HIGHWAYS DEPARTMENT

GUIDANCE NOTES

ON

PRESERVATION OF BITUMINOUS CARRIAGEWAY

Research & Development Division

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1. INTRODUCTION

This set of guidance notes is intended to serve as a comprehensive reference for staff in Highways Department (HyD) on the preservation of bituminous carriageway. Focus is placed on both technical aspects and practical considerations related to the planning, design and construction of the preservation works.

This set of guidance notes should be read in conjunction with other internal guidelines, including Maintenance Administration Handbook (MAH), Asset Management Manual (AMM), Guidance Notes and Technical Reports. Wherever these documents are quoted in this set of guidance notes, staff should refer to their latest version for the relevant details.

2. PRESERVATION STRATEGY

2.1 Backgrounds and objectives

Conventional pavement theory suggests that the repeated cycles of tensile and compressive strains caused by traffic loading will eventually lead to structural failure of a flexible pavement. The two failure modes are (i) fatigue cracking initiated from the base of asphalt layer and (ii) permanent deformation induced at the top of subgrade. A thicker pavement can reduce the level of strains at critical positions under traffic and thus last longer. Nevertheless, reconstruction was believed to be unavoidable when the pavement design life span is over or the pavement residual life determined by structural assessment methods approaches zero while repeated resurfacing could hardly maintain the pavement serviceability effectively.

From local experiences gained over the past decades, the cumulative damage in bituminous carriageway is however not that substantial in affecting the structural performance to an extent which cannot be effectively and sustainably maintained by regular resurfacing and/or deep inlay at a reasonable frequency. Overseas researchers and highways agencies also provoke the concept of long life pavements and its associated maintenance principle, which highlight that a pavement structure reaching a certain thickness threshold depending on the traffic loading, and built on a good quality foundation, would have a very low risk of structural failure. The concept advocates that such pavement can have its life prolonged indeterminately provided proper maintenance of the surfacing layers be carried out timely. Further, as the social impact caused by large scale full-depth reconstruction is always significant and beyond public tolerance, current worldwide trend is to put reconstruction as the very last resort and explore all possible means of rehabilitation to extend the pavement service life.

To review the suitability of incorporating and rationalizing the above ideas into the local preservation strategy of bituminous carriageway, the Research and Development Division commenced an in-house research study in 2010. The study included desktop literature review and analysis of historic data, maintenance practice and experience with due consideration of the overall maintenance pattern, pavement performance, life cycle cost and social impacts. Details are elaborated in a technical report RD/TR/057 issued in June 2011.

The study concluded that the long-life pavement concept is applicable for preserving existing bituminous carriageway under local environment. Every effort should be made to avoid large-scale full depth reconstruction works, which are highly disruptive and costly. Preservation by means of good quality and smaller scale rehabilitation works at a timely and sustainable manner, i.e. resurfacing of wearing course, deep inlay, and as the last resort, localized reconstruction and continuous monitoring, can effectively upkeep the safety and serviceability of the road network, protect the road foundation and extend the pavement service life.

2.2 Principles on network level monitoring, project level investigation and localized repairs

The main objective of network level monitoring is to ascertain the general trend of pavement service condition by means of systematic and periodic inspections and/or field testing in order to identify the needs and extent for pavement maintenance, rehabilitation and reconstruction as well as to provide reference data for longer term budget forecast.

Project level investigation is a process to identify the causes of premature or repeated failure so that specific treatment scheme can be tailored to preserve the deteriorated pavements in question. Some useful investigation methods are described in section 2.3.3.

Localized repairs refer to the corrective actions taken to rectify small area distresses causing imminent hazard or unsatisfactory level of service to the road users. Such distresses have a high potential to be rapidly deteriorated if unattended. Various types of localized repairs will be introduced in section 3.

2.3 Data collection and analysis

2.3.1 Defect notifications and complaints

Data collection through defect notifications and complaints are direct but passive means to note the up-to-date pavement defects on the carriageways which cause nuisance to road users. Appropriate and positive response action should be taken according to the nature and severity of the reported defects. In case the defects fall within the performance pledged items, they should be promptly addressed in accordance with the performance standard.

2.3.2 Routine inspections

Safety Inspections (SI) and Detailed Inspections (DI) are the two core elements in the existing inspection mechanisms to collect regular pavement condition data for the planning and implementation of road maintenance works. They are highlighted in chapter 5 of MAH with details given in the Road Inspection Manual (RIM, i.e. RD/GN/016).

Based on the DI results, the overall conditions of bituminous carriageway can be quantified using the Pavement Condition Index (PCI) to facilitate the maintenance works prioritization. The method and workflow of PCI calculation and the planning of maintenance works are detailed in the Pavement chapter of the AMM.

2.3.3 Project level investigation

In case of any premature or repeated distresses found, project-level investigation should be conducted to identify the root cause(s) of the problem by reviewing relevant site-specific engineering issues in order to devise appropriate treatment measures. The following aspects may be considered in the investigation:

(i) Signs of weak soil foundation and disintegrated bituminous roadbase, e.g. surface depression, pumping out of subgrade soil or early development of fatigue crocodile cracks and potholes;
(ii) Inappropriate use of pavement materials, e.g. instability rutting of surfacing layers under heavy axle load; and
(iii) Change in road usage leading to substantial increase of traffic loading.

The following paragraphs summarize some diagnostic methods which can assist in explaining the pavement deterioration mechanism and thus selecting a more durable maintenance option after a detailed project-level analysis. A combination of these methods may need to be applied to collect sufficient evidence in supporting such decision making.

(a) Works records

Critical review of previous maintenance treatment works records and associated compliance test results can identify any potential factors affecting the performance of surfacing layers. For carriageway sections experiencing rapid deterioration within a few years after any major rehabilitation treatment, it is likely that the concerned pavement structure is suffering from one of the above-mentioned aspects.

