Dr Iswandaru Widyatmoko, BSc MSc PhD,
Senior Materials Engineer
Scott Wilson Pavement Engineering, UK

Richard Elliott, BSc BEd MPhil,
Associate,
Scott Wilson Pavement Engineering, UK

ASPHALT PAVEMENT RECYCLING FOR HONG KONG

Abstract

The Special Administrative Region of Hong Kong has an area of 400 sq miles and a population of 6.5 million. The road network extends to around 1900km. Historically, Hong Kong has used 100% virgin materials in its pavement asphalt, and Reclaimed Asphalt Pavement (RAP) from maintenance work has been used for land reclamation. However, restrictions on land fill and environmental and political pressure led the Hong Kong Highways Department to commission a research project to investigate the potential for the use of asphalt pavement recycling in Hong Kong. The results from this project, carried out between 2000 and 2002, are described in this paper.

Preliminary discussions held in Hong Kong, and a global literature search, revealed that Hot In Plant Recycling (HIPR) was the most appropriate process logistically for Hong Kong's densely populated environment, with its heavily trafficked urban/rural mix of bituminous pavements primarily in need of surfacing renewal. Once this had been agreed, preliminary guidelines were developed for the selection, design and construction of asphalt pavement recycling processes for use in Hong Kong, and a laboratory test programme was then carried out to demonstrate how mixtures containing RAP could be designed to produce mixtures whose performance was equivalent to that of 100% virgin mixtures. The laboratory assessment showed that it is possible to recycle up to 50% RAP in Hong Kong asphalt concrete mixtures, and the mechanical properties of the asphalt concrete wearing course (ACWC) and base course (ACBC) materials tested were broadly comparable to those of standard mixtures without RAP manufactured to the current Hong Kong Specification.

A preliminary catalogue of pavement designs was then prepared to provide a means for potential users to make use of the mechanical properties derived from the laboratory test programme, in order to carry out a flexible pavement design. Technically, HIPR was shown be a viable, cost-effective and environmentally friendly procedure for pavement rehabilitation and new construction. Full Scale Trials are planned for a site in Hong Kong in late 2002, followed by the development of a suitable specification for more general use. The project demonstrates how a region new to asphalt recycling is tackling the various economic, environmental, political and technical issues involved.

1.0 INTRODUCTION

Old asphalt pavement removed during most road resurfacing and reconstruction projects can be economically recycled into good quality asphalt materials while conserving aggregates and bitumen, eliminating disposal problems, reducing transportation requirements, and lowering fuel consumption. A range of cold and hot asphalt recycling processes, which include cold in plant, full depth cold in situ with emulsion or foamed bitumen, hot in situ surface, and hot in plant, are well developed and widely used around the world. With proper design and good quality control, recycled asphalt can be expected to perform as well as conventional materials.

The Special Administrative Region of Hong Kong has an area of 400 sq miles and a population of 6.5 million. The road network extends to around 1900km. Historically, Hong Kong has used 100% virgin materials in its pavement asphalt, and Reclaimed Asphalt Pavement (RAP) from maintenance work has been used for land reclamation. Figures provided for 1997 to 1999 indicate that 2-300,000 tonnes of asphalt materials are removed each year from road resurfacing and reconstruction works, and about 1 million tonnes of new asphalt materials are produced. However, restrictions on land fill and environmental and political pressure led the Hong Kong Highways Department (HKHyD) to commission a research project to investigate the potential for the use of asphalt pavement recycling in Hong Kong. The research, carried out between 2000-2002 by Scott Wilson Pavement Engineering, is described in this paper.

2.0 DESCRIPTION OF THE PROJECT

The investigation comprised the following main elements of work:

1) a literature review of overseas practices;
2) a facilitated discussion held in Hong Kong to canvas the views of all interested parties;
3) development of preliminary guidelines on the selection of appropriate processes, and design and construction, for recycled asphalt materials;
4) a laboratory assessment of the feasibility of utilising RAP in wearing course and base course at addition levels up to 50%, and;
5) development of a preliminary catalogue of designs, based on the mechanical properties derived from the laboratory test programme, to enable users to carry out a flexible pavement design.

