Evaluating the effect of asphalt binder and biochar based Geopolymer Composite on the Permanent Deformation Resistance of Asphalt Concrete employing response surface method

Presented By:

Nura Shehu Aliyu Yaro

Civil & Environmental Engineering

Universiti Teknologi PETRONAS

Research Background

- Million tones of waste are generated yearly, and its potential is not fully harnesses
- To help improve asphalt binder's and asphalt mixtures characteristics, several experts have turned to waste materials
- Permanent deformation, also known as rutting, transpires when the asphalt pavement develops excessive and permanent distortion because of frequent traffic loading, eventually leading to decreased road safety
- The recent interest in the use of composite is a relatively new phenomenon with little study on the topic of modifying asphalt binder with waste material-based composites

Problem Statement

Waste disposal crisis due to the non-biodegradability nature of waste material because they are polluting the oceans, littering the landfills, generation of toxic fumes

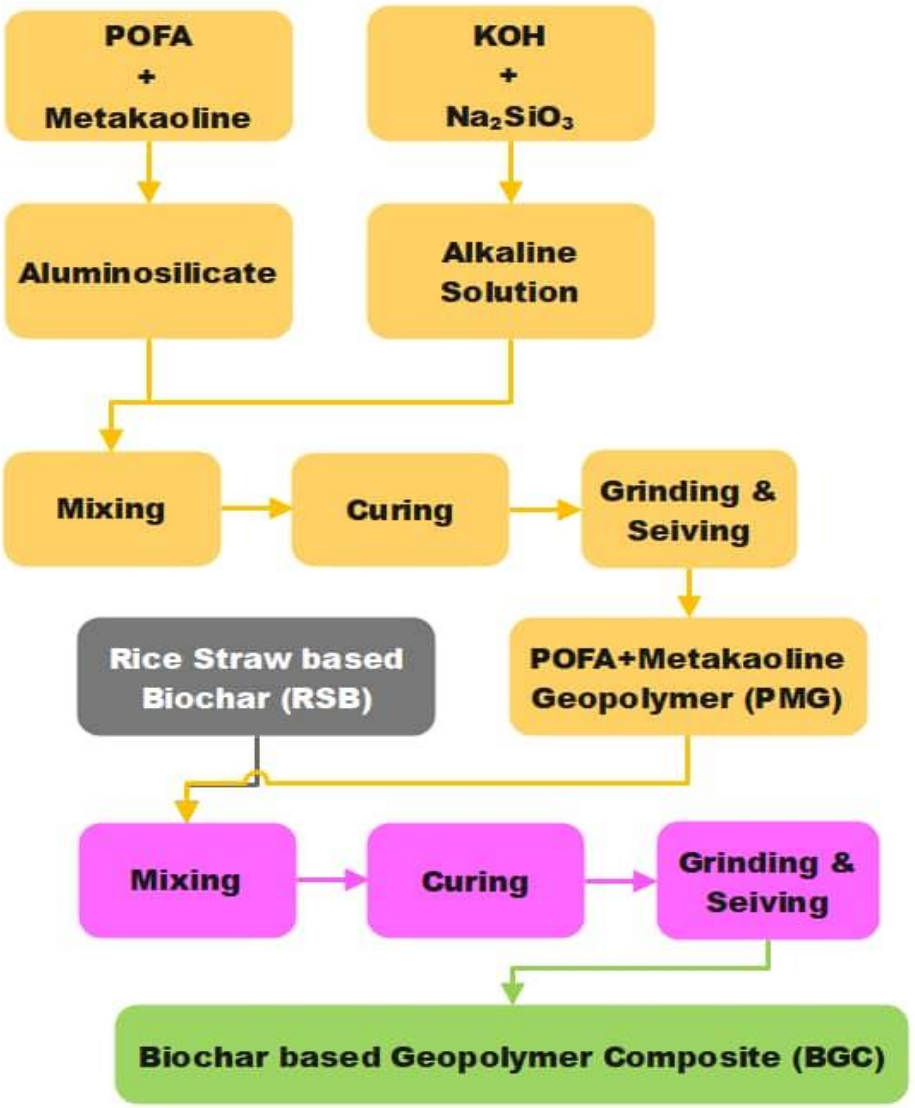
The present exposure to excessive tire pressures, and traffic volumes which make the conventional materials unable to withstand these challenges.

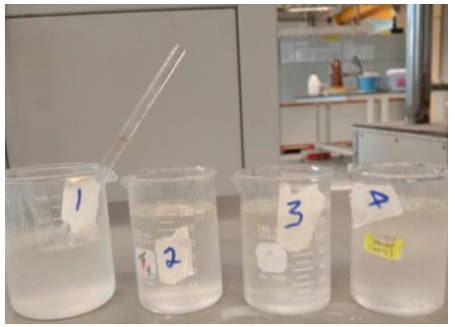
The cost, practicality and environmental issues of the current available bitumen modifier mostly chemical .