(b) Coring

Retrieval of pavement cores is a useful method to confirm the bound layers’ thicknesses against as-constructed records and to appreciate the physical conditions of individual layers. The respective layer thickness measured from the cores taken from lane center and wheel paths can indicate the source of deformations. Crack depth and its way of propagation can also be traced visually from the core holes.

It should be noted that the observations and findings obtained from coring tend to be on a conservative side as the core cutting operation is somehow destructive and would unavoidably disturb the in-situ material conditions, particularly when a pavement structure has already reached a marginally intact state.

Locations and sizes of the cores should be determined with reference to the surface distress pattern, Falling Weight Deflectometer (FWD) deflections and/or any particular type of laboratory tests going to be conducted.

For more detailed investigation or research study, core samples can be tested in laboratory to evaluate the physical and mechanical properties of individual bound layers in terms of gradation, void content, load spreading ability, resistance to fatigue and rutting, degree of binder ageing, etc.

(c) Inspection trench

Excavation of inspection trench with full-depth saw cut can clearly reveal the substratum conditions and is very useful in diagnosing the contribution of different pavement layers to the distresses under investigation. Considering its disruptive nature, inspection trench is normally not treated as a standard investigation tool.

(d) Dynamic cone penetration (DCP)

DCP is an efficient method to estimate the strength of unbound layers and is usually arranged in association with coring or trenching. A standard cone is hammered through the unbound pavement layers using a standard force by falling a weight at specific height. The shear strength or the California Bearing Ratio of the unbound material can be determined based on empirical correlations with the number of blows per unit of penetration.

DCP is worth to be conducted over locations with sign of weak foundation to collect necessary engineering data for the investigation and rehabilitation design. Sufficient care and precautionary measure should be taken over locations with underground utility installation.

3. CORRECTIVE REPAIRS FOR LOCALIZED DISTRESSES

The nature of maintenance works is broadly classified into four types under chapter 3 of the MAH. This section elaborates the corrective repairs for localized distresses on bituminous carriageway.

3.1 Pothole repairs

Under normal circumstances, potholes develop gradually from pavement surfaces which have been severely cracked and triggered by wheel loading action during rainy season. Presence of potholes adversely affects the riding quality and safety standard of a carriageway. To minimize its potential risk on road users, prompt action needs to be taken to repair the potholes. Either pre-packed instant hole filling material or plant-mixed hot bituminous material can be applied for urgent and temporary repair.

Under existing contractual arrangement, road maintenance term contractors have the obligation, as part of their role in managing and maintaining the road network, to carry out permanent reinstatement works for defective bituminous surfaces, including potholes, up to 2.5m$^{2.}$ The use of thermal patcher should be given a priority for such reinstatement works.

3.2 Repairs on localized disintegration

Vehicle braking or diesel attack causes gradual disintegration of bituminous surfacing over localized areas in form of raveling, whereas the general pavement condition over the entire road section can still be kept at a satisfactory level. Localized corrective repair by means of conventional square patching or thermal patcher should be arranged. Defective areas are to be regulated with hot bituminous materials to provide an even and smooth road surface and to stop the damage go further down to the underlying courses.

3.3 Repairs on localized depression, rutting and shoving

Uneven surfaces can be leveled up with temporary patching in order to restore the riding comfort to an acceptable standard. For areas with localized rutting and/or shoving, in particular those away from kerbsides, square patching or other appropriate measures should be carried out to remove the potential hazards to road users.

For locations with watermains burst or utility trenching works occurred in close proximity within a few weeks, the depression is likely caused by either insufficient compaction of the backfilling materials while performing reinstatement works or gradual loss of subgrade lateral support during road excavation. Liaison work with the concerned utility undertaker should be carried out promptly for the permanent rectification works.

In case no utility works near the depression spot was noted, such distress is probably caused by localized loss of unbound material in association with either water leakage or deteriorated drainage pipe. Relevant parties should be notified promptly for their further investigation and early rectification.

3.4 Repairs on subsided manhole covers and gratings

The RIM has specified that subsided manhole covers and gratings should be recorded in the DI and repair actions to be taken once their level difference with adjoining pavement exceeds an acceptable limit. The repair work is more desirable to be carried out in association with resurfacing works. However, if the overall pavement condition does not warrant any planned resurfacing works, the raising of subsided cover/grating should be separately arranged. The extent of repair, by means of thermal patcher or conventional square patching, should be orthogonal in shape with squared edges to include all the defective pavement materials around the subsided objects.

3.5 Crack repairs

Development of cracks within a bituminous pavement structure is a slow process and the existence of isolated cracks on pavement surface may not necessarily have an imminent impact on its level of service to the driving public. Filling up of surface cracks by means of hot bitumen or any other approved crack sealant helps to glue the aggregates adjoining the cracks together, and to stop water and foreign incompressibles from penetrating into and staying within the pavement sub layers. Crack filling can therefore reduce the deterioration rate of the overall pavement structure and extend its service life prior to receiving major rehabilitation works.

Although the site operation of crack repair is less disturbing than typical square patching or resurfacing works, similar extent of temporary lane closure arrangement is still required. Moreover, the appearance of crack filled pavement surface may induce some aesthetic concerns. Unlike the climatic condition in cool regions, Hong Kong rarely has frost action attacking the pavement structures. The benefits of crack repair are comparatively less significant. A balance should be struck among the works preparatory effort, associated social impact and potential gain in service life. Generally speaking, site conditions with either of the following characteristics may warrant the application of crack filling:

(a) isolated single cracks (photo 1) of surface width more than 5mm (above which the detrimental effect of water infiltration and incompressibles entering into the cracks is growing) over a pavement section with generally satisfactory condition and not planned for resurfacing within a few years, particularly on inclined roads or at localized ponding spots;
(b) all kinds of cracks over road sections with low traffic volume but with site constraints hindering implementation of large scale roadworks (photo 2); and
(c) reflective cracks on bituminous overlay surfacing generated from discontinuities in underlying concrete pavement or from bridge joints.

