UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# NATURAL FIBRES AND POLYMERS SELECTION WITH A COMBINATION OF ASPHALT MIXTURE BASED ON MECHANICAL AND PHYSICAL PROPERTIES

MUHAMMAD FIKRI BIN MUHAMMAD SABRI
B091810204

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BACHELOR OF MANUFACTURING ENGINEERING TECHNOLOGY WITH HONOURS

2022

**Faculty of Mechanical and Manufacturing Engineering Technology**

# NATURAL FIBRES AND POLYMERS SELECTION WITH A COMBINATION OF ASPHALT MIXTURE BASED ON MECHANICAL AND PHYSICAL PROPERTIES

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**Muhammad Fikri Bin Muhammad Sabri**

**Bachelor of Manufacturing Engineering Technology with Honours**

**2022**

# NATURAL FIBRES AND POLYMERS SELECTION WITH A COMBINATION OF ASPHALT MIXTURE BASED ON MECHANICAL AND PHYSICAL PROPERTIES

**MUHAMMAD FIKRI BIN MUHAMMAD SABRI**

**A thesis submitted**
**in fulfillment of the requirements for the degree of**
**Bachelor of Manufacturing Engineering Technology with Honours**

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**Faculty of Mechanical and Manufacturing Engineering Technology**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2022**

**DECLARATION**

I declare that this Choose an item. entitled " NATURAL FIBRES AND POLYMERS SELECTION WITH A COMBINATION OF ASPHALT MIXTURE BASED ON MECHANICAL AND PHYSICAL PROPERTIES " is the result of my own research except as cited in the references. The Choose an item. has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : Fikri

Name : MUHAMMAD FIKRI BIN MUHAMMAD SABRI

Date : 17/1/2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**APPROVAL**

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology with Honours.

Signature : *aiman*

Supervisor Name : PN. NUR AIMAN HANIS BINTI HASIM

Date : 18/1/2022

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**DEDICATION**

***To my beloved parents who are always supported me:***

*Muhammad Sabri bin Othman*

*Norlela binti Hasim*

And

***For my Supervisor,***

*Pn. Nur Aiman Hanis binti Hasim*

***For my Families, my Special Friend and my Friends***

*who provide a loving, caring, encouringing, and supportive atmosphere. These are characteristics that contribute to the environment that is always needed to achieve the goals a heads.*

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## ABSTRACT

Road was designed and built for people to go to work, travel, and vacation. However, even roads can reach their limits and be damaged. Potholes, in general, are bowl-shaped holes in the surface of asphalt road pavement and their presence will bring dangerous situation to users, drivers or riders. Potholes are repaired by filling the damaged area with an asphalt mixture. However, the fix is temporary, and they are prone to damage. This is due to the quality of asphalt pavement. There have been a few studies about on how to increase the performance of potholes repair where researchers and experts have state that combining natural fibres and polymers with asphalt mixture can improve their performance. Thus, there are a lot of natural fibres and polymers that can be used to be mix in the asphalt mixture. The list of natural fibres and polymers to be evaluated are coconut, jute, hemp, sisal fibres and Polypropylene (PP), High-Density Polyethylene (HDPE), Polystyrene (PS), Polyethylene Terephthalate (PET) respectively. Therefore, this paper is to provide a case study on the material selection of natural fibres and polymers based on design requirements by focusing on the physical and mechanical properties of natural fibres, polymers and asphalt mixtures. Then, to compare the results of natural fibres and polymers by using two different methods which are Pugh Decision Matrix and Grey Relational Analysis (GRA). The results shows the highest ranking score for natural fibre and polymer are jute fibre and Polyethylene Terephthalate (PET) from Pugh Decision Matrix analysis. From the Grey Relational Analysis (GRA), the highest ranking score for natural fibre and polymer are hemp fibre and Polyethylene Terephthalate (PET). Based on these two method analysis which are Pugh Decision Matrix and Grey Relational Analysis (GRA), jute fibre, hemp fibre and Polyethylene Terephthalate (PET) are selected as the best natural fibre and polymer to combine with asphalt mixture.


UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## *ABSTRAK*

Jalan dirancang dan dibangun bagi orang - orang untuk pergi bekerja, bepergian, dan berlibur. Walau bagaimanapun, walaupun jalan raya boleh mencapai had mereka dan rosak. Lubang, secara umum, adalah lubang berbentuk mangkuk di permukaan turapan jalan asfalt dan kehadiran mereka akan membawa keadaan berbahaya kepada pengguna, pemandu atau penunggang. Lubang dibaiki dengan mengisi kawasan yang rosak dengan campuran asfalt. Walau bagaimanapun, pembaikan adalah sementara, dan mereka terdedah kepada kerosakan. Ini disebabkan oleh kualiti turapan asfalt. Terdapat beberapa kajian tentang bagaimana untuk meningkatkan prestasi pembaikan lubang di mana penyelidik dan pakar telah menyatakan bahawa menggabungkan gentian semulajadi dan polimer dengan campuran asfalt dapat meningkatkan prestasi mereka. Oleh itu, terdapat banyak gentian semulajadi dan polimer yang boleh digunakan untuk dicampur dalam campuran asfalt. Senarai gentian asli dan polimer yang akan dinilai ialah kelapa, jute, hem, gentian sisal dan Polipropilena (PP), Polietilena Ketumpatan Tinggi (HDPE), Polistirena (PS), Polyethylene Terephthalate (PET). Oleh itu, kertas ini adalah untuk menyediakan kajian kes mengenai pemilihan bahan gentian semulajadi dan polimer berdasarkan keperluan reka bentuk dengan memberi tumpuan kepada sifat fizikal dan mekanikal gentian semulajadi, polimer dan campuran asfalt. Kemudian, untuk membandingkan hasil gentian semulajadi dan polimer dengan menggunakan dua kaedah yang berbeza iaitu Matriks Keputusan Pugh dan Analisis Hubungan Kelabu (GRA). Keputusan menunjukkan skor kedudukan tertinggi untuk gentian semulajadi dan polimer adalah serat jute dan Polyethylene Terephthalate (PET) dari analisis Matriks Keputusan Pugh. Dari Analisis Hubungan Kelabu (GRA), skor kedudukan tertinggi untuk serat semula jadi dan polimer adalah serat hem dan Polyethylene Terephthalate (PET). Berdasarkan dua analisis kaedah ini iaitu Pugh Decision Matrix dan Grey Relational Analysis (GRA), jute fibre, hem fibre dan Polyethylene Terephthalate (PET) dipilih sebagai gentian semulajadi dan polimer terbaik untuk digabungkan dengan campuran asfalt..


UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**ACKNOWLEDGEMENTS**

In the Name of Allah, the Most Gracious, the Most Merciful

First and foremost, I would like to thank and praise Allah the Almighty, my Creator, my Sustainer, for everything I received since the beginning of my life. I would like to extend my Universiti Teknikal Malaysia Melaka (UTeM) for providing the research platform.

My utmost appreciation goes to my main supervisor, Pn. Nur Aiman Hanis binti Hasim for all her support, advice and inspiration. Her constant patience for guiding and providing priceless insights will forever be remembered. Also, to my co-supervisor, Dr. Mastura binti Mohammad Taha who constantly supported my journey.

Last but not least, from the bottom of my heart a gratitude to my beloved parents, En Muhammad Sabri bin Othman and Norlela binti Hasim, for her encouragements and who have been the pillar of strength in all my endeavors. My eternal love also to my siblings, Ahmad Zaidah for the endless support, love and prayers. I would also like to thank my beloved friends for their endless support and help. Finally, thank you to all the individual(s) who had provided me the assistance, support and inspiration to embark on my study.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## TABLE OF CONTENTS


**PAGE**

**DECLARATION**

**APPROVAL**

**DEDICATION**

**ABSTRACT** **i**

**ABSTRAK** **ii**

**ACKNOWLEDGEMENTS** **iii**

**TABLE OF CONTENTS** **iv**

**LIST OF TABLES** **vi**

**LIST OF FIGURES** **viii**

**LIST OF SYMBOLS AND ABBREVIATIONS** **xi**

**LIST OF APPENDICES** **xii**

**CHAPTER 1 INTRODUCTION** **1**
1.1 Background 1
1.2 Problem Statement 3
1.3 Research Objective 4
1.4 Scope of Research 5

**CHAPTER 2 LITERATURE REVIEW** **6**
2.1 Introduction 6
2.2 Natural Fibre 7
2.2.1 Development of Natural Fibre 7
2.2.2 Classification of Natural Fibre 8
2.2.3 Type of Natural Fibre 11
2.2.4 Advantages of Natural Fibre 14
2.3 Polymer 15
2.3.1 Advantages of Thermoplastic 16
2.3.2 Advantages of Thermoset 17
2.4 Natural Fibre Reinforced Polymer Composites (NFRPCs) 18
2.4.1 Advantages of Natural Fibre Reinforced Polymer Composites (NFRPCs) 18
2.4.2 Mechanical properties of Natural Fibre Reinforced Polymer Composites (NFRPCs) 21
2.5 Requirement on Material Selection 25
2.6 Pugh Decision Matrix 27


UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.7 Grey Relational Analysis 31
2.8 Summary of Chapter 35

**CHAPTER 3 METHODOLOGY 45**
3.1 Introduction 45
3.2 Planning of the Study 45
3.3 Material Selection 48
3.4 Design Requirement for Asphalt Mixture 48
3.5 Data Collection of Mechanical Properties of Asphalt Mixture, Natural Fibres and Polymer Matrix. 52
3.5.1 Physical and Mechanical Properties of Asphalt Mixture. 52
3.5.2 Physical and Mechanical Properties of Natural Fibres. 53
3.5.3 Physical and Mechanical Properties of Polymer matrix. 54
3.6 Pugh Decision Matrix Method 55
3.7 Grey Relational Analysis 57
3.7.1 Step for Grey Relational Analysis 57

**CHAPTER 4 62**
4.1 Introduction 62
4.2 Pugh Decision Matrix 62
4.2.1 Results for Natural Fibres 62
4.2.2 Results for Polymers 67
4.3 Grey Relational Analysis 71
4.3.1 Results for Natural Fibres 71
4.3.2 Results for Polymers 77
4.4 Discussion 83
4.4.1 Comparison of Result between Pugh Decision Matrix and Grey Relational Analysis (GRA) for Natural Fibres 83
4.4.2 Comparison of Result between Pugh Decision Matrix and Grey Relational Analysis (GRA) for Polymers 84

**CHAPTER 5 86**
5.1 Introduction 86
5.2 Conclusion 86
5.3 Recommendation for Future Study 86

**REFERENCES 88**

**APPENDICES 93**

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## LIST OF TABLES


| TABLE | TITLE | PAGE |
|---|---|---|
| Table 2.1: | Summary of previous researches findings | 36 |
| Table 3.1: | Design requirement for asphalt mixture. | 52 |
| Table 3.2: | The physical and mechanical properties of natural fibre (Keya et al., 2019) . | 53 |
| Table 3.3: | Physical and mechanical properties of Polypropylene (PP), High-Density Polyethylene (HDPE), Polystyrene (PS), Polyethylene Terephthalate (PET) (Mastura et al., 2018). | 54 |
| Table 4.1: | The mechanical and physical properties of natural fibres | 63 |
| Table 4.2: | The rating factors of natural fibres for pugh decision matrix | 64 |
| Table 4.3: | The weighting factor of natural fibres for pugh decision matrix | 65 |
| Table 4.4: | The mechanical and physical properties of polymers | 67 |
| Table 4.5: | The rating factors of polymers for pugh decision matrix | 68 |
| Table 4.6: | The weighting factor of polymers for pugh decision matrix. | 69 |
| Table 4. 7: | The comparison of properties and normalized of natural fibres for highest value requirement. | 72 |
| . Table 4. 8: | The comparison value of Normalized Table and Deviation Sequences Table | 74 |
| Table 4. 9 | The comparison of properties and normalized of polymers for highest value requirement. | 79 |


UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Table 4.10: The comparison value of Normalized Table and Deviation Sequences Table. 80

Table 4. 11: The comparison of GRA and Pugh Decision Matrix for Natural Fibres. 84

Table 4.12: The comparison of GRA and Pugh Decision Matrix for Natural Fibres. 85

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## LIST OF FIGURES


| FIGURE | TITLE | PAGE |
|---|---|---|
| Figure 2.1: | Classification of natural and synthetic fibres (Gurunathan et al., 2015) | 9 |
| Figure 2.2: | The classification of natural fibre (Keya et al., 2019). | 10 |
| Figure 2.3: | Commercially major fiber sources (Rohit & Dixit, 2016). | 11 |
| Figure 2.4: | Advantages and disadvantages of thermoplastic resins (Gholampour & Ozbakkaloglu, 2020). | 16 |
| Figure 2.5: | Advantages and disadvantages of thermoset resins (Gholampour & Ozbakkaloglu, 2020). | 17 |
| Figure 2.6: | The mechanical properties of selected natural fibres and synthetic fibres. | 22 |
| Figure 2.7: | Natural fibre mechanical properties for composites applications (Keya et al., 2019). | 23 |
| Figure 2. 8: | Mechanical Properties of Natural Fiber Composites with Different Resin and Matrix Combinations (Mathur, 2021). | 24 |
| Figure 2.9: | The hierarchy framework in weighting customer requirements (Mastura et al., 2017). | 26 |
| Figure 2.10: | The properties table of agencies with parameters | 28 |
| Figure 2.11: | The properties table of agencies with score parameters | 28 |
| Figure 2.12: | The properties table of the agencies with weightage factor | 29 |
| Figure 2.13: | The decision matrix total score | 30 |
| Figure 2.14: | The qualitative measure of layout alternatives table | 32 |
| Figure 2.15: | The result of grey relational generating table | 33 |
| Figure 2.16: | The result of grey relational coefficient table | 33 |


UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 2.17: The result of grey relational analysis table 34

Figure 3.1: Flow Chart 47

Figure 3.2: Summary of design requirements of aggregate properties on Asphalt Mixture (Tahmoorian et al., 2017). 50

Figure 3.3: The properties table example of natural fibres 57

Figure 3.4: The value of normalized table for natural fibres 58

Figure 3.5: The deviation sequences table for example natural fibres 59

Figure 3.6: The grey relational coefficient table of natural fibres 60

Figure 4.1: Ranking Score for Natural Fibres from Pugh Decision Matrix 66

Figure 4.2: Ranking Score for Polymers from Pugh Decision Matrix 70

Figure 4. 3: Properties Table of Natural Fibres 71

Figure 4.4: The Normalized Table of Natural Fibres 72

Figure 4.5: The Deviation Sequences table of Natural Fibres 73

Figure 4.6: The Formula used to calculate the grey relational coefficient 75

Figure 4. 7: The grey relational coefficient table of natural fibres 75

Figure 4. 8:The value in grey relational coefficient convert to grey relational grade value. 76

Figure 4.9: The ranking score of the natural fibres 77

Figure 4.10: Properties Table of Polymers 77

Figure 4. 11: The Normalized Table of Polymers 78

Figure 4.12: The Deviation Sequences table of Polymers 80

Figure 4.13: The Formula used to calculate the grey relational coefficient 81

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 4.14: The grey relational coefficient table of Polymers 81

Figure 4.15: The value in grey relational coefficient convert to grey relational grade value 82

Figure 4.16: The ranking score of the Polymers 82

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاک
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| NFRPCS | - | Natural Fibre Reinforced Polymer Composites |
| GRA | - | Grey Relational Analysis |
| QFD | - | Quality Function Deployment |
| QFDE | - | Quality Environmental Function Deployment |
| VOC | - | Voice of Customers |
| VOE | - | Voice of Environment |
| ARB | - | Automotive Roll Bar |
| MCDM | - | Multi-criteria decision-making |
| MODM | - | Multi-objective decision-making |
| MCDA | - | Multi-criteria decision analysis |
| PVC | - | Polyvinyl Chloride |
| PP | - | Polypropylene |
| HDPE | - | High-Density Polyethylene |
| PS | - | Polystyrene |
| PET | - | Polyethylene Terephthalate |
| HMA | - | Hot-mix asphalt |
| MPa | - | Megapascal |
| GPa | - | Gigapascal |
| $Kg/m^3$ | - | Kilogram per meter cube |
| $kJ/m^2$ | - | KiloJoule per meter square |
| Rf | - | Rating factor |
| Wf | - | Weighted factor |
| Df | - | Decision Factor |
| % | - | Percentage |
| GRC | - | Grey Relational Coefficient |
| GRG | - | Grey Relational Grade |

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## LIST OF APPENDICES


| APPENDIX | TITLE | PAGE |
|---|---|---|
| APPENDIX A | Gantt Chart PSM 1 | 93 |
| APPENDIX B | Gantt Chart PSM 2 | 94 |


UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Potholes and road pavement are basically made from asphalt, which consist of hydrocarbons and can leak into the environment, polluting it. Every year, potholes cause damage to automobile wheels, tyres, and suspensions, as well as accidents that result in deaths and injuries. Potholes, in general, are bowl-shaped holes in the surface of asphalt road pavement and their presence will bring dangerous situation to users, drivers or riders (Han et al., 2019). Potholes are normally formed because of the heavy traffic loads by vehicles, terrible and unstable weather especially during rainy seasons or hot season in Malaysia. In an article news from Rojak Daily in January 2021, according to Universiti Putra Malaysia Department of Civil Engineering lecturer Prof Dr Ratnasamy Muniandy, there are some factors that causes potholes which are road design, material design and enviromental factors, moisture and unstable temperature. Potholes form when there are cracks on the roads, which, over time, will cause the road materials to damage. Other than that, water also the critical factor in forming potholes as it can absorb and diffuse into internal road pavement and the foundation of road can become soft hollow and apparently this is where the potholes and road damage can formed. Besides, low temperatures and water can decrease the quality of potholes repair and patching process of road pavement.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

So, a lot of time and a good quality repair are required to prevent the potholes from happening again. Most common problem of potholes are shoving, dishing, bleeding, edge disintegration, stripping and alligator cracking.

