THE RELIABILITY OF ‘DEVELOPMENT LENGTH TEST AND ULTIMATE LOAD TEST’ ON PRESTRESS CONCRETE SLEEPERS

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Especially dedicated to

My Beloved Husband ...Azman Bin Ismail

My Beloved Family

My Friends and Colleague

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ABSTRACT

The prestressed concrete sleepers are well known on its ability to sustain high loading capacity from train and wagon thus, the use of it has been increased nowadays. This research discusses the bond development and ultimate load test in prestressed concrete sleepers. The deformation of the tendon is low and physically hard to determine by naked eyes compared with the cracking propagation due to bending. The samples are provided by MASTRAK Sdn. Bhd. and tested on Development Length Test and Ultimate Load Test procedure in accordance to Australian Standard 1085.14-2003. The samples were of trapezium cross section with a dimension of 232 mm high ×280 mm bottom width × 190 mm top width and the length is between 2000 mm and 2006mm.Total of 200 samples have been tested to monitor the bond slippage in the concrete sleepers. Tendon gauge placed at the bottom layer of the tendons was to monitor the deformation of the tendons. The test result shows the slippage in most of the sleepers was less than 0.025mm and was in accordance to the standard. There was not much differs in slippage of tendon 1 and 2 although the load was increased from 186kN to 279kN.The results for each length were compared to identify the critical length of sleepers for maximum slippage to occur. Out of the 200 samples, only two sleepers were found to have a maximum slippage of between 0.005mm and 0.006mm.However, this occurs when the ultimate load was between 413.7 kN and 422.9 kN, which was higher than the design load. Standard cube compression test on 226 samples were also carried out and the result for the standard deviation was 0.44 which was in excellent range of control. Further comparison on ultimate bending moment capacity on the rail seat was made with AS1085.14-2003 and BS 8110 and the results show that they were lower than the experimental value. An empirical analysis had been carried out to analyse the relationship between the experimental and the proposed mathematical model. The

comparison between the development length data with previous researchers also show that the experimental value is less than the theoretical method. Thus it proved that the data is reliable.

ABSTRAK

Landas konkrit prategasan terkenal pada keupayaannya untuk menanggung kapasiti beban yang tinggi daripada keretapi dan wagon menjadikan penggunaannya semakin meningkat pada masa kini. Kajian ini membincangkan tentang peningkatan ikatan dan ujian beban muktamad dalam landas konkrit prategasan.Perubahan yang berlaku di dalam tendon adalah rendah dan secara fizikalnya sukar untuk ditentukan melalui mata kasar berbanding dengan perambatan retak disebabkan oleh lenturan. Sampel ujian telah disediakan oleh MASTRAK Sdn. Bhd dan diuji menggunakan Ujian Peningkatan Pemanjangan dan Ujian Beban Muktamad mengikut piawaian Australian Standard 1085.14-2003. Bentuk sampel adalah trapezium dengan dimensi 232 mm tinggi x 280 mm kelebaran x 190 mm kelebaran atas dan panjangnya antara 2000 mm dan 2006 mm.Sebanyak 200 sampel telah diuji untuk memantau gelinciran ikatan di dalam landas konkrit.Tolok tendon diletakkan di bahagian bawah jajaran tendon untuk memantau pemanjangan tendon. Keputusan ujian menunjukkan bahawa landas konkrit prategasan mempunyai gelinciran kurang daripada 0.025mm mengikut piawaian Australian Standard 1085.14-2003. Tidak banyak perbezaan gelinciran antara tendon 1 dan 2 walaupun beban meningkat dari 186kN ke 279kN.Keputusan bagi setiap landas dibandingkan untuk mengenalpasti panjang kritikal landas bagi gelinciran maksimum berlaku. Berdasarkan kepada analisis gelinciran, hanya dua sampel daripada landas konkrit prategasan yang mempunyai gelinciran maksimum antara 0.005mm dan 0.006mm.Manakala beban muktamad ujikaji adalah di antara 413.7 kN dan 422.9 kN lebih tinggi daripada beban reka bentuk. Sebanyak 226 kiub konkrit telah diuji untuk menentukan kekuatan mampatan landas konkrit prategasan dan hasil sisihan piawai konkrit adalah 0.44 iaitu mempunyai kawalan kualiti yang sangat baik. Perbandingan