Photo 1 – Filling of wide single longitudinal cracks caused by the adjacent trench excavations

Photo 2 – Filling of interconnected cracks on a low-volume rural road

4. GENERAL PREVENTIVE AND REHABILITATION MEASURES

This section describes the functions and recommended areas of applications of various preventive and rehabilitation measures as well as best practices of these measures in preserving the bituminous carriageway.

4.1 Cold milling and resurfacing

Cold milling and resurfacing is the most common method locally applied in the preservation of bituminous carriageway. Such treatment process replaces the existing defective surfacing material and improves riding quality. As the treatment only limits to the top 40-50mm surfacing material, the effective structural gain is minimal. Depending on the road usage and the nature of deterioration, suitable type of surfacing material should be provided. The selection criteria will be elaborated in section 7.

Cold milling operation is performed by milling machine which carries a rotating drum with replaceable carbide bits. The machine cuts the bituminous materials to a preset depth and collect the broken materials to a dump truck automatically through a conveyor belt. Depending on the model and accessories of a milling machine, a milling operation can remove paving materials of some 0.5 m – 2.5m wide and up to 300 mm deep in one pass. Constrained by roadside kerbs and metal works, e.g. manhole and grating, cold milling machine cannot fully remove all the materials to the required depth in most of the local road sections. Some additional breaking works by handheld tools are required in order to break up the whole layer of defective materials.

4.2 Deep inlay

Deep inlay down to base course layer can further restore the overall pavement structural conditions by removing the disintegrated or cracked materials in the top and intermediate pavement bound layers so that the pavement service life can be extended effectively. The field operation is very similar to cold milling and resurfacing, except a longer duration of lane closure is required for laying and compaction of an additional layer.

4.3 Local strengthening

For road sections experiencing premature structural failure which could not be effectively preserved even by deep inlay, local strengthening or localized full depth reconstruction should be considered together with the findings obtained from project level investigation. In case localized full depth reconstruction is found to be the most suitable treatment option, the pavement thickness should be designed in accordance with RD/GN/017. Any soft spot in the subgrade identified during the local reconstruction works should be properly compacted or replaced by well-graded granular materials if considered necessary before construction of new pavement.

4.4 Hot-in-place resurfacing (HIR) by thermal patcher

HIR is an environmentally friendly treatment method for restoring defective bituminous pavement surface. It restores pavement serviceability by means of in-situ recycling or replacement of defective bituminous surfacing materials to correct surface distresses depending on the size of resurfacing area.

(a) Site operation

The site operation consists of the following steps:

In-situ recycling by thermal patcher for resurfacing area not exceeding 150m^2

(i) Depending on site factors, including road geometry, pavement conditions, weather, complexity of temporary traffic arrangement, etc., HIR by one set of thermal patcher currently used in Hong Kong, with heating power of not less than 12.6kW and heating panel(s) capable of heating up to a typical 3.3m wide x 5m long carriageway lane, can typically repair a pavement section of about 5 m lane length within 60 – 75 minutes, summing up to a treatment area of about 100 m^2 within an 8-hour lane closure duration, says from 2200 to 0600 hrs. The resurfacing area can be extended up to not exceeding 150m^2 if one more thermal patcher is deployed;

(ii) Safety checking and provision of fire safety precaution measures to any nearby gas installations;

(iii) Surface preparation to clean foreign materials;

(iv) Heating and softening of pavement surface to a depth of not less than 50mm;

Details: Surface temperature of the bituminous material needs to be regularly checked during the heating process to avoid excessive heating which will damage the asphaltic binder, cause burning of the bituminous pavement and create unfavourable smoke. The temperature at the pavement surface at any time during the heating process should not exceed 200 °C. Particular attention should be drawn to the intermittent heat and cool cycle from the infrared technology of the thermal patcher to allow the heat to gradually transfer downwards without burning of road surface. After the pavement is heated up, visual inspection is needed; any burnt bituminous materials on the surface, if noted, are to be removed by shovel and discarded immediately.

(v) Removal of thermoplastic road marking, instant filling material or burnt material, if any, during the heating process;

(vi) Scarification of the softened layer;

(vii) Application of bituminous emulsion;

Details: The bituminous emulsion should be applied at a rate of 0.4 kg/m^2 ± 0.05 kg/m^2 for road of the existing surfacing layer being in-service for less than 8 years; and at a rate of 0.6 kg/m2 ± 0.05 kg/m^2 for the existing road surfacing layer being in-service for over 8 years, or the pavement surface with an old outlook in the judgement of the Engineer.

(viii) Spreading of additional bituminous materials where necessary;

Details: For locations with highly aged surfacing, say in-service for over 8 years, topping up using higher binder content bituminous material, e.g. stone mastic asphalt (SMA) etc., could be considered subject to verification of the effectiveness and practicality of the material in site trials.

(ix) Compaction to finished level;

Details: To ensure good compaction, the minimum bituminous mixture temperature (except for polymer modified stone mastic asphalt (PMSMA) material) at the start of compaction shall be 110 °C; and the temperature of the pavement surface shall be higher than 85 °C right after the rolling. For PMSMA material, the minimum bituminous mixture temperature at the start of compaction shall be 140 °C; and the temperature of the pavement surface shall be higher than 115 °C right after the rolling.

(x) Testing of surface regularity; and

(xi) Extracting cores for verification of compacted layer thickness.

