

## GREEN RETREADED TYRE BASED ON EPOXIDISED NATURAL RUBBER (ENR) BLENDS IN URBAN BUSES

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### ABSTRACT

Utilization of Epoxidised Natural Rubber (ENR) in tyre tread compounds significantly improved wet grip performance and reduce rolling resistance of tyre. The blend of ENR with Polybutadiene Rubber (BR) shows a promising result for laboratory abrasion test however to date no direct correlation with the actual performance on the road. This study is conducted to evaluate on the road performance of ENR/BR blends tread compounds on retreaded tyre fitted on Malaysia's urban buses. Two main routes which subjected with heavy traffic in Kuala Lumpur city center were selected for the test and a total of 10 buses were selected for this study. Each buses of rear drive axles was fitted with 2 units of ENR blends retreaded tyres on one side and 2 units of standard Natural Rubber (NR) blended with BR retreaded tyres formulation on the opposite side as comparison with both of tyre size of 275/70R22.5. The wear performance of the tyre tread was studied for 3 to 6 months and data collection of tread depth was done every two weeks interval. From the study, it was found ENR blends retreaded tyre formulation performed better wear resistance than standard retreaded tyres formulation. The mileage percentage of ENR tread compounds was found 30 % to 40% better than standard retreaded tyre formulation for both selected routes.

**Keywords:** epoxidised natural rubber; retreaded tyre; wear

### INTRODUCTION

The new generation of green tyre compound has the advantages of having low rolling resistance and improved wet grip. It was found that a 3% decrease in rolling resistance is equivalent to 1% saving in fuel, and thus green tyre can provide cost saving and consumer satisfaction [1]. To achieve the unique of green tyre properties, silica is widely utilized as the main filler in the tyre tread compound. Michelin is the first tyre manufacturer introduced the silica reinforced tyre. However, many studies have found that silica has poor interaction and dispersion in non-polar tyre rubbers such as NR, styrene butadiene rubber (SBR) and polybutadiene rubber (BR) as compared to carbon black [20]. Generally, silica particles possess very strong particle-particle interactions than carbon black and causes it is much more difficult to disperse in rubber matrix than carbon black even though at equivalent particle size or BET surface area [3]. Application of coupling agent is practiced by rubber compounder to enhance interaction between silica filler and rubber. Several studies suggested the possibility of rubber compound filled with silica without the usage of coupling agents such as silane coupling agent. The good example is Epoxidised Natural Rubber (ENR), the modified form of natural rubber which gives better compatibility to silica and higher reinforcement for silica compound. The epoxy group of polar ENR can interact with the silanol group of silica, where the use of coupling agents such as silane [4,5] can be eliminated or greatly reduced. Eco-friendly tire has been developed by Sumitomo using at least 97% by weight of tire based on non-petroleum raw materials including natural rubber or modified

natural rubber and silica in the compound recipe [6]. Commercial city bus consumes high fuel, carries heavy load and exposed to frequent acceleration and braking thus the tyre tread requires good wear resistance, good grip and low rolling resistance with high strength. Conventional carbon black NR/BR bus tread provide good wear resistance, high strength but average performance on grip and rolling resistance. Utilization of full composition of ENR for tyre application provide good wet grip, high strength, high silica interaction and further potential for reducing rolling resistance but gave drawn back impact on material cost and wear performance can be unequal to common conventional tyre tread formulation. Blend of ENR with BR can be another alternative to improve wear performance and reduce the material cost without scarifying the green characteristics of the tread rubber compound. However, blend of non-polar BR with ENR can be challenging because these two different polarity rubbers may affect the compounds and vulcanizates properties. The impact of this blends on wear performance needs to be concerned for urban commercial vehicle or city bus tyre tread application. As a part of green tyre technology development, this work will investigate the actual road of wear performance of ENR/BR blends for city bus tyre tread. The study will also compare the wear performance of this blend with commercial tyre tread of retreaded tyre tested on similar type of city buses.

## EXPERIMENTAL

The effect of performance of tyre tread based on ENR/BR blend (EK) as compared to standard tread based on NR/BR blend (ST) in bus tyres was investigated in this study. The compounding ingredients are based on standard truck/bus tyre tread compounds formulation. The material used are epoxidized natural rubber (Ekoprena 25), high cis polybutadiene rubber (NdBR Buna CB40), natural rubber (SMR20), precipitated silica, carbon black, rubber processing oil, stearic acid, antioxidants, sulphur and TBBS.

