# Pavement Tech Note

## ALTERNATIVE PROCEDURE TO ESTIMATE FLEXIBLE PAVEMENT REHABILITATION REQUIREMENTS FOR PROJECT SCOPING

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*The procedure found in this technical note is condensed from a paper entitled* "New Criteria for Selecting Overlay Thickness for Scoping of Flexible Pavement Rehabilitation Projects" *by Imad Basheer, PE, Ph.D., Chief of Pavement Rehabilitation Design Branch of Office of Pavement Rehabilitation, Materials Engineering and Testing Services, dated April 2004.*

## 1.0 – APPLICATION

The purpose of this technical note (Guide) is to provide guidance for estimating flexible pavement rehabilitation requirements (e.g., hot mix asphalt overlay, or mill and replace with hot mix asphalt) during the project initiation document (PID) and project report (PR) phases of a project when deflection studies are not available. A deflection study involves conducting a number of field tests such as nondestructive deflection testing and coring, as well as determining rehabilitation requirements using the Caltrans flexible pavement rehabilitation methods. The decisions on whether to use this Guide or perform a deflection study during the PID and PR phases rests with the Project Development Team, which includes the project manager, project engineer, and district materials engineer. In deciding whether to use this Guide or complete a deflection study, the Team must evaluate the value of the data obtained versus the cost (approximately $25,000 to $35,000 in 2005 dollars) and time (approximately 1 to 6 months) of completing a deflection study. Cases where a deflection study during the PID and PR phase could be justified include:

## 2.0 – EXPLANATION

A flexible pavement (also known as an asphalt concrete pavement) rehabilitation project requires a deflection study to determine the structural thickness needed to accommodate future traffic needs. This is true whether the project is a roadway rehabilitation project or an existing pavement being modified or used for a project in the State Transportation Improvement Program (STIP). In the HDM Index 635.1(3), it is stated that all final designs are to be based on deflection studies that are completed within eighteen months of the commencement of construction.

Because projects are often programmed several years ahead of construction, deflection studies done at the Project Initiation Document, PID (Project Scope Summary Report, PSSR/Project Study Report, PSR), or the Project Report (PR) phases must be repeated in order to provide current information for the Plans, Specifications, and Estimate (PS&E) phase. Since resources, including time, may be limited, it is not always possible or practical to complete a deflection study for a scoping document. For those instances, the procedure described in this guide provides a method to estimate pavement thickness, and thereby cost, for the scoping phase. This procedure can be used for estimating rehabilitation costs for all phases of the project (PID, PR, PSSR, PSR) except for the final design (PS&E) where both field deflection testing and a comprehensive deflection study are required. Scoping documents that use this procedure need to clearly state that thickness values are only for estimating purposes and that final design must be based on a deflection study to be done during the design (PS&E) phase.

## 3.0 – LIMITATIONS OF THIS PROCEDURE

a) The procedure described herein may be used for any flexible pavement rehabilitation project, at PID or PR phases, whose individual designs utilize a traffic index (TI) of 15.0 or less. The restriction on TI is to avoid extrapolating the guidelines beyond the range of TI of the cases (totaling about 2000) used in the statistical analysis. For projects whose TI is greater than 15.0, detailed design based on comprehensive field testing should be conducted.

b) This procedure shall not be used in projects in which existing shoulders need to be evaluated to determine if they are structurally adequate to be used as traffic lanes.

c) This procedure does not apply to new pavement construction.

d) This procedure does not apply to the rehabilitation of portland cement concrete pavements. Rehabilitation of this type of pavements is covered in HDM index 625.1 and in the rigid pavement Preservation and Rehabilitation Guidelines, both documents can be found in the Office of pavement Design website. .

e) Projects involving pavement preservation as defined in HDM Index 603 are outside the scope of this document.

f) The rehabilitation requirements calculated by this procedure do not take into account any repairs made to the existing pavement such as digouts. These will need to be estimated separately.

## 4.0 – DATA REQUIREMENTS

In order to estimate the required thickness of a basic overlay or the mill and overlay requirements, or to perform a deflection study report, it is necessary to accurately determine the projected traffic index over the design life span of the project. The procedure to determine the traffic index is found in HDM Topic 613.

## 5.0 – OVERLAY METHOD

According to HDM Index 635.1, the thickness of a flexible pavement rehabilitation overlay is governed by one of three criteria: (1) structural adequacy, (2) reflective crack retardation, and (3) ride quality. These criteria are addressed for all phases of a project, even for determining preliminary estimates for scoping documents. The procedure in this guide provides an alternative method for estimating thicknesses when deflection studies and other data are not available at the scoping phase.

