Unconfined Compressive Strength of Chemical Stabilised Recycled Asphalt Pavement (RAP) and Crusher Run Mixture for Road Base Course Application

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Abstract. Due to depletion of natural resources and rising awareness of environmental preservation, the road construction practitioners are always seeking alternative materials and technology to make the industry more sustainable in pavement construction. This paper examines the chemical stabilisation of Recycled Asphalt Pavement (RAP) materials and Crusher Run (CR) mixtures with a proprietary chemical binder as a potential way forward. The materials were mixed in ratios of 0, 25, 50, and 75% RAP replacement of CR, with the chemical stabiliser added in dosages between 2-4% per dry weight of the materials. Compacted and cured for 7 days as per requirements of the local authority, the samples were then subjected to the Unconfined Compression Test where the strength UCS (qu7) was recorded. Triple samples were tested for each case to ensure reliability of the results obtained. It was found that with RAP substitution, the UCS is inversely proportionate to ratio RAP used in the mixture, while UCS is directly proportional to dosage chemical added. Besides, it is technically viable to partially replace CR with RAP during chemical stabilization for road base course application.

1. Introduction
Road transport network is a vital asset of a nation, promotes both social and economic activities. According to JKR Arahan Teknik 5-85 (Pindaan 2013), typical structural components of a major road consist of asphaltic concrete wearing course, binder course, bituminous mix road base, crushed aggregate or wet mix road base, sub-base and subgrade.

Typically, raw granular materials, such as granular soils or granite stones, are used to construct subgrade, sub-base or base course. In order to harvest raw materials, the natural environment is adversely affected and the process is costly [1]. Rocks are blasted to produce granite stones, and rivers are mined to produce sands. Natural environment is being destroyed while resources being harvested. Besides, haulage and disposal of these unsuitable in-situ materials are always a disturbance to the environment. Transportation to remove unsuitable materials consumes fuels, yet causes air pollution. With ever stringent environmental restriction, disposal of unsuitable materials becomes more and more difficult. Apart from environmental consideration, with increasing demand as urban development goes on, suitable gravel materials might not be available at reasonable monetary cost.

Chemical stabilization is a method involving mixing of soil with chemical binder. Through chemical reaction, strength and stiffness of soil can be improved, while soil permeability, compressibility, plasticity and swelling/shrinkage potential can be reduced, between soil and binder [2-5]. By adding appropriate chemicals, in-situ materials can be reutilised and strengthened to meet engineering requirements, thus reducing the demand and usage of raw materials. Apart from the
conventional road paving material crusher run (CR), recycled asphalt pavement (RAP), as a by-
product from milling of asphalt concrete process, is also selected as part of soil substrate to be studied,
to provide a greener option.

This study aims to verify technical feasibility to substitute CR with RAP, for road base application
with addition of chemical stabilization, as well as to establish correlation between CR-RAP mixing
ratio and chemical dosage, with resultant UCS.

2. Materials and Methods

2.1. Material

Three types of raw materials are required in this research. Crusher run and recycle asphalt pavement as
the soil substrate to be stabilized, and one polymer modified cementitious (PMC) chemical as the
chemical binder. The PMC used is a commercialized product, supplied by industrial collaborator from
Malaysia. The product has been applied in Malaysia road construction for more than five years. This
proprietary product consists of cementitious chemical, ionic chemical and polymeric fiber.

Crusher run and RAP were purchased from suppliers separately. In order to eliminate variables arise
among different batches of CR (variables could be grain size distribution and quality of granite) and
RAP (variables could be the condition of existing bitumen coating which depends on age of RAP and
grain size distribution), all CR and RAP to be used in this research were purchased at once, from
single source.

2.2. Laboratory Unconfined Compressive Test (UCT)

Unconfined Compressive Strength (UCS) is the measurement of material’s mechanical properties to
resist compressive deformation, carried out in unconfined condition. This is a direct gauge of
material’s strength, and commonly used as design guideline or judgement criteria. Upon over dried,
CR and RAP were mixed the PMC, and then moulded into UCS mould of 100mm inner diameter and
200 mm effective internal height, in accordance to BS 1924:1990 (Part 2). Compaction was done in
six equal layers, using either 2.5 kg rammer or 4.5 kg modified rammer, compacted in twenty five
blows for every layer. Upon hardening, the samples were de-moulded with care, cured in moisture
room before UCT.