Replacement of defective bituminous surfacing materials by thermal patcher for resurfacing area exceeding 150m^2 but not exceeding 300m^2

(i) More than one set of thermal patcher should normally be used when the road and traffic conditions allow;

(ii) Safety checking and provision of fire safety precaution measures to any nearby gas installations;

(iii) Surface preparation to clean foreign materials;

(iv) Heating and softening of pavement surface to a depth of not less than 25mm;

Details: Similar as for resurfacing area not exceeding 150m^2.

(v) Removal of thermoplastic road marking, instant filling material or burnt material, if any, during the heating process;

(vi) Removal of the softened layer by hand shovel or by milling machine);

(vii) Application of bituminous emulsion (and tack coat, if necessary);

Details: The bituminous emulsion should be applied at a rate of 0.4 kg/m^2 ± 0.05 kg/m^2 for road of the existing surfacing layer being in-service for less than 8 years; and at a rate of 0.6 kg/m2 ± 0.05 kg/m^2 for the existing road surfacing layer being in-service for over 8 years, or the pavement surface with an old outlook in the judgement of the Engineer. If new bituminous material is laid within 30 minutes after the softened bituminous road surface is removed and laid when the pavement surface temperature is at least above 60°C, application of tack coat shall not be required unless instructed by the Engineer. In any other situation, application of tack coat shall be required.

(viii) Laying of new bituminous material;

Details: For locations with highly aged surfacing, say in-service for over 8 years, topping up using PMSMA could be considered for improving the crack resistance performance subject to verification of the effectiveness and practicality of the material in site trials.

(ix) Compaction to finished level;

Details: Similar as for resurfacing area not exceeding 150m^2.

(x) Testing of surface regularity and testing of texture depth for surfacing material of polymer modified stone mastic asphalt; and

(xi) Extracting cores for verification of compacted layer thickness and verification of air voids content.

(b) Advantage

Compared with other rehabilitation methods, HIR by thermal patcher has the following advantages:

(i) As cold milling and breaking operations in traditional resurfacing are no longer required, it would generate lower construction noise. Resurfacing using thermal patcher is best for correcting road pavement surface distresses near/at noise sensitive urban areas with stringent noise restriction (such as locations near to residential areas where excessive noise due to construction work is prohibited);

(ii) HIR by thermal patcher can prevent/reduce the large aggregates in the existing pavement from degradation due to broken surface induced during the breaking operations in the traditional method; and

(iii) Due to the small size and the maneuverability of the HIR by thermal patcher, the use of this maintenance method occupies relatively less road space, that makes it a suitable candidate for repairing locations with limited road space (such as narrow roads) and with little traffic interference tolerance (such as road junctions), or repairing localized defects across all lanes.

For resurfacing area not exceeding $150m^2$,

(iv) It does not need great amount of transportation of bituminous pavement materials from or to the asphalt production plant, resulting in less traffic disruption and less carbon emission. And it does not require any modification of asphaltic mixture production facilities and additional stockpiling area for reclaimed materials;

(v) Since the temperature at the pavement surface at any time during the softening process is kept below 200 °C, the bituminous material at the surface shall not be overheated. Hot-in-place resurfacing by thermal patcher not only largely reduces the demand on raw materials but also minimizes the amount of construction waste; and

(vi) Hot-in-place resurfacing by thermal patcher can produce enhanced bonding with adjacent surfaces preventing water infiltration into the pavement through joints. Due to the use of in-situ recycling, shear strength near the surface zone can be improved by the thermal bonding of surfacing material with the immediate support layer.

For resurfacing area exceeding $150m^2$ but not exceeding $300m^2$,

(vii) With two sets of thermal patcher deployed, area exceeding $150m^2$ but not exceeding $300m^2$ can also be repaired at limited road space, lower construction noise and little traffic interference.

(c) Application

With the above advantages, particularly its environmental friendliness in quietness, but higher unit construction cost, HIR should be deployed on busy road sections close to noise sensitive areas along which temporary lane closure for works is only allowed on public holidays or at night. HIR can also be used for upgrading cycle path.

However, in view of the high temperature generated by the thermal patcher, HIR cannot be used for roads near to petrol stations or vegetation/trees. Gas leakage detection should be carried out for any nearby gas installations. Temporary protective measures, such as the use of fire resisting blanket as heat shield, should be laid over the gas installations. HIR is also not applicable to road sections with porous asphalt surfacing or bituminous overlay on concrete pavement.

Pavement area treated by thermal patcher should cover all the major cracks as far as practicable without leaving the repair boundaries running across major cracks. HIR is not effective for pavements with premature shoving/rutting distresses, or defects arising from the lower layers or within bituminous sub-layers. For such areas, HIR can provide a temporary treatment to the surface layer and allow time for scheduling a major maintenance work.

4.5 Other measures adopted worldwide

Apart from the measures mentioned in the above paragraphs, there are some other treatment methods commonly applied overseas to preserve bituminous carriageway. They are briefly introduced in the following paragraphs though with their limitations for local application envisaged.

(a) Fog seals

Fog seals involve a light application of a slow setting emulsion to an aged pavement surface with or without fine cracks. This method is low-cost and able to postpone the need for a more substantial type of surface treatment for 1 – 2 years over low-volume roads. However, for the generally high-volume traffic condition in Hong Kong, such effect is considered minimal and not cost-effective.

(b) Chip seals

Chip seals involve a thin layer of aggregates stuck to an existing bituminous surface by bitumen emulsion and rolling compaction. The laying process can be repeated to give a multi-layered seal coat behaving as a waterproofing cover and also a light protection for the existing surface against traffic abrasion. While cheaper than normal resurfacing, its riding quality is inferior to a properly compacted new bituminous layer. Moreover, the thin layer of aggregates has a high potential to be loosen and then freely be picked by vehicle wheels to cause nuisance and damage to other road users.