3.0 LITERATURE REVIEW

3.1 Summary

A wide ranging review of overseas practices was carried out. Experience from different countries demonstrates that the hot in situ recycling (HISR) processes (Repave and Remix) and the hot in plant recycling (HIPR) process can be considered viable to renew or replace the distressed asphalt surface (wearing course), subject to the structural condition of the pavement. The plant mixed recycled material is relatively of superior quality. The performance of these processes has been compared with conventional wearing course replacement by constant monitoring of rut resistance, profile, texture, skidding resistance and visual condition of sites. The results showed that deterioration under traffic was similar for the recycled and conventional wearing courses. In fact, deterioration of the road surface was largely dependent on the condition of the underlying pavement, rather than whether the surfacing was new or recycled. The modulus and creep test results obtained from field testing indicated that when a recycling agent is used, the rejuvenating process may take place over a period of 3-6 months, followed by a hardening phase [1]. The long term result of the rejuvenation can only be measured and evaluated after the completion of the project.

Cold recycling using foamed bitumen is a proven technology and is potentially suitable for base and/or sub-base layers. The key benefits are its ease of application, environmentally friendly nature

and cost effectiveness. However, given the nature of Hong Kong's heavily trafficked urban/rural mix of bituminous pavements primarily in need of surfacing renewal, it was considered likely that the HIPR process may prove to be the most appropriate.

3.2 Appropriate Recycling Processes for Use in Hong Kong

Roads in Hong Kong are generally constructed over a stable foundation with a relatively sound subgrade. Complete reconstruction of roads is therefore likely to be more of an exception rather than the norm, and most of the maintenance operations are therefore restricted to the surfacing layers. This limits the potential for certain recycling processes such as cold in situ recycling (CISR). Further limitations include the fact that most of the urban roads (and some high speed roads) in Hong Kong are in close proximity to residential or commercial properties, and this, combined with the complex geometry and topography of Hong Kong's roads, restricts the potential for certain processes requiring the operation of large amounts of construction plant, such as HISR and CISR.

On this basis, only HIPR was considered suitable for use without restrictions for most situations in Hong Kong. The remaining recycling processes are restricted at present in their applicability for use in Hong Kong, primarily for operational reasons (HISR and CISR, because of the road space required for the plant) or for structural reasons (cold in plant recycling (CIPR), and CISR, because of uncertainty about the suitability of cold recycling processes in surfacing layers of heavily trafficked roads). Looking to the future, it is considered foreseeable that in situ recycling of certain expressway routes may be viable, particularly as confidence is gained in recycled asphalt material through the adoption of HIPR.

4.0 WORKSHOP IN HONG KONG

Preliminary interviews were held with key organisations and personnel in June 2000. Issues discussed included costs, government policy on road maintenance, planning and the environment, constructability, quality of asphalt materials reclaimed and produced, environmental concerns, available equipment and material sources. The need for each party in the supply chain to gain some benefit (from milling contractor to recycling operator` to material supplier to surfacing contractor) was emphasised, if more materials were to be recycled. Legislative issues were introduced, such as whether to tax the disposal of surfacing materials planed off the highway, or whether to encourage re-use by providing incentives. It was also recognised that there was a limit on the percentage of RAP that could be used in new surfacing materials, so it was unlikely that all the planed material (even if suitable and stockpiled in an appropriate way) could ever be fully re-used in highway maintenance. Therefore there was a need to consider the use of RAP in non-highway applications, as well as to improve the life of present surfacings so they do not need re-planing as frequently as at present. The various meetings and discussions culminated in a Workshop held in Hong Kong on 15 June 2000.

The principal outcome of the Workshop highlighted HIPR as the most appropriate method currently for re-using the RAP originating from planing the surface of highways. RAP was already being stockpiled and materials suppliers were either making enquiries overseas, or taking initial steps, to adapt their existing plant to take RAP.

It was considered that in situ recycling (HISR) would need the importation of expensive, specialised plant, which could not operate economically within the limited access constraints applicable to Hong Kong. (ie. Typically cold planing is only allowed from about 8-11pm due to noise restrictions, and highways must be operational the following morning, meaning that at most only 450m of two lane carriageway can be resurfaced in a night. However, whether these restrictions need always apply was questioned).