Ratio of CR to RAP mixture was varied to study the effect of mixing ratio on UCS. The proposed
ratios were shown in table 1. Since it was predicted that UCS of 100% RAP samples would be
extremely low and unsuitable for road base application, UCT for 100% RAP was not included
in this study. The prediction was later on proven by extrapolation of the UCS vs CR ratio curve.

Table 1. Ratio of crusher run and RAP mixture.

| Sample Reference | CR Percentage (%) | RAP Percentage (%) |
|------------------|-------------------|--------------------|
| C100R0           | 100               | 0                  |
| C75R25           | 75                | 25                 |
| C50R50           | 50                | 50                 |
| C25R75           | 25                | 75                 |

Curing duration was kept constant at 7-day for all samples. Curing duration of 7-day was chosen as
the reference because it is always the standard curing duration specified in requirement of UCS during
commercial application. PMC dosage was set at 2%, 3% and 4%, to investigate correlation of strength
development against dosage.

3. Results and Discussions

Figure 1 shows relationship between UCS and PMC dosage. It was observed that UCS is direct
proportionate to PMC added, in linear model. By increasing dosage by double from 2% to 4%, UCS
attained in PMC-stabilized materials was increased by nearly 100% for all four CR-RAP ratios tested. From figure 2, it is apparent that the strength of PMC stabilised CR-RAP mixture increases with increasing percentage of CR component in the mixture, in a linear model. The highest UCS of C25R75 series was at 1MPa, with PMC dosage of 4%. By extrapolating the trend line, even with of PMC Dosage at 4%, UCS of 100% RAP is estimated to be 0.5MPa, which is below minimum requirement of 0.8MPa from Malaysian Public Works Department for application of road base course [4]. Therefore UCT for C0R100 series was omitted.

![Figure 1. UCS vs PMC dosage at 7-day curing.](image1)

![Figure 2. UCS vs Crusher Run Percentage at 7-day curing.](image2)

Referring to figure 2, at lower PMC dosage of 2%, increment of UCS with increasing CR ratio is less significant than higher dosage of 4%. Therefore it is more beneficial to apply high dosage at high CR ratio, in order to maximise the resultant compressive strength. Furthermore, the same UCS is achievable with various combination of PMC dosage and CR-RAP mixing ratio. If the UCS requirement is fixed, it is a trade-off to either use a higher PMC dosage with lower CR ratio, or lower PMC dosage with higher CR ratio.
Particle size distribution plays an important role in the strength, compaction, and permeability of the road base. Besides, it affects surface ratio, which is crucial for bonding and adhesion during chemical stabilization, hence the resulting strength of chemically treated materials. Sieve analysis was carried out for both the CR (C100R0) and RAP (C0R100) respectively. Figure 3 summarises results of the sieve analysis done, against sieve envelope required by Malaysia Public Works Department on road base materials, expressed as the lower and upper limits in the same plot. RAP, as a by-product from milling process of asphaltic concrete layer, consist more uniform grain size distribution, which leads to lower compactability as well as lower resultant compressive strength. On the other hand, grain size of CR is well-controlled during crushing process. Therefore, with addition of CR, overall grain size distribution of the mixture can be improved. Thus explained direct proportionate relationship between CR percentage and resultant compressive strength.

![Figure 3. Sieve Analysis for C0R100 and C100R0.](image)

### 4. Conclusions

Unconfined compressive strength is direct proportionate to dosage of the polymer modified cementitious chemical added, as well as crusher run ratio in the mixture. In engineering point of view, it is possible to partially-substitute crusher run with recycled asphalt pavement during PMC treatment, for road base course application. From this study, the correlation obtained among these parameters serves as a guideline to decide CR-RAP ratio and PMC dosage required, to achieve the desirable UCS.

### References

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