(c) *Rejuvenators*

Aged asphalt near the top 2 to 3 cm of the pavement surface can be rejuvenated by applying certain proprietary rejuvenators to delay the need for surface treatment. Overseas applications are mostly on low traffic and low speed roads. Previous local site trials of some products revealed that the resulting low skid resistance led to a safety concern hindering their applications in Hong Kong.

(d) *Slurry seals*

A slurry seal is a blended mix of properly proportioned fine aggregates, mineral filler, asphalt emulsion and water. Tailor-made truck mounted mixers are used to deliver and continuously blend the ingredients until the slurry is spread on site to give a smooth and thin layer. The layer thickness is roughly equal to the maximum aggregate size ranging from about 2mm to 8mm. Slurry seals can be used for filling surface cracks, improving riding quality by leveling spots with local subsidence or severe raveling. Considering the high social cost of road closure and the marginal benefit expected to be brought to the generally high volume local roads, slurry seals seem not to be a cost-effective measure in Hong Kong.

(e) *Micro-surfacing*

Micro-surfacing, with the whole idea similar to slurry seal, contains coarser aggregates which gives the layer thickness ranging from about 10mm to 20mm. The limitations for local use of slurry seal mentioned above are also applied to micro-surfacing. Furthermore, the additional overlay thickness is a concern in most of the city roads with roadside kerb height requirement.

The above techniques are well-developed overseas with their respective functions and advantages in preserving bituminous carriageway. However, their cost effectiveness for applications in Hong Kong is considered to be relatively low, with particular reference to the high social cost of road closure and heavy axle loads over our highly urbanized road network as well as the associated specialist contractors and equipment not currently available in the local construction industry.

4.6 Best practices

Resurfacing and deep inlay are the most commonly adopted rehabilitation measures for bituminous pavements. Their construction and compliance test requirements can be found in relevant technical specifications. This section supplements with some best practices by which a more durable end product could be attained.

(a) Weather considerations

While planning a critical resurfacing project, it is advisable to attempt scheduling the works away from the period with extreme weather conditions, e.g. not to carry out resurfacing works over rutting black spots in the mid summer to reduce the chance of material instability due to high temperature.

(b) Temperature

Laying and compaction of hot bituminous mixtures have critical effect on the durability and structural performance of the final product. Depending on the material types, such processes have to be carried out within certain temperature ranges in order to ensure its workability and thus the final degree of compaction. Random checking of bituminous material temperatures should be conducted at various works stages in accordance with the specifications.

(c) Tack coat

Proper application of asphalt emulsion as tack coat is essential to promoting a good layer bonding and precluding water from going into the interfaces of bound layers through cracks and joints. Sufficient dosage of asphalt emulsion over the vertical joints with utility covers, roadside concrete kerbs and adjacent dense-graded materials are needed for the same purpose. As stipulated in the existing specifications, tack coat application rate should be within the range from 0.4 to 0.6 l/m^2. This dosage is applicable to both bituminous and concrete surfaces. While carrying out deep inlay in which two or more fresh layers of bituminous materials are laid within a few hours, no tack coat is required to be applied at the interface of two freshly laid mats. Proper control needs to be stepped up to ensure the cleanliness of substrate and prevent it from contamination by detritus.

While spraying tack coat under typical resurfacing works within a temporary lane closure, it is a good practice to hold a board alongside the edges of the milled area to prevent the emulsion from over-spraying onto pedestrians or vehicles running close to the works site. However, attention should be paid not to block the vertical joints from receiving tack coat.

The quantity of tack coat should not be excessive; otherwise it would behave as a lubricating film rather than an adhesive agent, especially under hot weather.

While resurfacing porous asphalt layer, tack coat should not be sprayed on the vertical exposed surfaces of porous layer or the drainage path may be blocked.

(d) Coring positions and joint formation

Taking core specimens for determination of air void is part of the quality control in normal bituminous paving works (except for friction course). Such operation is, to some extent, a destructive process affecting the overall integrity of the pavement structure. To strike a balance between the requirements on quality control and the detrimental effect on durability, it is advisable to select the coring position away from the stress-concentrated area. In other words, coring on wheel path or within accelerating / braking zone, like road junction and roundabout, are to be avoided as far as possible.

Similarly, joints are also weak zones prone to surface deterioration. Under large scale resurfacing works, the longitudinal joints should be formed either along the edge or the center of a traffic lane. Localized square patching works would be carried out based on the actual extent of distresses. Consideration should be given not to locate edges of a patch area on the wheel path zone.

(e) Preparation of milled surface

The milled surface should be properly cleaned and free from loose material to form a good bonding of the newly laid materials with the underlying pavement. As far as practicable, localized disintegrated materials found in-situ after milling should be removed till an intact layer is reached and regulated by new hot bituminous material.

(f) Records of disintegrated sublayer

Cold milling operation provides the best opportunity to inspect the overall physical condition of the exposed sub layer. In case the approved lane closure duration for a particular resurfacing works does not allow all the weak or disintegrated substrata materials (like those illustrated on photo 3 and photo 4) be properly made good within the same operation as suggested in the above paragraph, proper records of the weak spots, including substrata with sign of water seepage found, should be kept as part of the as-built information to facilitate future works planning and project-level diagnosis.

Photo 3 – Disintegrated base layer materials exposed after cold milling

Photo 4 – Disintegrated base layer materials exposed after cold milling

5. PRESERVATION OF ANTI-SKID DRESSING ON BITUMINOUS CARRIAGEWAY

A thin epoxy based anti-skid dressing material laid on SMA material is currently the standard surface treatment on bituminous carriageway for improving the skid resistance of local roads. Calcined bauxite aggregates, with high wear resistance and hardness, are used as the dressing material. Both the macrotexture and microtexture of the thin aggregate layer contribute to an improved skid resistance of a road surface. Localized aggregate loss or superficial stripping would not affect the overall skidding performance until the entire thickness of the anti-skid surface is worn out with the underlying pavement exposed. Years of local experience and trials have confirmed that the durability and cost effectiveness of epoxy based anti-skid dressing are better than many other anti-skid systems.