Furthermore, since most bituminous material placed in Hong Kong is in the higher quality surfacing layers (or hot mix roadbase for new construction) there is little market at present for cold mix material, whether in situ stabilised (CISR) or mixed in plant (CIPR). Three sub-groups then formed 'Breakout Sessions' to discuss specific topics, as summarised below.

4.1 Group A : Policy and Planning

Although concerns were expressed prior to the Workshop that land for a central storage facility would be difficult to find, the group realised that the amounts of RAP to be stored at any one time were in fact very small, since the material would be produced and consumed at a gradual rate. Some existing or new recycling facilities could stockpile the necessary amounts. The Environmental Protection Department would need to co-ordinate the storage of RAP, which should be kept separate from other construction materials if it was not to become contaminated and unsuitable for re-use.

Although it is not, at present, Government policy to tax material going to Public Filling Areas, incentives could be applied or a combination of the two (ie. "carrot" and "stick" approach). The specification or conditions of contract could insist that a certain percentage of RAP was used. RAP could even become the property of the Highways Department, and paid for, as long as delivered to an approved Storage or Recycling Facility. Whatever system is adopted needs to be policed, and consequently a system based on incentives is better than one based on penalties. (Note: Landfill Tax in the UK is £10/tonne for 'active' waste, which will increase to £15/tonne in 2004; inert waste is £2/tonne. These charges have already had an influence on re-use of construction materials).

Whatever contractual framework is set up to encourage recycling, the Highways Department needs a Particular Specification developed for materials and conditions in Hong Kong. (This was the main objective of the present research project). It was considered important to perform some small scale trials (of HIPR), on a non-critical site, to maintain the momentum of development and increase awareness of recycling opportunities.

4.2 Group B : Specification, Design and Compliance

This group recognised the need for suitable site investigation and material testing, combined with small plant trials, in order to assess whether the materials to be planed off would be suitable for re-use, and in which pavement layers. There was concern over the possible variability of RAP and the changes that might occur to binder if RAP is stockpiled. In order to develop a Particular Specification for Hong Kong, a number of different RAP samples would need to be investigated (and this was part of the present research project).

It was considered that it would be more difficult to recycle RAP in a Friction Course, due to the tight (and essentially single sized) grading requirements, even if the RAP was predominantly from Friction Course, since it would have become contaminated with fines (wind and water borne dust and products from vehicles, tyres, brakes and exhausts) when in service. Therefore perhaps only 10% of a new Friction Course might be RAP, whilst 20% might be possible in Wearing Course, and 30% or more might be possible in Basecourse. For larger percentages of RAP, binders (or rejuvenators) would be required that are not currently available in Hong Kong.

For maintenance works, a recipe based specification (but with some performance verification) would probably be the only practicable approach to utilising RAP. Use of a higher percentage of RAP could be justified for major works (new build), where the additional testing and trials required would be spread over a larger project, and the potential savings could be much greater. If such a project was of the "Design and Build" type, the contractor would take responsibility for the material design, and a Performance Specification (especially to try to assess long term ageing) would be required to help ensure that the Highways Department obtained a satisfactory outcome.

4.3 Group C : Minimising Excess Supply

This group emphasised the need for a co-ordinated approach by the various Government Departments concerned with recycling and site operations (Highways Department/Traffic Department/Environmental Protection Department).

It was considered that a cultural change was required if RAP was to be re-used (the General Specification at present would not allow use of RAP, but this is soon to be changed). Proposed changes to the Highways Department Specification for sub-base and roadbase to use recycled materials should encourage the use of RAP in the lower pavement layers.

It was recognised that more research was needed to look at the use of RAP in, for example, concrete; and methods need to be developed for extending the life of surfacings for the aggressive conditions in Hong Kong, so that planing and replacing on busy highways is no longer required every 3-5 years.

