

RGC Ref. No.: <u>UGC/FDS25/E04/16</u> (please insert ref. above)
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**RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR**

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

<p><u>Submission Deadlines:</u></p> <ol style="list-style-type: none"> 1. Auditor's report with unspent balance, if any: within six months of the approved project completion date. 2. Completion report: within 12 months of the approved project completion date.
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Part A: The Project and Investigator(s)

1. Project Title

Study of the performance of asphalt with high-volume plastic waste for highway
pavement in Hong Kong

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Wong Ho Fai, Simon/ Associate Professor	Department of Construction Technology and Engineering/ THEi
Co-Investigator(s)	Leung Lai Ming, Gordon/ Secretary-General	Hong Kong Road Research Laboratory
Others	Wong Wing Gun, Alan/ Chairman	Hong Kong Road Research Laboratory

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval <i>(must be quoted)</i>
Project Start Date	1 Jan 2017	N/A	N/A
Project Completion Date	31 December 2019	30 June 2020	16/8/2019 by Institution
Duration <i>(in month)</i>	36 months	42 months	16/8/2019 by Institution

Project Completion Date	30 June 2020	31 December 2020	14/7/2020 by RGC
Duration (<i>in month</i>)	42 months	48 months	14/7/2020 by RGC
Deadline for Submission of Completion Report	31 December 2020	31 December 2021	14/7/2020 by RGC

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. *To study the properties of blended binder composed of various percentages of plastic waste, particular for PP and PE plastic wastes*
2. *To compare the effectiveness of superpave method and other methods for mix design with plastic waste as road paving enhancement and/or modification materials.*
3. *To recommend a mix design for high-volume plastic waste modified binder as road paving materials.*
4. *To examine the recyclability potential of plastic modified asphaltic binder as subsequent road paving materials, and*
5. *To integrate the applied research and teaching by developing teaching materials in lectures, presentation in seminars and final year project.*

5.2 Revised objectives

Date of approval from the RGC: N/A

Reasons for the change:

- 1.
- 2.
3.

5.3 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

5.4 Summary of objectives addressed to date

Objectives <i>(as per 5.1/5.2 above)</i>	Addressed <i>(please tick)</i>	Percentage Achieved <i>(please estimate)</i>
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1. <i>To study the properties of blended binder composed of various percentages of plastic waste, particular for PP and PE plastic wastes</i>	✓	100%
2. <i>To compare the effectiveness of superpave method and other methods for mix design with plastic waste as road paving enhancement and/or modification materials.</i>	✓	100%
3. <i>To recommend a mix design for high-volume plastic waste modified binder as road paving materials.</i>	✓	100%
4. <i>To examine the recyclability potential of plastic modified asphaltic binder as subsequent road paving materials, and</i>	✓	100%
5. <i>To integrate the applied research and teaching by developing teaching materials in lectures, presentation in seminars and final year project.</i>	✓	100%

Research Outcome

6.1 Major findings and research outcome

(Maximum 1 page; please make reference to Part C where necessary)

Polymer modifiers are commonly supplemented to bitumen to enhance the stiffness and strength of the bitumen. However, it alters the rheological properties of the binder because of the non-polar nature of polymer particles. In this research study, different proportions of polypropylene (PP) and Polyethylene (PE) were added to virgin bitumen and the corresponding properties were verified. At the same time, different types of additive modifications were also applied to the polymer modified bitumen (PMB). The samples were prepared under high shear mixing. The bitumen was heated and polymer (either PP or PE) was added and mixed. Additives, e.g. waste engine oil, carbon black or phosphoric acid, were added. The study included samples with various percentage of polymer (up to 20% by weight of the bitumen) together with different percentage of additives (up to 5%).

In general, the increase of PP and PE content in PMB resulted in decrement of penetration and ductility but increment in softening point. Based on this particular experimental study, the optimum binder-PP-additive ratio, by considering the weather condition in Hong Kong (sub-tropical area), could be concluded as follows: 1.) 5% of PP with 3% of Phosphoric acid; 2.) 15% of PP with 3% of carbon black or 3.) PP to waste engine oil could be 5:1 (up to 15% of PP). The experimental results were summarized in conference papers listed in Part C of the completion report.

Polymer Modified Asphalt (PMA) is an improved asphalt which has a better performance in terms of fatigue and rutting resistance comparing to hot mix asphalt (HMA). There are two common methods to incorporate polymer to asphalt and they are dry mixing method and wet mixing method. Polymer in dry mixing is acting as filler and interface adhesive additive between aggregate and bitumen while those in wet mixing method were the modifier to the bitumen to enhance the mechanical properties of the bitumen. In this study, PMA with various percentage of PP and PE (up to 20%) were produced using both dry and wet mixing method. The objective is to investigate the fatigue life and rutting resistance of PP and PE modified asphalt and compare the effectiveness of mixing method. The fatigue and rutting resistance of PMA were determined by indirect fatigue test (IDFT) and Wheel Tracker Test, respectively.