The mixing process was carried out using commercial Intermix® 270 liter internal mixer. Two steps involved in the mixing which include preparation of masterbatch and additional of curatives. Extrusion of tread liner was conducted using hot feed extruder followed by vulcanization of the liner at 160°C for 20 minutes on heated press. Retreading process was carried out according to MS224 specification and requirements [7]. The city bus tyre size retreaded for the experiment was 275/70R22.5 with urban tread pattern as shown in Fig. 1. and the tyre specification is presented in Table 1.



**Fig. 1** Tread pattern for city bus tyre

**Table 1** Retreaded tyres specification for the city bus

Tyre Parameter	Specification
Rim size	22.5 inch
Section width	275 mm
Section height	192.5 mm
Aspect ratio	70%
Diameter	966 mm
Circumference	2,950 mm
Construction	Radial (all steel)
Speed rating	J (100km/h)
Load index	148/145 (3150kg/2900kg)
Inflated air pressure	758 kPa

The evaluation of the tyre performance was done on 10 buses at 2 different routes for 6 months duration. Two main routes were selected in the experiment which are exposed to heavy traffic in Klang Valley/Kuala Lumpur city center and 5 units buses were tested on each route which the distance of each route is about 30km in single way and the routes are presented in Table 2.

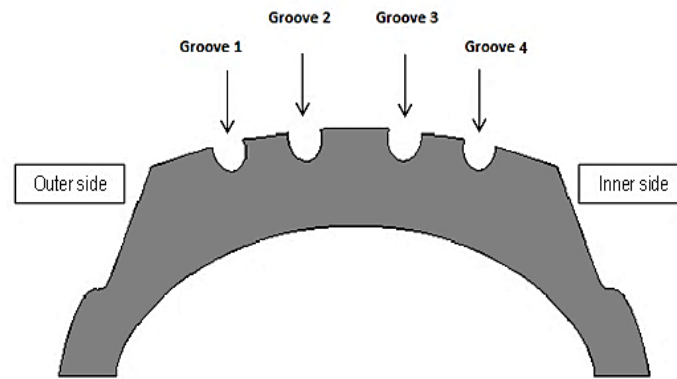
**Table 2** Route selection of the city buses for the experiment

Route	Itinerant Location
Route 1 (5 buses)	Terminal Kajang Sentral ↔ Kuala Lumpur city center
Route 2 (5 buses)	Bandar Sungai Long ↔ Kuala Lumpur city center

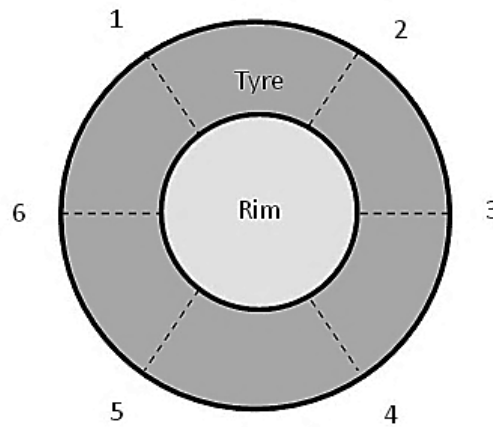
**Table 3** Selected city bus specification

Bus Parameter	Specification
Bus model	Scania K250UB4X2
Engine type	Diesel
Engine capacity	9300 cm <sup>3</sup>
Kerb weight	11300 kg
Gross weight	18000 kg
Maximum capacity	64 passengers

Each bus assembled with two units of retreaded ENR blends formulation tyres on one side and two units of standard retreaded formulation tyres on the other side for comparison test on drive axle. The bus specification for the trial is shown in Table 3 which can be identified in 4 positions such as Left Outer Tyre (LOT), Left Inner Tyre (LIT), Right Outer Tyre (ROT) and Right Inner Tyre (RIT). The bus is operated 6 to 7 days a week and the limit of the speed is 60 to 70km/h in city center.