It was clear that a gradual process of information dissemination and consultation needed to be pursued, keeping all sections of the industry informed of the changes which would occur, and educating individuals with the technical reasons for the specification requirements. Finally, although recycling was considered to be equally suitable for new construction, the Workshop found that the choice of HIPR was largely a result of the environmental constraints imposed on maintenance operations on the highway, and the need to fully re-open highways to traffic each morning. It was questioned whether these factors need always predominate. It was recommended that a study was performed to identify whether alternative methods of working might be possible in the future, subject to the agreement of the Environmental Protection and Transport Departments.

5.0 PRELIMINARY GUIDELINES

Preliminary guidelines were developed for the selection of asphalt pavement recycling processes for use in Hong Kong and for design and construction with recycled asphalt materials. These guidelines were derived primarily from the processes used in the UK([2], [3], [4]), the USA ([5], [6]) and Australia ([7], [8]), and comprised three main elements:

1) Assessment of the suitability of reclaimed material
2) Mixture design
3) Construction

It was anticipated that these "preliminary guidelines" would be modified particularly as practical experience was gained in the use of recycled asphalt material in the field.

No special construction requirements were considered necessary for HIPR mixtures containing up to 50% RAP, and the recycled mixtures could therefore be mixed, transported, laid and compacted in a similar manner to 100% virgin mixtures. However, it was recognised that some modifications might be required in the mixing plant to handle the RAP, including granulation or crushing prior to mixing, and preheating for levels of RAP addition above 15-20%.

Recycled materials have to provide similar performance to conventional materials as well as demonstrating cost effectiveness, in order to be acceptable. It is essential therefore that the reclaimed materials to be recycled are consistent, as variable materials will cause difficulties with the control of quality and impede the efficiency of the recycling operation. The procedures laid down in the preliminary guidelines were designed to ensure that the assessment and design of mixtures containing RAP result in a final mixture which behaves similarly to a 100% virgin mixture. The laboratory testing programme described below demonstrated how this could be achieved in practice.

6.0 LABORATORY TESTING

A major part of this investigation involved a laboratory assessment of the feasibility of utilising RAP in Asphaltic Concrete Wearing Course (ACWC) and Base Course (ACBC).

The first part of the laboratory assessment involved classification tests on the source materials, including RAP and virgin materials sourced from Hong Kong. This work confirmed the suitability of the RAP for recycling in Hong Kong's aggressive conditions, and further work demonstrated that suitable blends of RAP and virgin binder and aggregate could produce an end product of satisfactory composition. The final stage of the assessment involved combining RAP and virgin materials, and manufacturing samples of recycled asphalt pavement in a laboratory roller compactor, from which specimens could be cored for mechanical testing.

The laboratory assessment of the recycled mixtures showed that it is possible to recycle up to 50% RAP in Hong Kong asphalt concrete mixtures, and the mechanical properties of the ACWC and ACBC materials tested were broadly comparable to those of standard mixtures without RAP manufactured to the current Hong Kong Specification. Major findings from the laboratory investigation were:

- although the properties of recovered RAP aggregate appeared to be similar to those of virgin aggregate, some increase in fineness was apparent in the former, particularly for aggregate greater than 2.36mm or less than 0.075mm (filler) in size;
- it was possible to rejuvenate binder with a penetration as low as 15 and a softening point as high as 70°C to one whose properties were comparable to those typically found for the straight-run, unaged, 60/70 penetration bitumen conventionally used for asphalt materials in Hong Kong;
- compared with conventional mixtures manufactured with virgin materials, the mixtures containing RAP tended to have slightly lower stiffness, slightly lower resistance to permanent deformation, and slightly improved fatigue resistance. All of these changes were believed to be a function of the rejuvenation afforded by the use of 80/100 pen virgin bitumen, with or without rejuvenating oil, to manufacture the recycled mixtures.

The tests carried out included empirical (penetration and softening point), cohesion and fundamental (rheological) tests on virgin and RAP binder, classification tests on virgin and RAP aggregate, and stiffness, deformation resistance, fatigue, durability and volumetric assessments on the recycled and virgin control mixtures. Space precludes a detailed review here; some typical data from the binder and mixture tests are shown in Figures 1 and 2 below. Figure 1 shows how the binders recovered from 2 RAP binders have been successfully rejuvenated by blending with 80/100 pen bitumen (with or without rejuvenating oil) to binders whose properties were comparable to those typically found for straight-run unaged 60/70 pen bitumen.