Objectives

The goal of this study is to determine the influence and interaction of the asphalt binder and biochar-based geopolymer composite as a sustainable modifier on asphalt concrete's permanent deformation resistance by employing the response surface method.

Methodology Flow Chart





(a)

(b)

(c)

(d)

(e)

Results and discussions cont'd

Table 1. Table: study design of experiments matrix

Run no.	Input variables			Response
	Biochar	Geopolymer	Asphalt binder	ARD (mm)
1	4	2	6	2.59
2	0	4	5	3.34
3	0	2	6	3.29
4	2	0	4	4.89
5	2	2	5	2.59
6	2	4	6	2.36
7	2	4	4	4.39
8	2	2	5	2.62
9	4	2	4	4.02
10	0	0	5	4.43
11	2	2	5	2.61
12	0	2	4	5.47
13	2	0	6	3.32
14	4	0	5	2.94
15	2	2	5	2.63
16	2	2	5	2.61
17	4	4	5	2.51

Table 2. ANOVA and fit statistics for the study ARD model

Variable	SS	DF	MS	F-value	P-value	Observation
Type of model	Quadratic					
Model	14.71	9	1.63	2309.20	< 0.0001	Significant
A-Biochar	2.50	1	2.50	3528.41	< 0.0001	
B-Geopolymer	1.11	1	1.11	1568.18	< 0.0001	
C-Asphalt binder	6.50	1	6.50	9179.84	< 0.0001	
AB	0.1089	1	0.1089	153.84	< 0.0001	
AC	0.1406	1	0.1406	198.66	< 0.0001	
BC	0.0529	1	0.0529	74.73	< 0.0001	
A^2	0.6661	1	0.6661	941.05	< 0.0001	
B^2	0.3670	1	0.3670	518.53	< 0.0001	
C^2	2.92	1	2.92	4124.96	< 0.0001	
Residual	0.0050	7	0.0007			
Lack of Fit	0.0041	3	0.0014	6.17	0.0555	Not significant
Pure Error	0.0009	4	0.0002			
Cor Total	14.72	16				
Fit statistics						
R2		0.997	Standard deviation		0.0266	
Adjusted R2		0.992	Mean		3.33	
Predicted R2		0.995	Adequate precision		153.8	

The derived model for ARD is represented by equation

$$ARD = 2.612 - 0.559A - 0.373B - 0.901C + 0.165AB + 0.188AC - 0.115BC + 0.295B^2 + 0.833C^2 \quad (1)$$