In accordance with the requirements stipulated in the RIM, "anti-skid surface worn" is a defect to be recorded in detailed road inspection so as to regularly monitor the condition of anti-skid surfaces over the road network.

The following key points should be noted regarding the preservation works on anti-skid dressing. More details can be obtained from RD/TR/045.

(a) Anti-skid materials should be applied on a strong enough substrate. Structural condition of the underlying pavement should be checked and made good before applying anti-skid dressing;
(b) For road sections requiring a new layer of SMA material, about four weeks should be allowed for the bituminous materials to bed down before applying anti-skid dressing;
(c) Careful surface preparation is vital to the durability of the dressing layer. The condition of receiving surface needs to be dry, free from dust, oil, excess bitumen or other contaminant so as to achieve a better adhesion;
(d) For anti-skid treated pavements suffered from rutting or slippage cracks, consideration should be given to replace the defective bituminous layer by polymer modified SMA so that a stronger layer can be provided for receiving the new anti-skid dressing;
(e) Fast curing epoxy products should be used only when limited time is available for curing; and
(f) Localized re-laying of anti-skid materials by regular patches should be considered if the defective areas are only concentrated on some local spots.

6. PRESERVATION OF LOW NOISE ROAD SURFACING (LNRS) ON NON-HIGH SPEED ROADS

Retrofitting existing local roads with LNRS is one of the engineering solutions implemented since 2002 to reduce the road traffic noise. As stipulated in RD/GN/011, all LNRS on local roads should be laid using PMFC with specific construction details depending on the construction type of the existing pavement.

With its nature of high porosity and lower strength, ravelling is the predominant type of distress and rapid development to potholes is also noticed over pavement sections subjected to frequent turning and braking forces. Repair of localized distresses on LNRS using dense grade material, i.e. ordinary wearing course material, is acceptable although it would have localized effect on the original drainage path within the porous surfacing.

While planning for resurfacing works for an existing LNRS, the past performance of PMFC over a particular road section should be checked. If there is any evidence of premature distress over the PMFC occurred in less than 5 years after laying, a stronger and more durable surfacing material, e.g. wearing course or stone mastic asphalt, should be selected instead. Once the existing PMFC of a traffic lane is replaced by a non-porous material, the drainage path within the porous surfacing of the adjoining traffic lanes should be reviewed to make sure its proper functioning according to the cross fall of the carriageway.

7. FORMULATION OF REHABILITATION SCHEMES

In the Pavement chapter of the AMM, the criteria and approach in identifying and prioritizing the items of pavement maintenance and rehabilitation works have been provided. This section lays down further technical considerations to be taken while formulating the details of individual rehabilitation schemes for bituminous carriageway.

7.1 General Considerations

(a) Extent and severity of distresses

The Catalogue of Road Defects (RD/GN/015) provides pavement maintenance personnel with a practical reference in defect descriptions, their possible causes and remedial actions. In real situations, various types of defects can appear within a certain stretch of pavement. Judgment should be made to identify the predominant defect in order to select the most appropriate remedial treatment for a particular road section. Sections with severe and deep structural distresses should be rehabilitated in a proper manner to avoid the occurrence of premature distresses. More guidance will be described in the following paragraphs.

(b) Maintenance records

Maintenance records contain the dates and details of previous treatments, which can provide a reliable indicator on the durability of the previous treatments over a specific road section. In case premature failure is noted, technical project level investigation should be carried out to identify the root causes in order to design appropriate rehabilitation works.

(c) Traffic impacts

Implementation of a rehabilitation scheme would unavoidably induce inconvenience to road users by temporary occupation of a road section. In practice, the permitted period of lane closure, after considering the potential traffic impact, often governs the technical construction details and limits the scope of rehabilitation works.

For cases when substantial rehabilitation works, say deep inlay, is considered necessary to bring a road section back to a more structurally sound and durable condition, a more sophisticated temporary traffic arrangement scheme has to be formulated. This requires a longer planning lead time in order to agree on a feasible traffic diversion scheme among relevant authorities and stakeholders.

(d) Noise impacts

Under typical resurfacing or deep inlay works, the noisiest operation would be the mechanical breaking and removal of the old pavement materials near roadside kerbs or around metal works where the operation of milling machine is restrained. Arrangement should be made to schedule such noisy operations away from the restricted hours under the Noise Control Ordinance where possible in order to minimize the associated noise impacts. It is also a good practice to well publicize the duration of noisy operation to the nearby residents to avoid complaints. On the other hand, the deployment of quieter construction plants, e.g. thermal patcher, can be considered as alternatives.

7.2 Inlay thickness

Bituminous pavement is by nature a multi-layered construction. Under normal circumstances, the upper layers, including the wearing course and sometimes the base course, experience a higher degree of deterioration during their service lives than the underlying road base. This is due to the combined effect of bottom-up fatigue failure mechanism, direct wheel load induced stresses as well as environmental attack on the upper layers. While implementing a rehabilitation scheme, it is desirable to have the defective layer(s) removed and replaced by suitable new materials so as to better restore its structural strength and durability rather than just to improve its short-term serviceability. A new surfacing layer paved on a generally disintegrated base course is prone to be less durable. Such an “isolated” layer might not perform as a fully bonded flexible pavement structure but behave as if a thin bituminous surfacing layer laid on granular base in which reflective cracks and fatigue failure are expected to develop rapidly.