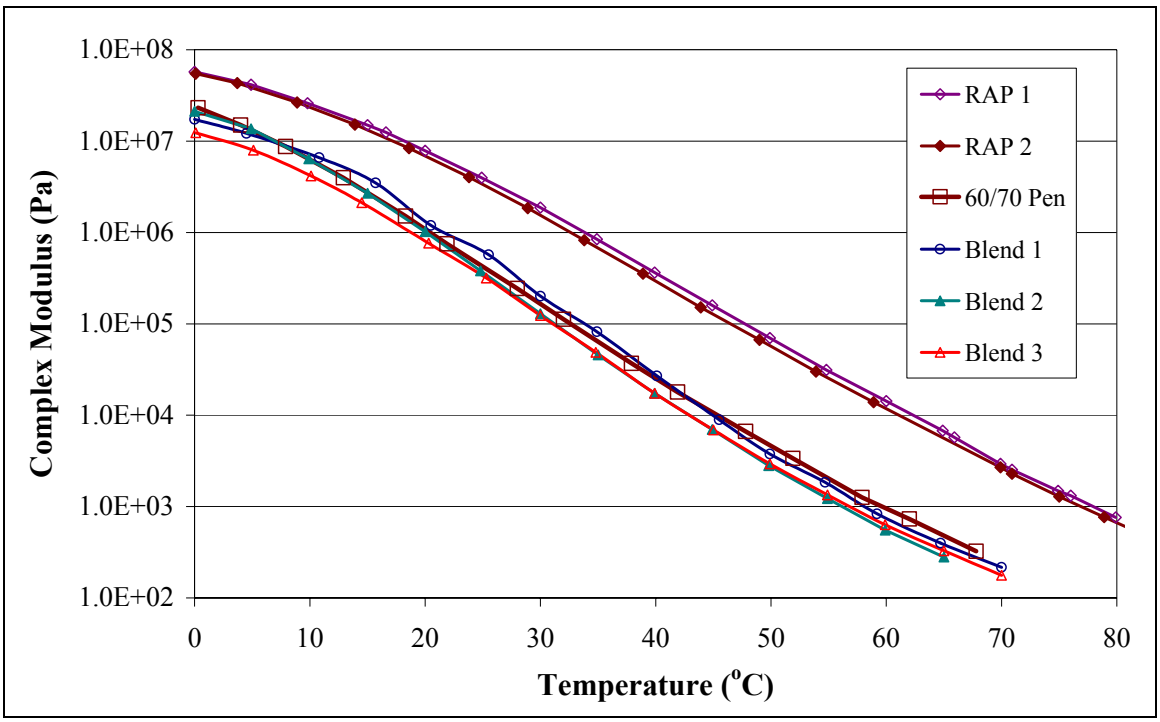

Figure 1 : Rheology of Recovered Binders before and after Rejuvenation

Notes: Blend 1 : 9% RAP 1 + 91% 80/100
Blend 2 : 31% RAP 2 + 67% 80/100 + 2% Rejuvenating Oil
Blend 3 : 50% RAP 2 + 42% 80/100 + 8% Rejuvenating Oil

Figure 2 shows the slight improvement in fatigue resistance - consistent with the slightly lower stiffness - found with increasing percentages of RAP addition.