In general, all PMA have improved performance in fatigue and rutting resistance. PP modified (either dry mixed or wet mixed) asphalts (PPMA) have similar fatigue resistance lifetime under different portions of the PP added. Nevertheless, the wet mixed PPMA have better performance than dry mixed ones. PE modified asphalts (PEMA) have similar trend in fatigue resistance but PEMA shows better performance than PPMA in both dry and wet mixed samples. For rutting resistance, both PEMA and PPMA shows better performance with increment in polymer content and wet mixed one is more effective. From this particular study, it is concluded that both PP and PE modified asphalts have improved mechanical properties and wet mixing method is recommended to be adopted. The experimental results were summarized in conference papers listed in Part C of the completion report.

In this study, the recyclability potential of PMA was also explored by using the wheel tracking test. The experimental results shown that all mixes had higher rutting resistance with increase of the percentage of replacement of recycled PMA.

6.2 Potential for further development of the research and the proposed course of action (Maximum half a page)

Upon completion of the research project, the following areas are proposed for further development.

1. Use of different coupling agents, e.g. lignin, to improve the mechanical properties PP and PE modified bitumen
2. Commercial plastic waste may contain different chemicals instead of pure polymer. The behavior of polymer modified bitumen with different chemical additives is unknown. The rheological, thermal and mechanical properties of bitumen modified by PP and PE with various chemicals are proposed to be investigated.
3. In most of the former studies, polymers were added separately to modify the mechanical properties bitumen. There is a new trend to have hybrid modification which incorporates two or more polymeric modifiers of different nature in order to take their complementary features to the modified bitumen. To investigate the effect of hybrid modification on rheological and mechanical properties of modified bitumen, different hybrid blend of polymer with various percentage may be included. Common polymer modifier e.g. crumb rubber, EVA and SBS can be included in the further study.

6. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

In Hong Kong, over 2,000 tons of plastic waste is generated every day. Management of plastic waste becomes challenging due to its slow degradation rate and high-volume occupation in landfill. Leaching of toxic additives from plastic wastes, e.g. plasticizer, to the environment would potentially lead to contamination of ground water and harmful to the ecosystem. Incomplete incineration of plastic wastes may create toxic emissions, e.g. sulfur dioxide, sulfide and dioxin. In view of the situation, Environmental Protection Department (EPD) promotes a sustainable waste management strategy for future development of Hong Kong, which emphasizes on 3Rs: Reduce, Reuse and Recycle. The overall aim of the research project is aligned with the Environment Policy of the Hong Kong Government which promotes the use of recycled plastic wastes in Hong Kong. The outcome of the proposed research would provide an effective and sustainable solution to incorporate the domestic plastic wastes to modify bitumen for pavement in Hong Kong. The proposed solution is not only saving cost by providing an enhanced source of construction materials but also reduces the occupation of landfills. The result of the research project could largely beneficial to the general community in Hong Kong.

Part C: Research Output**7. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project**

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) (denote the corresponding author with an asterisk*)	Title and Journal / Book (with the volume, pages and other necessary publishing details specified)	Submitted to RGC (indicate the year ending of the relevant progress report)	Attached to this Report (Yes or No)	Acknowledged the Support of RGC (Yes or No)	Accessible from the Institutional Repository (Yes or No)
Year of Publication	Year of Acceptance (For paper accepted but not yet published)	Under Review	Under Preparation (optional)						
			✓	Ho Fai Wong	An Experimental Study of Rheological and Mechanical Properties of PP Modified Bitumen	N/A	No	No	No
			✓	Ho Fai Wong	An Experimental Study of Rheological and Mechanical Properties of PE Modified Bitumen	N/A	No	No	No

8. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

(Please attach a copy of each conference abstract)

Month / Year / Place	Title	Conference Name	Submitted to RGC (indicate the year ending of the relevant progress report)	Attached to this Report (Yes or No)	Acknowledged the Support of RGC (Yes or No)	Accessible from the Institutional Repository (Yes or No)

Dec/2018/Hong Kong	Study on Improved Polypropylene Modified Bitumen by Incorporating Phosphoric Acid	23th international Conference of Hong Kong Society for Transportation Studies, Hong Kong	2020	No	Yes	Yes
Sep/2019 /Korea	Study of Behavior of Plastic Modified Bitumen by Incorporating Carbon Black	The 2019 World Congress on Advances in Nano, Bio, Robotics and Energy (ANBRE19)	2020	No	Yes	Yes
Sep/2021 /Korea	Laboratory performance comparison of the polypropylene (PP) modified bitumen with different additives	The 2021 World Congress on Advances in Nano, Bio, Robotics and Energy (ANBRE21)	No	Yes	Yes	Yes
Sep/2021 /Korea	Laboratory mechanical properties evaluation of the PP modified bituminous material and asphalt with different mixing method	The 2021 World Congress on Advances in Nano, Bio, Robotics and Energy (ANBRE21)	No	Yes	Yes	Yes

9. Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning

(Please elaborate)

The research experience has contributed to teaching and learning. During the project period, six final year students joined the study and the results were published in the international conferences. Students gained new knowledge by performing various experiments in laboratory. They also involved in paper drafting which is a valuable experience to prepare them in future research study.

10. Student(s) Trained

(Please attach a copy of the title page of the thesis)

Name	Degree Registered for	Date of Registration	Date of Thesis Submission / Graduation
██████████	██████████	██	██
██████████	██████████	██	██
██████████	██████████	██	██

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██████████	██████████	██	██
██████████	██████████	██	██

11. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

N/A

12. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
No. of outputs arising directly from this research project		4			Type	No.
					N/A	

13. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
N/A	