mengenai kapasiti momen lentur muktamad di bahagian rail seat dibuat antara AS1085.14-2003 dan BS 8110 dan keputusan menunjukkan bahawa nilainya adalah lebih rendah daripada nilai uji kaji.Kajian analisis empirikal telah dilakukan untuk menganalisis hubungan di antara eksperimen dan model matematik yang dicadangkan.Perbandingan data bagi peningkatan pemanjangan tendon dengan teori penyelidik-penyelidik sebelum ini juga telah menunjukkan bahawa nilai eksperimen adalah kurang daripada teori.Oleh itu,ia membuktikan bahawa data yang eksperimen adalah sah dan boleh dipercayai.

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A_t	-	Transformation area of nominal section being tested
d_b	-	Nominal strand diameter
e	-	Eccentricity of the centroid of pre-stress at the section being tested
f'_{ci}	-	Compressive strength of concrete at time of initial prestress
$f'_{c,dyn}$	-	Dynamic compressive strength
$f'_{c,st}$	-	Static compressive strength of concrete
f_{pe}	-	Effective pre-stress
f_{pu}	-	Ultimate pre-stress
f_{si}	-	Stress in prestressing steel at transfer
f^*_{su}	-	Stress in prestressed reinforcement at nominal strength
f_{se}	-	Effective stress in prestressed reinforcement after all losses
f'_t	-	Flexural tensile strength of the concrete in the extreme fibre at testing
$f_{y,dyn}$	-	Dynamic upper yield point stress
$f_{y,st}$	-	Static upper yield point stress of pre-stressing wires
έ	-	Strain rate in tendon
g	-	Distance between rail centers at the head of the rail
l_x	-	Distance from the end of the member to the section under consideration
L	-	Length of sleeper at base
L_b	-	Flexural bond length of prestressing strand

L_d	-	Development length
L_t	-	Transmission length of prestressing strand
M_{R+}	-	Maximum positive (design) moment at the rail seat
P	-	Calculated prestress force at the section at the time of test
P_2	-	Load required to produce proof rail seat moment (rail seat vertical load test)
R	-	Design rail seat load
$M^{cr}{}_{R+}$	-	Positive cracking moment at the rail seat
τ_{bd}	-	Average design bond stress
Z	-	The transformed section modulus of the nominal uncracked section referred to the extreme fibre at which cracking occurs

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Railway system has become one of the choices for transportation in the world today including Malaysia. Since 1885 during the British Colonial era, train was used to transport tin from mining activities. Nowadays; it has become an important transportation used by the Malaysian especially who lives in cosmopolitan and busy area such as Kuala Lumpur. Malaysian Government has taken a step ahead to overcome the traffic problems by providing the rail network system. In Malaysia, Keretapi Tanah Melayu Berhad (KTMB) wholly owned by the Federal Government acts as one department to provide services in railway transportation.

Based on the increased numbers of passengers who used train as their main transport from one place to another, KTMB has taken initiatives to upgrade and construct better facilities for the railway network. Besides that, train is also being used to transport materials and merchandise across the states. Thus, a new or improved technology should be adopted to enhance the system. Due to that, the rail and the components of the railway itself such as sleepers, rail fastening and ballast should be upgraded to provide better, smoother and safer rides, yet cost-efficient.

Prestressed concrete sleepers which often called as “railroad tie” in the United States and Canada are among the major and most common structural components of the railway track structures [1]. Their main duty is to carry and transfer the wheel loads from the rails to the ballast bed or ground. In general, railway track suffers extreme impact loading conditions which are attribute to the train operations with either wheel or rail abnormalities such as flat wheel and dipped rails [2]. These loads have very high magnitude but occur in a short period during the design life of the prestressed concrete sleepers. In spite of the most common use of the prestressed concrete sleepers in railway tracks, their impact responses and behavior are not appreciated nor taken into the design consideration.