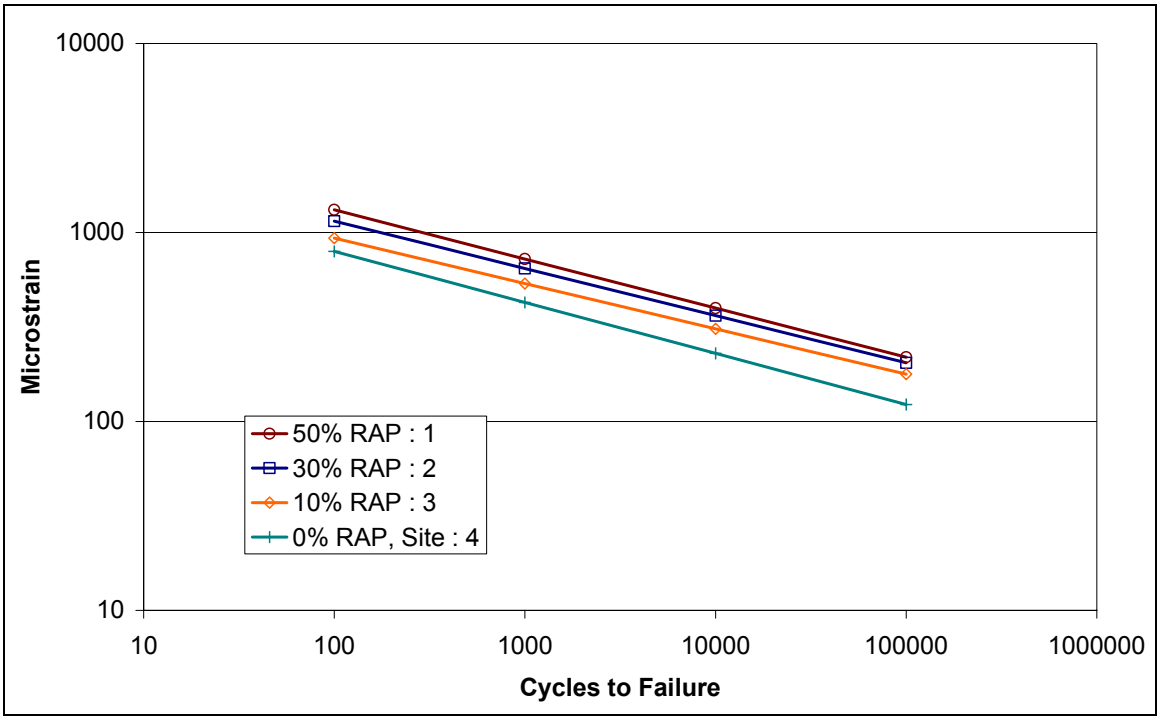

Figure 2 : Fatigue Resistance of ACWC with and without RAP

Note: All mixtures were laboratory prepared.

7.0 PRELIMINARY CATALOGUE OF DESIGNS

A preliminary catalogue of pavement designs was prepared to provide a means for potential users to make use of the mechanical properties derived from the laboratory test programme, in order to carry out a flexible pavement design. A total of 24 design charts were developed for various wearing course and base course conditions (with/without RAP) over standard roadbase and a standard foundation, but with eight different subgrade stiffness levels. In each design, the total bituminous thickness (wearing course, basecourse and roadbase) was plotted against the cumulative traffic in msa. A typical design chart is shown in Figure 3.

