited so as not to crack the concrete. For 15 cm thick concrete, maximum pavement length is limited to only 4.81m long and concrete quality of at least 25 MPa. As for the thickness of concrete 20 cm, permitted maximum span of 6.19 m with concrete quality of at least 25 MPa, this applies to the construction of concrete at night. As for the work of concrete in the day maximum length for 15 cm thickness of 2.75 m with a minimum concrete quality of 35 MPa. As for the thickness of concrete 20 cm, maximum length allowed 4.13 m with a minimum of 35 MPa concrete strength. For 25 cm thick concrete, permitted concrete length of 5.5 m with concrete quality of at least 35 MPa.

Table 2: The Minimum Thickness h(cm) of JPCP required due to early age for night construction with k = 13 MPa/m, and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	15	15	15	15	15	**15**
3.44	15	15	15	15	15	**15**
4.13	20	20	15	15	15	**17**
4.81	25	20	20	20	15	**20**
5.50	25	25	25	20	20	**23**
6.19	30	30	25	25	20	**26**
6.88	35	30	30	25	25	**29**

Table 3: The Minimum Thickness h(cm) of JPCP required due to early age for night construction with k = 27 MPa/m, and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	15	15	15	15	15	**15**
3.44	15	15	15	15	15	**15**
4.13	20	20	20	15	15	**18**
4.81	25	25	20	20	15	**20**
5.50	25	25	25	20	20	**23**
6.19	30	30	25	25	20	**26**
6.88	35	30	30	25	25	**29**

Table 4: The Minimum Thickness h(cm) of JPCP required due to early age for night construction with k = 55 MPa/m and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	15	15	15	15	15	**15**
3.44	20	15	15	15	15	**16**
4.13	20	20	20	15	15	**18**
4.81	25	25	20	15	15	**19**
5.50	25	25	25	20	20	**23**
6.19	30	30	25	25	20	**26**
6.88	35	30	30	25	25	**29**

Table 5: The Minimum Thickness h(cm) of JPCP required due to early age for night construction with k = 83 MPa/m, and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	15	15	15	15	15	**15**
3.44	20	15	15	15	15	**16**
4.13	20	20	20	15	15	**18**
4.81	25	25	20	20	15	**21**
5.50	25	25	25	20	20	**23**
6.19	30	30	25	25	20	**26**
6.88	35	30	30	25	25	**29**

Table 6: The Minimum Thickness h(cm) of JPCP required due to early age for day construction with k = 13 MPa/m, and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	20	15	15	15	15	**16**
3.44	25	20	20	20	20	**21**
4.13	25	25	25	20	20	**23**
4.81	30	25	25	25	20	**25**
5.50	30	30	25	25	25	**27**
6.19	35	30	30	30	25	**30**
6.88	40	35	35	30	30	**34**

Table 7: The Minimum Thickness h(cm) of JPCP required due to early age for day construction with k = 27 MPa/m, and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	20	20	20	15	15	**18**
3.44	25	20	20	20	20	**21**
4.13	25	25	25	20	20	**23**
4.81	30	25	25	25	20	**25**
5.50	35	30	30	25	25	**29**
6.19	35	35	30	30	30	**32**
6.88	40	35	35	35	30	**34**

Table 7: The Minimum Thickness h(cm) of JPCP required due to early age for day construction with k = 55 MPa/m, and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	20	20	20	15	15	**18**
3.44	25	20	20	20	20	**21**
4.13	25	25	25	20	20	**23**
4.81	30	25	25	25	20	**25**
5.50	35	30	30	25	25	**29**
6.19	40	35	35	30	30	**34**
6.88	45	40	35	35	30	**37**

Table 8: The Minimum Thickness h(cm) of JPCP required due to early age for day construction with k = 83 MPa/m, and P = 8 ton

Length (m)	*Concrete Strength fc' (MPa)*					*Average Width (m)*
	25	**28**	**30**	**33**	**35**	
	Width (cm)					
2.75	20	20	20	15	15	**18**

3.44	25	20	20	20	20	**21**
4.13	25	25	25	20	20	**23**
4.81	30	25	25	25	20	**25**
5.50	35	30	30	25	25	**29**
6.19	40	35	35	30	30	**34**
6.88	45	40	40	35	30	**38**

For nigh casting, from the above Table data 5-8 it is found that the minimum pavement thickness (h) required for early age is inversely proportional to the quality of the concrete (*fc* '). The higher quality of concrete then the required pavement thickness is smaller. However, proportional to the soil subgrade reaction (k), the higher of soil subgrade reaction (k) could made greater the thickness of the pavement. And also for daytime implementation, but the minimum pavement thickness requirement is higher than on casting at night. For the analysis of road pavement due to fatigue of working vehicle load, the variation of road length does not significantly affect the determination of pavement thickness. This is because the main factor determining the stress acting on the pavement is the amount of work load, the thickness of the rope and the effective long radius. So that the variation in length due to vehicle load is not too influential to the thickness of concrete pavement. For the required thicknesses based on variations of the soil subgrade reaction (k), and the quality of the concrete (*fc* ') and the minimal outer load repition (n) 25156 seen in Figure 15 bellow.