Pothole repairs remain a major maintenance item in the budgets of many highway agencies and the annual appearance of potholes each spring is a major public relations concern for these agencies. This is especially true when repairs are temporaries and the same areas are repaired over and over. Despite significant advances in pavement materials and pavement mechanics, pothole repair remains a relatively undeveloped area (Ghosh et al., 2018). There is clearly a need for long-lasting, low-cost materials and construction technologies for repairing potholes.

There are numerous reports and news stories in Malaysia about potholes. Repairing potholes entails filling the damaged area with an asphalt mixture. Even if the potholes have been repaired, the repair does not last long and they are easily damaged again. A few studies have been conducted on how to improve the performance of pothole repair, and Fu *et al.* (2017) state that combining natural fibre reinforced polymer composites (NFRPCs) with asphalt mixture can improve their performance.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## 1.2 Problem Statement

Natural Fibres and Polymers are the main focus in this case study which is to combined with asphalt mixture for patching potholes application based on mechanical and physical properties. NFRPCs is the composite that consist the mixture of natural fibre and polymer matrix. NFRPCs is important to study because when the design of NFRPCs combined with asphalt mixture indirectly can improve the mechanical performance of asphalt mixture. This can be proven by studies in Bhosale *et al.* (2019) article, they state that natural fibre availability, low cost, and ease of manufacturing have drawn researchers' attention to the possibility of combining natural fibre and polymer to improve mechanical properties and study the extent to which they satisfy the required specifications of good reinforced polymer composite for industrial and structural applications.

Eventhough, there are studies in this area, there are still several unanswered questions. Firstly, there is no investigation about the relationship between material selection criteria for natural fibre and polymer combined with asphalt based on design requirement by focusing on mechanical and physical properties. According to Milad, Ali and Yusoff, (2020) article, they have review a brief discussion of the asphalt mixtures modified with waste material, and the recycled materials used as a modifier in the asphalt mixture. So, there is research gap that needs to be studied which is material selection criteria for natural fibre and polymer that can use to combine with asphalt mixture based on mechanical and physical properties.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Secondly, the problem is most of the studies and research do not states the rank for best natural fibres and polymers that can be used in the asphalt mixture. Thus, further studies need to be done for material selection criteria. This can be done to determine and compare the ranking score by using decision making method analysis.

The focus on this case study are to study and determine the material selection criteria for natural fibres and polymers based on mechanical and physical properties and to give rank to the material selection by using two different methods which are Pugh Decision Matrix and Grey Relational Analysis (GRA). Then, to explain the comparison of result obtained from Pugh Decision Matrix and Grey Relational Analysis (GRA) for natural fibres and polymers to combine with asphalt mixture.

## 1.3 Research Objective

Specifically, the objectives are as follows:

1) To study and determine the material selection criteria for natural fibres and polymers based on mechanical and physical properties.
2) To explain and compare the result obtained from Pugh decision matrix and Grey Relational Analysis (GRA) for natural fibres and polymers.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## 1.4 Scope of Research

The scope of this research are as follows:

1) To study the mechanical and physical criteria of natural fibres and polymers that can satisfy the design requirement of asphalt mixture.
2) To determine a ranking score of selected natural fibres and polymers properties by using Pugh Decision Matrix and Grey Relational Analysis (GRA).
3) To explain and choose the best natural fibre and polymer to mix into the asphalt mixture based on their ranking score based on mechanical and physical properties.

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاک
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter contains the literature review of this study which relates to the scope of this study. The research also being conduct based on the journal, thesis, case study, technical document, books, reports and also electronic- media sources. Each source was chosen based on how well it suited with the scope of the study. All of these sources must be relevant to customer satisfaction and were chosen for their similarity with the scope of the study.

Natural Fibre Reinforced Polymer Composites (NFRPCs) are attracting many industries, academicians and researchers all around the world as their compatibility and utilization on the mixture of natural fibre and polymer matrix need a lot of studies, research and experiment (Mohammed et al., 2015). The objective of this article review is to study and determine the usage and application of natural fibre reinforced polymer composites (NFRPCs) as mixture in the asphalt for the potholes repair or road pavement and to study and determine the material selection criteria for natural fibres and polymers based on mechanical and physical properties.