**Fig. 2** Tread grooves for depth measurement



**Fig. 3** Measurement points around tyre circumference

Tread depth of the tyre was taken at 4 grooves on 6 locations of around tyre circumference as shown in Fig. 2 and Fig. 3 respectively while the data collections were conducted every 2 weeks interval. For the wear performance analysis of the tyres, following equations are used to analyse the data.

$$\text{Tread wear (mm)} = \text{Original tread depth (mm)} - \text{measured tread depth (mm)} \quad (1)$$

$$\text{Wear (\%)} = \frac{\text{Tread wear (mm)}}{\text{Original tread depth (mm)}} \times 100 \quad (2)$$

$$\text{Wear rate (mm/1000km)} = \frac{\text{wear}}{1000\text{km}} = \frac{\text{tread wear in mm}}{\text{Distance travelled in km}} \times 1000 \quad (3)$$

$$\text{Projected tread life (km)} = \frac{\text{Original tread depth}-2\text{mm}}{\text{wear}/1000\text{km}} \quad (4)$$

## RESULTS AND DISCUSSION

### Tread Depth

Tread depth is a vertical measurement between the top of the tread rubber to the bottom of the tyre's deepest grooves. Tread depth is the main data collected for the measurement of wear performance of tyre tread. The tyre tread depth value indicates the remaining amount of tread rubber thickness that adhered on the tyre casing. From the experiment, it was found that all tyres tread depth was decreased by the increase of travelling distances. Fig. 4 and Fig. 5 presented the average of tread depth curves of every retreaded tyre when travels up to 32,000km for both Route 1 and Route 2 buses. Based on the finding, EK retreaded tyres showed higher tread depth average along travelled distance as compared to ST retreaded tyres for both routes of the buses. It was clearly seen that majority of EK retreaded tyres has shown higher tread depth value as compared to ST retreaded tyres as indicated in both figures. The result indicates that the remaining amount of EK tread rubber was higher than amount of ST tread rubber remaining on the retreaded tyres. From the road trial, it can be said that EK retreaded tyres performed better tread depth value as compared to ST retreaded tyres tread depth for both routes along travelling distance.

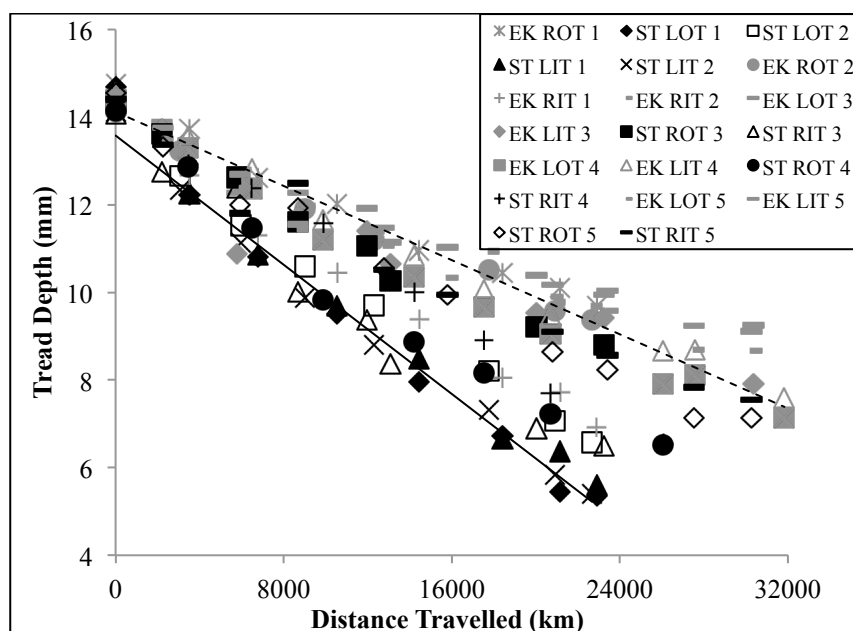
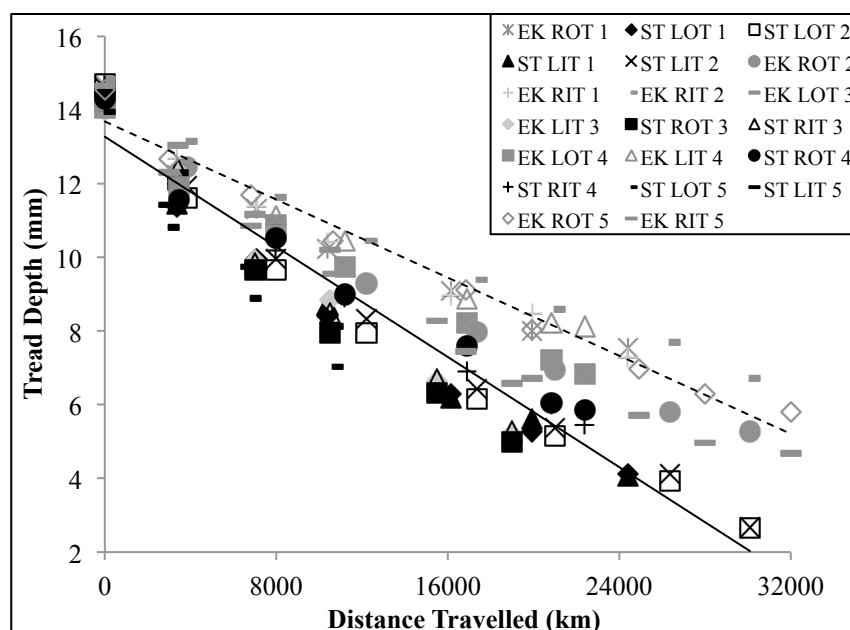