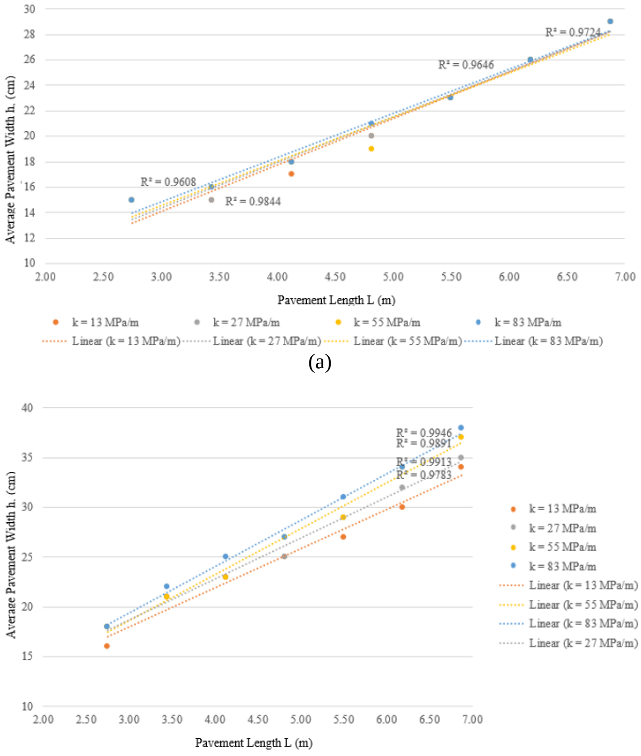


Fig. 14 : Relationship between pavement length and pavement thickness required on long term due to fatigue + creep + shrinkage for various subgrade reaction, k (MPa / m), for (a) daytime casting and (b) nighttime casting

6. Conclussion

Numeric simulation of creep, shrinkage, and the vehicle load obtained high concrete ratio (h) and concrete length (L) for nighttime casting; for k = 13 MPa / m, minimum plate thickness (h) = L / 9.94; for k = 27 MPa / m, minimum plate thickness (h) = L / 10.08; for k = 55 MPa / m, minimum plate thickness (h) = L / 10.08; for k = 83 MPa / m, minimum plate thickness (h) = L / 10.38 and for daytime casting, k = 13 MPa / m, minimum plate thickness (h) = L / 8.62; for k = 27 MPa / m, minimum plate thickness (h) = L / 9.99; for k = 55 MPa / m, minimum plate thickness (h) = L / 9.15; for k = 83 MPa / m, minimum plate thickness (h) = L / 9.33. so it can be concluded with various JPCP parameters then casting the night is more profitable 20% than foundry day.

References

[1] G.W. William, S.N. Shoukry, *3D finite element analysis of temperature-induced stresses in dowel jointed concrete pavements*, Int. J. Geomech. 1 (3) (2001) 291–307.

[2] Noor, R., & Asnan, M. (2018). *Prediction of Service Life Decline of Double Welded Wide Flanges due to Fatigue in Steel Arch Bridge under Excessive Loads*. Journal Of Engineering And Technological Sciences,50(3)(2018),392-408. doi:10.5614/j.eng.technol.sci.2018.50.3.6

[3] J.R. Roesler., *Concrete slab analyses with field-assigned nonuniform support conditions*, Int. J. Pavement Eng. 17 (7) (2016) 578– 589

[4] J. Tanesi, M.E. Kutay, A. Abbas, R. Meininger, *Effect of coefficient of thermal expansion test variability on concrete pavement performance as predicted by mechanistic-empirical pavement design guide*, Transp. Res. Rec. 2020 (2008) 40–44.

[5] V. Schaefer, J. Kevern, B. Izevbekhai, K. Wang, H. Cutler, P.Wiegand, *Construction and performance of pervious concrete overlay at Minnesota Road Research Project*, Transp. Res. Rec. 2164 (2010) 82–88.

[6] A. Ibrahim, E. Mahmoud, M. Yamin, V.C. Patibandla, *Experimental study on Portland cement pervious concrete mechanical and hydrological properties*, Constr. Build. Mater. 50 (2014) 524–529

[7] T.C. Fu, W. Yeih, J.J. Chang, R. Huang, *The influence of aggregate size and binder material on the properties of pervious concrete*, Adv. Mater. Sci. Eng. (2014)

[8] H. Ceylan, S. Kim, K. Gopalakrishnan, C.W. Schwartz, R. Li, *Sensitivity analysis frameworks for mechanistic-empirical pavement design of continuously reinforced concrete pavements*, Constr. Build. Mater. 73 (2014) 498–508.

[9] H. Ceylan, K. Gopalakrishnan, S. Kim, C. Schwartz, R. Li, *Global sensitivity analysis of jointed plain concrete pavement mechanisticempirical performance predictions*, Transport. Res. Rec. 2367 (2013) 113–122.

[10] J. L. Yao, and Q. H. Weng. *Causes of Longitudinal Cracks on Newly Rehabilitated Jointed Concrete Pavements.* Journal of Performance of Constructed Facilities. 26(1), 2012, pp. 84- 94

[11] D.H. Chen, and M. Won. *Field investigations of crackingon concrete pavements*. Journal of Performance of Constructed Facilities. 21(6), 2007, pp. 450-458

[12] N. Suthahar, A. Ardani, and D. Morian. *Early Evaluation of Long-Term Pavement Performance Specific Pavement Studies-2, Colorado*. In Transportation Research Record: Journal of the Transportation Research Board, No. 1699, Transportation Research Board of the National Academies, Washington, D.C., 2000, pp. 160-171.

[13] J. Hiller, and J. Roesler. *Determination of Critical Concrete Pavement Fatigue Damage Locations Using Influence Lines*. Journal of Transportation Engineering. 131(8), 2005, pp. 599-607