Some performance-based criteria are provided in the flow chart (Fig. 1) as general guidelines for the determination of inlay thickness taking into consideration the defect types/severity and maintenance history. Moreover, some pavement surface conditions over which deep inlay should be considered are described in the following paragraphs.

For any road section exhibiting severe surface distresses (e.g. extensive crocodile cracks and closely spaced patched potholes) (photo 5) for a long duration, the condition of its base course is likely at a certain degree of deterioration. Localized deep inlay should be considered.

For some existing bituminous carriageway designed and built before 1980s, lean concrete rather than bituminous material was used in the roadbase to form a composite structure. On local distributors, the bituminous surfacing thickness ranges from 50-130mm with around 200mm thick lean concrete roadbase. When sign of pumping is noticed over this type of semi-rigid pavements, it becomes an indicator showing a certain extent of deterioration at the base course (photo 6). Pumping describes the upward movement of unbound material underneath a pavement surface through its surface discontinuities, either joints or cracks, as a result of water pressure.

Photo 5 – severe surface distress requiring deep inlay

Photo 6 – sign of pumping from lean concrete base

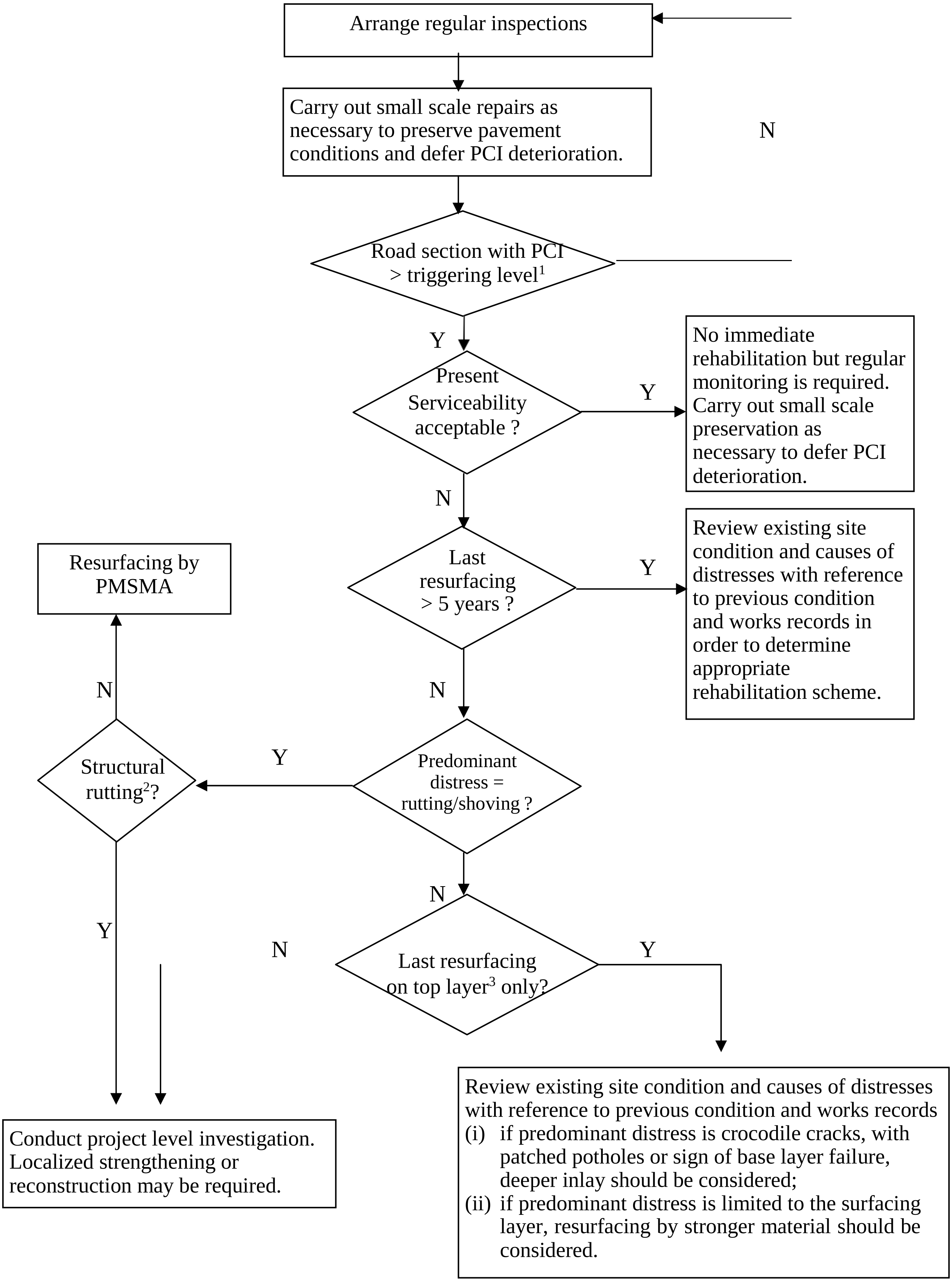

Fig. 1 – Guideline on preservation and rehabilitation of bituminous carriageway

Remarks on Fig. 1

1 Refer to the Pavement section of the AAM.

2 Based on local experience, premature rutting/shoving problems are mostly caused by high temperature instability of surfacing material (RD/TR/053 refers) and can be effectively dealt with by PMSMA. However, rutting can also be resulted from structural deficiency of underneath bound layers or subgrade foundation in which the wheel path deformations mainly go downward with no obvious bulges as that in instability rutting. Detailed investigation shall be conducted to identify the causes.

3 For road sections with porous friction course as the surfacing material, the top layer denotes both the friction course and its underlying cushion course or wearing course.