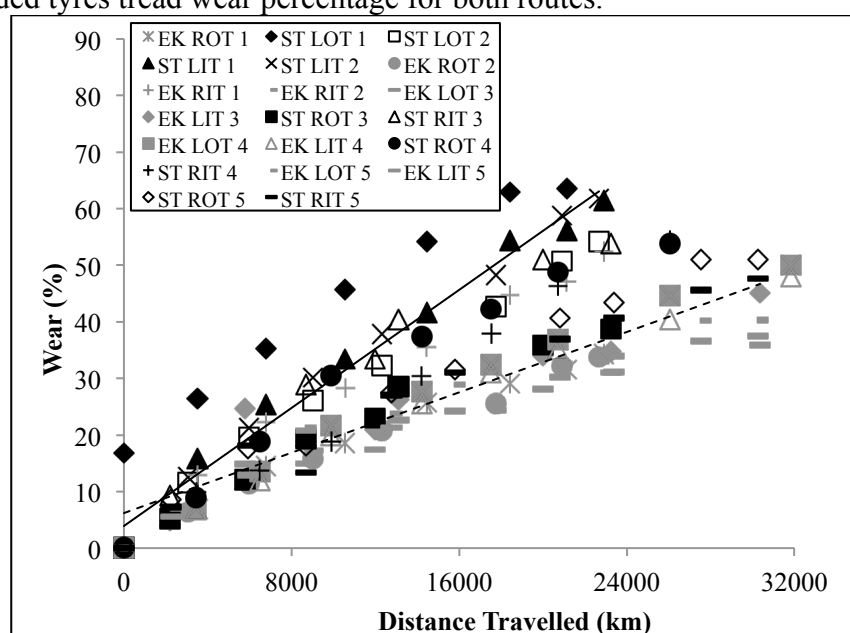
Fig. 4 Tread depth of Route 1 tyres



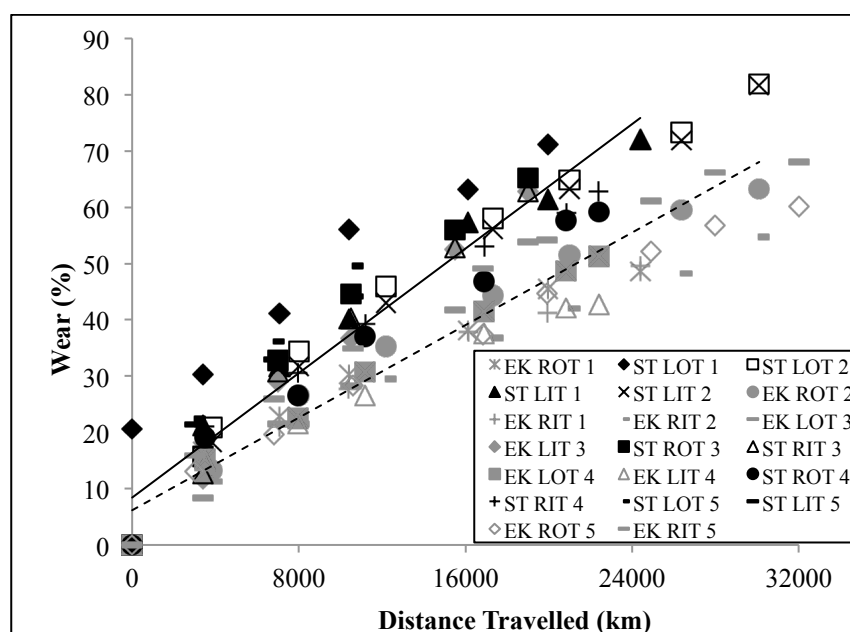
**Fig. 5** Tread depth of Route 2 tyres

### Tread Wear Percentage

Tread wear percentage is the ratio of tread depth lost over the original tread depth of tyre which expressed in percentage. Tread wear percentage can be the best parameter to compare wear performance of tyre tread whereby the variation on original tread depth of each individual tyre can be eliminated. In contrast to tread depth, higher tread wear value indicated higher amount of tread rubber lost from the tyre casing when subjected to wear process. Fig. 6 and Fig. 7 presented the average of tread wear percentage curves of all retreaded tyres when travels up to 32,000km for both routes respectively. From the experiment, it was found that all tyres tread wear percentages were increased by the increases of travelling distance. From the observation, it was clearly seen that majority of ST retreaded tyres has shown higher tread wear percentage as compared to EK retreaded tyres as indicated in both figures. From the finding, it can be said that ST retreaded tyres has higher tread wear percentage as compared to EK retreaded tyres tread wear percentage for both routes.



**Fig. 6** Tread wear of Route 1 tyres



**Fig. 7** Tread wear of Route 2 tyres

### Tread Wear Rate

Tread wear rate indicates tread wear or tread depth lost in millimetres at specific travelling distance. The value is important for determination of tread depth lost for every 1000km of the vehicle movement. Fig. 8 and Fig. 9 presented the curves of tread wear rate for every retreaded tyres and Table 4 and Table 5 shows the wear rates at from lower travelling distance to the final before the tyres