RGC Ref. No.:
UGC/FDS25/E14/17
(please insert ref. above)

RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

Submission Deadlines:	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.*

Part A: The Project and Investigator(s)

1. Project Title

Study on the use of high percentage reclaimed asphalt pavement materials in road

construction in Hong Kong

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

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	LUK Sung Hei / Lecturer	Civil Engineering/Faculty of Science and Technology/Technological and Higher Education Institute of Hong Kong
Co-Investigator(s)	Gordon Leung	N/A
Others	N/A	N/A

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval *(must be quoted)*
Project Start Date	01/01/2018	N/A	N/A
Project Completion Date	31/08/2020	N/A	N/A

Duration *(in month)*	32	N/A	N/A
Deadline for Submission of Completion Report	31/08/2021	N/A	N/A

Part B: The Final Report

5. **Project Objectives**

5.1 Objectives as per original application

1. To study the mechanical performances of bituminous mixtures with high percentages of RPA materials
2. To investigate how the age factor of the RAP materials, one of the most important factors in bituminous material science, affect the mechanical performances of the overall bituminous mixture.
3. To provide guidelines on the full utilization of RAP materials for road construction in Hong Kong by establishing design guidance notes and design charts.
4. To engage student helpers in the research study to provide hand-on experiences on the work and also to let them appreciate the values and implications of research findings for actual practices.
5. To organize seminars to share the research findings with students, researchers, government engineers and highway practitioners.
6. To provide new / updated information for teaching and learning, with the possible introduction of a selective course named "Pavement Engineering" in the near future.

5.2 Revised objectives

Date of approval from the RGC: N/A

Reasons for the change: N/A

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)

The key technical objectives of the project are to study the mechanical performances of bituminous materials with high percentage of RAP, to study the influences of the age of RAP on the performances of the bituminous materials, and to provide practical guidelines on the use of RAP materials in road construction. The project was transferred to the PI in 2019 Summer. However, due to the impacts of COVID-19, insufficient knowledge of the PI and lack of assistance of the CO-I, the project's objectives cannot be fully achieved. Due to the impacts of COVID-19, it was not safe to invite student helpers. On the other hand, some findings on structural safety and damage assessment were obtained by means of using computation simulation and fragility curve. The findings were presented in an international conference – *The 2019 World Congress on Advances in Structural Engineering and Mechanics* (ASEM19). Finally, the elective module "*Pavement Engineering*" could not be introduced due to lack of findings.

5.4   Summary of objectives addressed to date

Objectives *(as per 5.1/5.2 above)*	Addressed *(please tick)*	Percentage Achieved *(please estimate)*
1. To study the mechanical performances of bituminous mixtures with high percentages of RPA materials	√	5%
2. To investigate how the age factor of the RAP materials, one of the most important factors in bituminous material science, affect the mechanical performances of the overall bituminous mixture.	√	5%
3. To provide guidelines on the full utilization of RAP materials for road construction in Hong Kong by establishing design guidance notes and design charts.	×	0%
4. To engage student helpers in the research study to provide hand-on experiences on the work and also to let them appreciate the values and implications of research findings for actual practices.	×	0%
5. To organize seminars to share the research findings with students, researchers, government engineers and highway practitioners.	√	10%
6. . To provide new / updated information for teaching and learning, with the possible introduction of a selective course named "Pavement Engineering" in the near future.	×	0%

6. Research Outcome

6.1 Major findings and research outcome
(Maximum 1 page; please make reference to Part C where necessary)

The PI studies the vulnerability of buildings and structures by means of the application of fragility curve, which is a plot of damage probability of structures or materials versus different loading levels. The study found that low-rise and medium-rise buildings designed based on HK codes of practice were generally safe under normal levels of loading.

Beyond peak ground acceleration (PGA) of 0.15g, the probability of exceedance for damage level – immediate occupancy (IO) increased dramatically. This indicated that there was high possibility that damage of non-structural elements or building materials would take place at this level, yet the whole buildings remain safe. Beyond PGA of 0.30g, damage on structural elements or materials started to occur, resulting in deterioration in structural performance of the whole buildings. Beyond PGA of 0.50g, there was high possibility that damage of structural elements or materials exceeded the collapse prevention (CP) level, and thus collapse of buildings may occur in this case.

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

Fragility curves are normally constructed using the results obtained from extensive non-linear time-history analyses. This process is very time consuming and requires specific knowledge to set up the computer models and design parameters for the structures and loadings. Using data-driven approaches, such as machine learning, can be an alternative way to construct fragility curves. The advantages are to speed up the process for constructing the fragility curves and to avoid the need of highly specific skills for setting up the computer models. To achieve this goal, huge amount of data of fragility curves should be obtained in order to cover wide range of practical situations. This may require numerous computational simulations to get sufficient data at the beginning stage. Appropriate machine learning techniques, such as artificial neural network or deep learning method, shall be investigated to study their capability on this topic.

7. Layman's Summary
(Describe <u>in layman's language</u> the nature, significance and value of the research project, in no more than 200 words)

The project aimed to study the performance of bituminous materials with high percentages of RAP. Bituminous materials are commonly used as the pavement material for road and highway. It is important to select an appropriate pavement material to achieve safe and economic design and to meet adequate mechanical and environmental performance levels.

The level of safety of structures or materials can be assessed using the theory of probability and statistic. Fragility curve, which is a graphical representation of damage probabilities of structures or materials to a variety of loading levels, can be adopted to study the mechanical performance of materials. It was found that this technique is useful, efficient and practical for studying the behavior of structures and materials.

Part C: Research Output

8.   **Peer-Reviewed Journal Publication(s) Arising <u>Directly</u> 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)*						
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

9.   **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)*
09/2019/ Jeju, South Korea	Fragility curves for buildings in Hong Kong	The 2019 World Congress on Advances in Structural Engineering and Mechanics (ASEM19)	No	Yes	No	Yes

10.   **Whether Research Experience And New Knowledge Has Been Transferred / Has Contributed To Teaching And Learning**
   (Please elaborate)

   N/A

11. 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
N/A	N/A	N/A	N/A

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

N/A

13. 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	N/A	N/A	N/A	N/A	Type	No.
					N/A	

14. 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	N/A