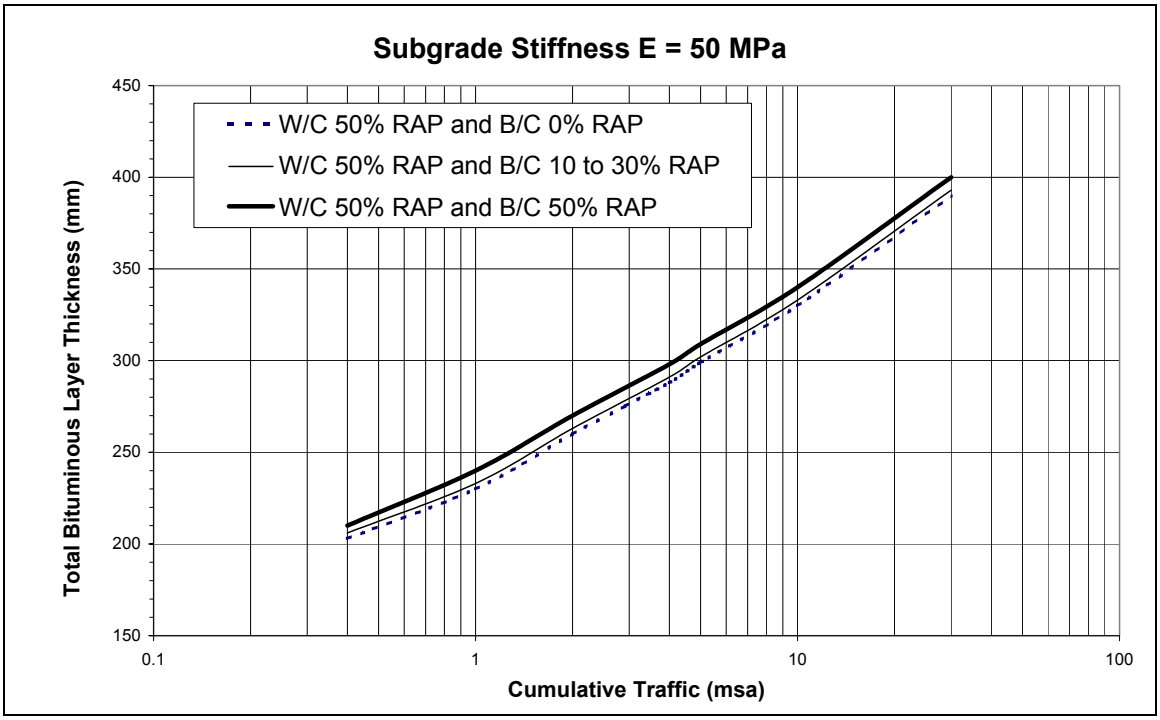

Figure 3 : Typical Design Chart

8.0 SUMMARY OF KEY FINDINGS

The literature review carried out for this preliminary investigation into asphalt pavement recycling for Hong Kong found that recycling of pavement materials was a viable, cost-effective and environmentally friendly procedure, both for pavement rehabilitation and for new construction. Hot In Plant Recycling (HIPR) was considered the most appropriate process for Hong Kong's densely populated environment, with its heavily trafficked urban/rural mix of bituminous pavements primarily in need of surfacing renewal.

The Workshop held with all interested parties in Hong Kong in June 2000 confirmed HIPR as the most appropriate method currently for re-using Reclaimed Asphalt Pavement (RAP) originating from planing the surface of highways. At the same time it was identified that a number of changes were required to facilitate the uptake of HIPR, including amendment of the General Specification, mandatory requirements for inclusion of RAP in asphalt mixtures, encouragement by Government of a co-ordinated approach within the supply chain, and by the use of incentives, and finally a gradual process of information dissemination and consultation within the industry.

In order to assist in the selection of asphalt pavement recycling processes for different conditions and purposes, preliminary guidelines were prepared for selection, and for design and construction with recycled asphalt materials. These preliminary guidelines were primarily concerned with

assessment of the suitability of reclaimed material, proportioning of RAP, and mixture design. The importance of the assessment stage to ensure that the reclaimed materials to be recycled were consistent was stressed, and the guidelines laid down were designed to ensure that the assessment and design of mixtures containing RAP resulted in a final mixture which behaved similarly to a 100% virgin mixture.

A detailed laboratory testing programme was then carried out to demonstrate how this could be achieved in practice. The laboratory assessment showed that it is possible to recycle up to 50% RAP in Hong Kong asphalt concrete mixtures, and the mechanical properties of the asphalt concrete wearing course (ACWC) and base course (ACBC) materials tested were broadly comparable to those of standard mixtures without RAP manufactured to the current Hong Kong Specification.

Finally, a preliminary catalogue of pavement designs was prepared to provide a means for potential users to make use of the mechanical properties derived from the laboratory test programme, in order to carry out a flexible pavement design.

The primary recommendation from the study was the immediate need for field trials of HIPR. Full Scale Trials are planned for a site in Hong Kong in late 2002, followed by the development of a suitable specification for more general use. The site in question includes both rehabilitation of existing construction and lane widening, so opportunities exist for the recycling of RAP in base binder and wearing course (new construction) and in binder and wearing course only (existing construction). Initial indications are that economic benefits will accrue to the Contractor from the re-use of material available on site; the Contractor has also already invested in asphalt plant modifications in anticipation of a more favourable 'climate' for recycling of asphalt in the future.

Hong Kong is a region of the world just starting with recycling of asphalt pavement materials. This paper has described how the various technical, environmental, political and economic issues have been raised with interested parties in the region and the progress that has been made is addressing them. It is anticipated that as asphalt recycling becomes more widespread, there will be long term benefits both to the local economy and environment.

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