removed from vehicles for Route 1 and Routes 2 respectively. From the experiment, it was found that all types of tyres tread wear rate have shown decrement of wear rate with the increase of travelling distance. This indicated that all the retreaded tyres encounter rapid wear process at initial few thousand kilometers and lower wear process to the end of the road trial. The result might be influenced by surface over cured of the tread rubber during vulcanization of thick tread liner which generated high wear at initial test kilometer and optimum vulcanization in the middle tread rubber generated low wear at the end of test kilometer. Other factors that can be considered is the geometry of tread rubber whereby higher tread elements height over width ratio reduces its rigidity thus exposing the tread elements to excessive deformation and chafing the road surface. The heat accumulation in the newly thick tread rubber accelerated the wear process at the initial test kilometer than thin tread at the end of the trial can be considered. Based on the result, majority of ST retreaded tyres recorded higher tread wear rate along travelled distance as compared to EK retreaded tyres. The result can be observed in both figures whereby ST retreaded tyres has shown higher tread wear rate as compared to EK retreaded tyres as indicated in the figures and the value presented in both tables. Wear rates of retread tyres for buses Route 2 was found higher than buses Route 1 for all tread formulations. This might be influenced by the various factors such as road condition, traffic, landform and number of daily passenger for each route. From the observation, it can be said that ST retreaded tyres has higher tread wear rate as compared to EK retreaded tyres wear rate.