For many years now, prestressed concrete sleepers for rail systems have replaced the use of steel or the wooden ones in public and private company rail networks. They last longer than the wooden sleepers and do not need to be impregnated with mineral tar oil, thus, reducing the cost of track maintenance [3]. Besides, all the shape of normal types of sleepers can be substituted with prestressed concrete. Thus, the quality of the prestressed sleepers will be in control and the Prestressed concrete sleepers are supplied ready for laying straight from the factory, meaning that all the reinforcing has been readily built and prestressed in accordance to the standard.performance will be increased compared with the wooden ones where there are a lots of problems arises in terms of stiffness, load bearing capacity and environmental hazardous due to the application of chemical onto the wood to increase its service life. Furthermore, high maintenance cost will incur during the adoption of these wooden sleepers.

1.2 Problem statement

Railway sleepers made of pre-stressed concrete have been used extensively recently in Malaysia. According to design requirement by KTMB which is based on AS1085.14-2003[9], the development lengths of the concrete sleepers should be closely monitored. Also known as bond failure, they are often ignored by designers since they are rarely occurred and are usually controlled by the routine load test. The routine load test is normally carried out by the manufacturer to control the quality of sleepers and to ensure that the design of sleepers can provide a safe and best life services. Due to the smaller size and evenly scattered distribution of wires, tensions due to bursting and spalling forces are minimal. According to AS1085.14-2003, the tendon slippage in concrete sleepers should be less than 0.025mm at specified test load. Thefore further analysis is needed in order to analyse the reliability and compliances of the test method carried out by the manufacturer to ensure that the sleepers perform effectively and provide a safe platform for the train system. An empirical analysis had been carried out to analyse the relationship between the experimental and the proposed mathematical model.

1.3 Objective of study

The objectives of the study are as follows:

(i) To determine the development length in pre-stressed concrete sleepers from experimental work.
(ii) To determine the ultimate loading capacity of pre-stressed concrete sleepers from experimental work.
(iii) To propose an empirical model of determining the development length and ultimate loading capacity of pre-stressed concrete sleepers.
(iv) To compare the experimental results with the proposed empirical model.

1.4 Scope of Study

The pre-stressed concrete sleepers were provided by MASTRAK Sdn.Bhd. which is the appointed manufacturer for Seremban to Gemas Electrified Double Track Project. The scope of this study is to produce an empirical model based on the experimental data according to the Australian Standard, AS1085.14-2003[9].Testing of the pre-stressed concrete sleepers were carried out at MASTRAK Factory Laboratory Testing Unit at Batang Benar, Nilai,Negeri Sembilan. The tests conducted were development length and ultimate load test. The testing procedures follow the KTMB specification and accordance with Australian Standard, AS1085.14-2003[9].There are four numbers of sleeper's beds produced in a day and one number of sleeper will be tested in each bed. One bed contains 240 pieces of sleepers. Beds of sleepers actually refers to a same batch of concrete sleepers that were stressed and cast together in one mixing operation and then steam cured. Each specimen has the same dimensional properties. The samples were of trapezium cross section with a dimension 232 mm high x 280 mm bottom width x 190 mm top width. The sample length is between 2000mm and 2006mm, where some tolerance of ± 6mm has been allowed by the manufacturer in controlling the length of sleepers accordingly to the standard [9]. Each sleeper contained 16 numbers of 5 mm diameter chevron-patterned indented wires. The sleepers are of high strength concrete with design cube compressive strength of 60 MPa based on 14 days of concrete age. The sleepers are allowed to test on 14 days as the sleepers follow the standard of 24 hours steam curing differ from a normal concrete. The sleepers tested are normal type sleepers only. No special sleepers such as the guardrail sleepers, turnout sleepers and others use in this testing.