discussions cont'd

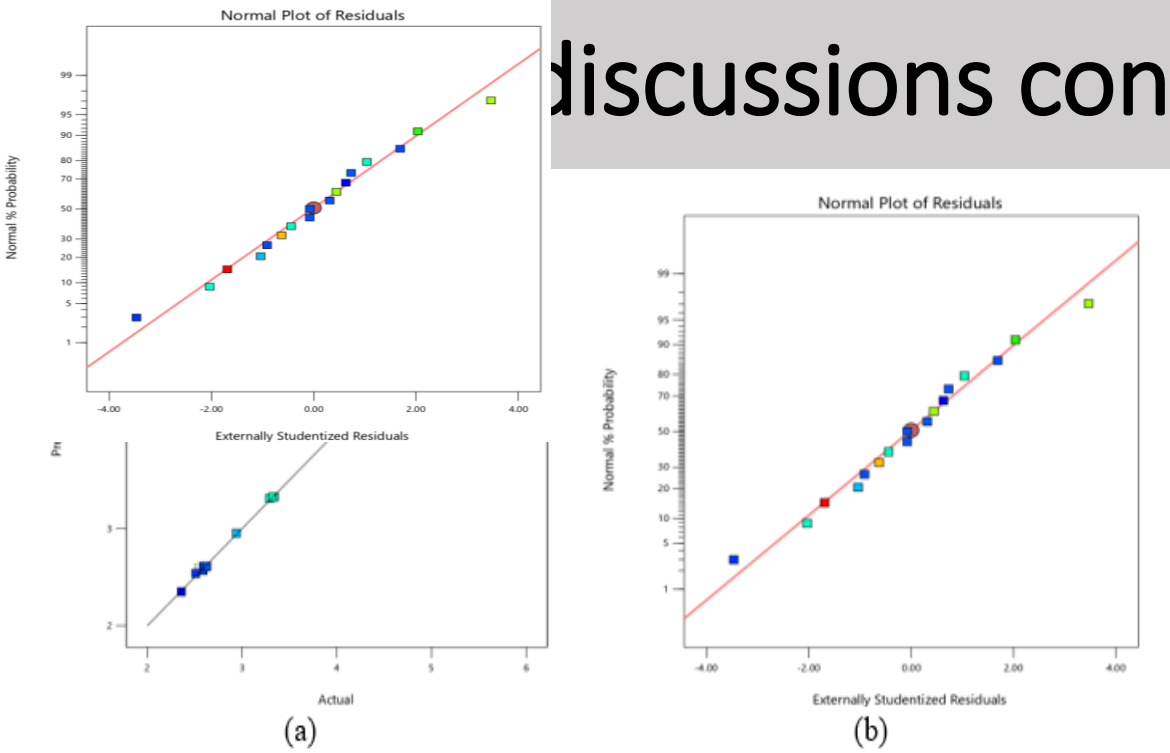


Figure 1. Degree of agreement between predicted and experimental results

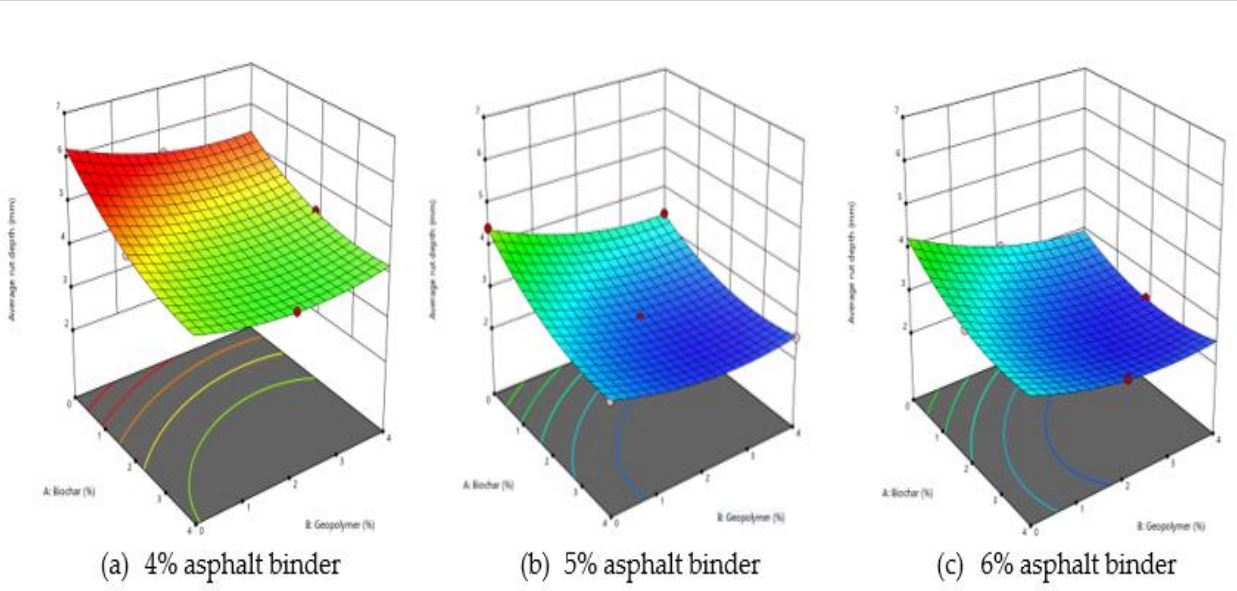


Figure 2. 3D synergetic influence of biochar and geopolymer on permanent deformation at different asphalt binder content

Table 3. Verification of optimized findings

Input Variable	% Content	ARD values (mm)		% Error
		RSM predicted	Experimental	
Biochar	3.22	2.27	2.36	3.96
Geopolymer	1.81			
Asphalt content	5.4			

As observed from the 3D contour lines with elliptical shapes, indicating a strong interaction between the input variables. This implies that all the variables considerably impact the model's response. The increased PDR in the asphalt concrete can be attributed to the asphalt binder's improved viscoelasticity and stiffness due to the incorporation of the composite binder. These contribute to a more efficient aggregate covering and promote a well-connected aggregate binder structure, which improves asphalt concrete permanent deformation resistance

Conclusions

Based on the study's findings, the following key findings can be drawn:

- The incorporation of biochar-based geopolymer composite as a modifier significantly impacted the rut depth resistance of asphalt concrete.
- The RSM models used in this study demonstrated a high degree of correlation, predictability, and level of agreement between predicted and experimental outcomes, as proven by high R2 values and appropriate accuracy (>4.0), indicating their reliability and efficacy for exploring the model space.
- The RSM optimization identified the optimum content of biochar, geopolymer, and asphalt binder (at 3.22%, 1.81%, and 5.4% respectively), with a percentage error of less than 5% between the RSM-predicted values and experimental data.

THANK YOU…!