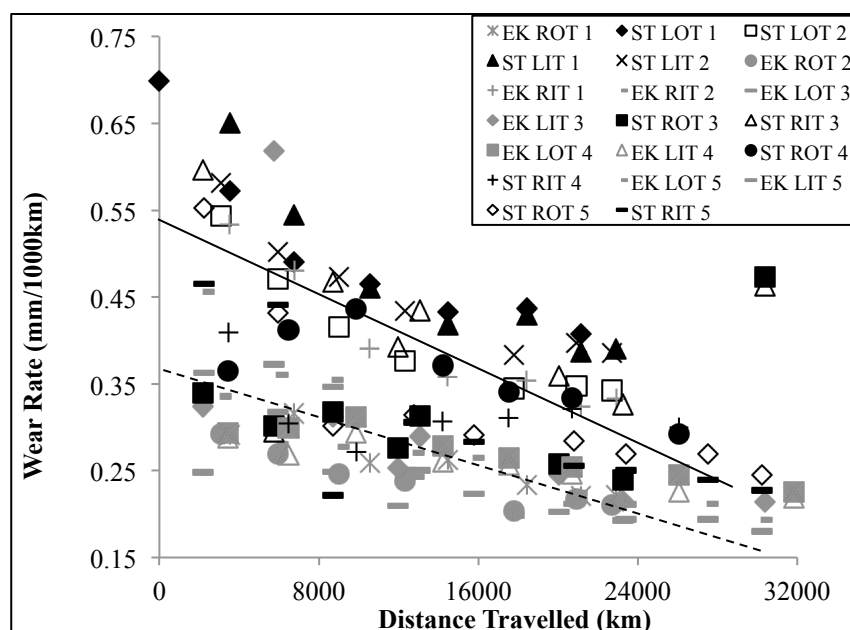


Fig. 8 Tread wear of Route 1 tyres

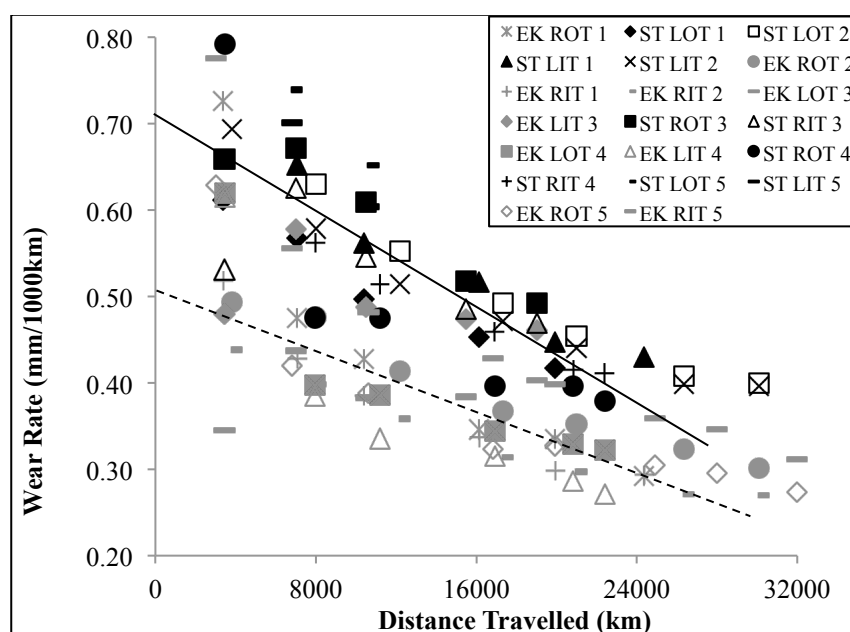


Fig. 9 Tread wear of Route 2 tyres

**Table 4** Wear rate (mm/1000km) of EK and standard retreaded tyres for Route 1 at specific distances

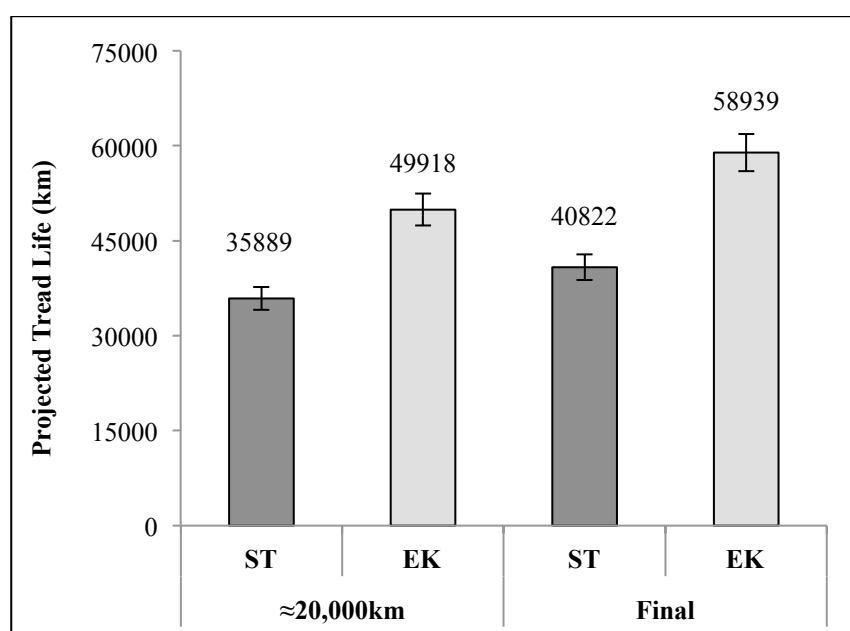
Distance travelled	6,000km		20,000km		Final	
Tread type	ST	EK	ST	EK	ST	EK
Mean	0.4276	0.3583	0.3380	0.2367	0.3526	0.2179
Standard Deviation	0.1004	0.1114	0.0601	0.0348	0.0857	0.0445
Minimum	0.2954	0.2680	0.2558	0.2021	0.2271	0.1706
Maximum	0.5718	0.6182	0.4369	0.3241	0.4732	0.3337