7.3 Material selection

Different pavement layers play their respective roles in order to achieve the overall purpose of a road pavement in an effective and economical manner. Among the bituminous layers, the function of base course and roadbase is mainly for load spreading, whereas that of wearing course is more complicated. The selection of surfacing materials thus warrants more attention as they are subjected to the highest traffic induced stresses, directly exposed to the environment and have more impacts on the overall pavement quality and serviceability. The selection criteria include:

(a) Resistance to weathering ;
(b) Resistance to rutting and cracking;
(c) Skid resistance;
(d) Tyre-surface induced noise; and
(e) Permeability.

However, no single bituminous mixture can completely fulfill all performance requirements in the above aspects. A range of bituminous mixtures, with variations in the aggregate gradation, binder and additive content and property, is therefore developed to achieve certain functionality with a reasonable balance of the other performances. All the provisionally approved mix designs from different suppliers can be found in the HyD homepage.

The bituminous surfacing materials currently available in Hong Kong include WC, FC, PMFC, SMA and PMSMA. Some have more than one nominal maximum aggregate size. Their properties are described in RD/GN/010 and chapter 2 of MAH with further guidelines on the applications and construction details of special mixes and polymer modified mixes, including PMFC, SMA and PMSMA, provided in RD/GN/011 and RD/GN/038.

Engineers are recommended to approach the Research and Development Division if they require any technical assistance in formulating a rehabilitation scheme.

7.4 Worked examples

Five worked examples with photographs are provided in this section to illustrate the considerations to be taken while formulating rehabilitation schemes for some typical defective bituminous pavements commonly encountered over the road network.

Example A

Photo 7

Predominant distresses

General ravelling along the wheel paths with a few isolated cracking and local patch-up areas

Details of last rehabilitation

Resurfacing of 45mm wearing course carried out 8 years ago.

Existing pavement composition

45mm wearing course + 60mm base course + 200mm bituminous roadbase + 150mm granular subbase

Traffic condition

Moderate traffic volume with a few bus routes using the middle lane

Considerations

The surfacing layer has been used for many years. Ravelling and general exposure of aggregates resulted from traffic wear and tear as well as ageing are normal, whereas no structural deficiency is noted.

Recommended rehabilitation scheme

Resurfacing the top layer of 45mm by ordinary wearing course materials would be adequate to effectively restore the pavement serviceability. Condition of base layer along the wheel paths should be carefully examined after milling off the WC to identify any disintegration for appropriate action.

Example B

Photo 8

Photo 9

Predominant distresses

Interconnected cracks along wheel paths with sign of pumping;

no sign of raveling

Details of last rehabilitation

Resurfacing of 50mm wearing course carried out 3 years ago

Existing pavement composition

50mm wearing course + 60mm base course + 150mm lean concrete roadbase

Traffic condition

Moderate traffic volume with a few bus routes

Considerations

The overall serviceability is still acceptable without bumpy surface, depression or patched potholes. However, such a large extent of crocodile cracks developed along the wheel path only after 3 years of resurfacing indicates certain degree of structural deficiency within the pavement structure. The grey fine particles accumulated along the surface cracks indicate the occurrence of pumping process in which eroded fine particles from the underlying lean concrete roadbase are transported to the surface by water under action of traffic, which hints that the entire 110mm bituminous layers be to a certain extent cracked through. The rate of deterioration is expected to be accelerating, particularly during rainy season.

Recommended rehabilitation scheme

Apply deep inlay down to base course and/or using PMSMA to better extend its service life.

Example C

Photo 10

Predominant distresses

Single longitudinal top-down cracks (of 5-10mm wide) developed in parallel to a previous trench opening

Details of last rehabilitation

Resurfacing of 50mm wearing course carried out 5 years ago

Existing pavement composition

45mm wearing course + 60mm base course + 150mm bituminous roadbase + 150mm granular subbase

Traffic condition

Light traffic volume with very few heavy vehicles

Considerations

General condition of the whole surfacing layer is still acceptable. Those wide longitudinal cracks are vulnerable to water attack and further deterioration which affect the long term durability of the overall pavement structure.

Recommended preservation scheme

Filling up those wide longitudinal cracks with hot bitumen or any other approved crack sealant

Example D

Photo 11

Photo 12

Predominant distresses

Serious rutting/shoving with rut depth over 50mm

No pothole nor crack

Details of last rehabilitation

Resurfacing with 45mm SMA was carried out 1.5 years ago.

Existing pavement composition

45mm SMA + 60mm base course + 200mm roadbase + 150mm granular subbase

Traffic condition

Moderate traffic volume with high percentage of heavy vehicles at the bus stop zone

Considerations

Assuming the base course condition be found intact during the last resurfacing, the premature rutting should be mainly contributed by the instability of SMA surfacing under frequent bus stop and go.

Recommended rehabilitation scheme

Resurfacing the top layer of 45mm by PMSMA to improve resistance to the frequent braking and steering wheel loading over that area.

Example E

Photo 13

Photo 14

<u>Predominant distresses</u>

The entire pavement surface is generally ravelled and contains a high density of interconnected cracks and temporary patch-ups.

<u>Details of last rehabilitation</u>

No resurfacing works has been carried out since its new construction 15 years ago.

<u>Pavement composition</u>

45mm wearing course + 65mm base course + 200mm roadbase + 150mm granular subbase

<u>Traffic condition</u>

Over a parking area for heavy vehicles

<u>Considerations</u>

In view of the age, usage and existing surface condition of the concerned pavement, the distresses would predominantly be surface initiated and caused by the combined effect of diesel attack, water ingress and slow motion wheel steering/braking. The downward development of these surface distresses would result in certain degree of disintegration down into the bituminous sub-layer over years.

<u>Recommended rehabilitation scheme</u>

Apply deep inlay down to base course to extend its service life.