**Table 5** Wear rate (mm/1000km) of EK and standard retreaded tyres for Route 2 at specific distances

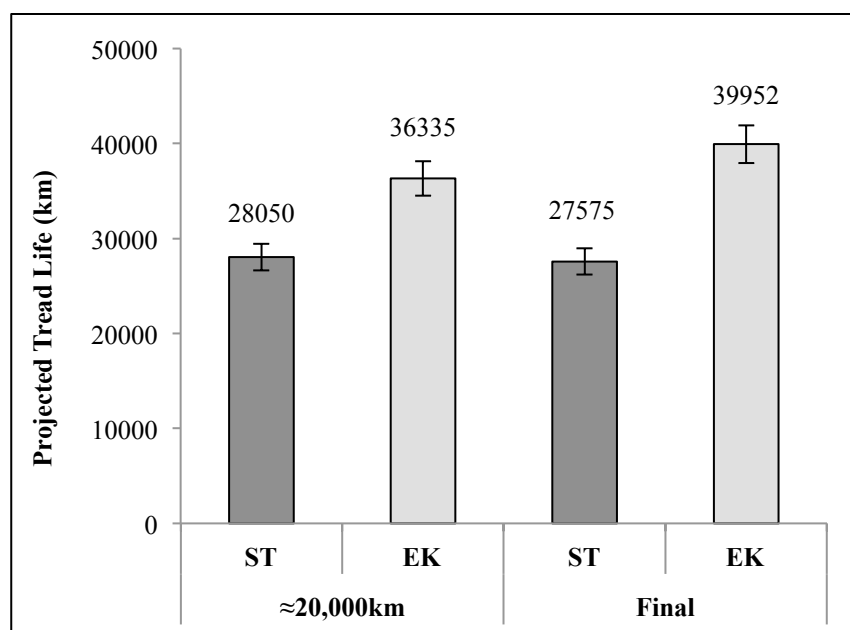
Distance travelled	3,500km		20,000km		Final	
Tread type	ST	EK	ST	EK	ST	EK
Mean	0.8225	0.5641	0.4462	0.3487	0.4651	0.3198
Standard Deviation	0.1610	0.1328	0.0300	0.0560	0.0931	0.0631
Minimum	0.5312	0.3452	0.3961	0.2869	0.3782	0.2695
Maximum	1.0361	0.7754	0.4925	0.4614	0.6522	0.4614

### Projected Tread Life

Projected tread life is the value of projection tread durability or maximum kilometer tread can be run on the road before reaching minimum pre-set tread depth and the tyre needs to be replaced. In the experiment, the minimum pre-set tread depth is set at 2.0mm and Fig. 10 and Fig. 11 presented the result obtained during the road trial for both routes. Based on the calculation, the result obtained is depending on the specific wear rate at selected kilometer measured. From the road trial, it was found EK retreaded tyres achieved higher average projected tread life than ST retreaded for both at around 20,000km and final trial. On average, EK retreaded tyres performed close to 59,000km or 38% better projected tread life than ST retreaded tyres for for Routes 1 while up to 40,000km or 31% better projected life for Routes 2. Projected tread life of retread tyres for Route 2 was found lower than Route 1, and this might be influenced by similar factors as discussed earlier for the case of tread wear rate. Better projected tread life value will benefiting user in term of less frequency and manpower need to maintain their tyres along the vehicles service life. For the summary, it can be said that EK retreaded tyres performed better projected tread life as compare to ST retreaded tyres for both routes buses.



**Fig. 10** Projected tread life of Route 1 tyres



**Fig. 11** Projected tread life of Route 2 tyres

### CONCLUSION

From the experiment, it can be summarized that ENR blends of retreaded tyre tested on city buses achieved average wear rate at 0.26 mm/1000km in the final result of the trial. The averages projected tread life obtained by ENR blends tread is 49,000km for both routes of the city bus tyres. By comparing ENR blends tread with standard commercial retread tyres, the average of ENR blends obtained less 35% of wear rate and higher projected tread life for both routes of the city bus tyres. Tread wear rate decreased with the increases of bus travelling distance for all type of retreaded tyres formulation.

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