5.1 – BASIC HOT MIX ASPHALT (HMA) OVERLAY THICKNESS ESTIMATION

Tables 1 and 2 (shown on p. 4) give the estimated overlay thickness requirement in terms of hot mix asphalt (HMA) in feet for a given traffic index and the desired "reliability of estimate", denoted ρ (in percent). The parameter ρ reflects the reliability that the selected overlay thickness will meet or exceed the actual overlay thickness required for the desired deign life. Note that quantity (100–ρ)% represents the likelihood that the actual overlay thickness needed for that particular pavement exceeds the selected value. These two tables were obtained by statistical analysis of about 2000 overlay designs (both mainline and ramp sections) for a large number of deflection studies conducted between 2000 and 2003 by the Office of Pavement Rehabilitation, METS, and exhibiting the various design criteria listed above. Table 1 provides the thickness for a ten-year design, and Table 2 provides the thickness for a twenty-year design. *These two tables are to be used for preliminary estimates in scoping documents (PSSR, PSR, or PR) only.*

5.2 – SELECTING THE RELIABILITY OF ESTIMATE

To use these two tables, the project engineer, in consultation with the District Materials Engineer and the District Maintenance Engineer, selects a value of the reliability of estimate ρ. Because this parameter reflects the probability that the thickness meets or exceeds the actual required thickness (i.e., reliability of estimated thickness), it can be related to cost of the overlay. In other words, it is related to the risk that the preliminary estimate will be under or over the final construction cost. The higher the ρ value used, the lower the risk of underestimating the overlay thickness and the corresponding rehabilitation cost of the project. Conversely, the lower the ρ value used, the lower the risk of overestimating the pavement cost of the project. For example, a ρ of 90% for a given traffic index range means that 90% of the project recommendations surveyed in the statistical study had a thickness equal to or less than the value shown in the table. A few other possible interpretations for the concept of reliability for the above example are: (i) the likelihood that the actual overlay thickness for a given project will not exceed the value obtained from the table is 90%, (ii) the reliability that the thickness obtained from the table would be adequate, is 90%, or there is 90% chance that the thickness obtained from the tables will meet the actual requirements (traffic, environment, materials variability, etc.) for the project, and (iii) for a large number of "identical" projects all receiving a HMA overlay with a thickness obtained from one of the tables, 9 out of 10 projects would be able to adequately provide the desired service for the required design life.

For scoping documents, a ρ of 80% is typically sufficient for cost estimation purposes; however, design engineers can choose to select higher or lower ρ value depending on the level of risk the district wants to take that the project cost will be either underestimated or overestimated. Conditions where a higher ρ value should be considered include pavements built on soft soils (i.e. those having a California R-value equal to or less than ten), pavements with higher than typical level of pavement distress, and pavements in locations or climates that have historically deteriorated at a faster rate than typically seen around the State. Again, the District Materials Engineers, and District Maintenance Engineers, because of their experience with local pavement conditions, are good resources and should be consulted when selecting the ρ value. The final decision concerning which ρ value to use rests with the district.

**Table 1. HMA overlay thickness in feet for a ten-year pavement design life**

| Traffic Index Range | Reliability of Estimate, ρ | | | | | | |
|---|---|---|---|---|---|---|---|
| | **50%** | **60%** | **70%** | **80%** | **90%** | **95%** | **99%** |
| 6.0-8.0 | 0.25 | 0.30 | 0.30 | **0.35** | 0.35 | 0.40 | 0.45 |
| 8.5-10.5 | 0.30 | 0.35 | 0.35 | **0.40** | 0.40 | 0.45 | 0.55 |
| 11.0-15.0 | 0.35 | 0.35 | 0.35 | **0.40** | 0.45 | 0.45 | 0.55 |

**Table 2. HMA overlay thickness in feet for a twenty-year pavement design life**

| Traffic Index Range | Reliability of Estimate, ρ | | | | | | |
|---|---|---|---|---|---|---|---|
| | **50%** | **60%** | **70%** | **80%** | **90%** | **95%** | **99%** |
| 6.0-8.0 | 0.30 | 0.35 | 0.35 | **0.40** | 0.40 | 0.50 | 0.55 |
| 8.5-10.5 | 0.35 | 0.40 | 0.40 | **0.50** | 0.50 | 0.55 | 0.65 |
| 11.0-15.0 | 0.40 | 0.40 | 0.40 | **0.50** | 0.55 | 0.55 | 0.65 |

5.3 – OVERLAY WITH RAC-G

The basic overlay thickness calculated using this procedure represents the thickness of hot mix asphalt (HMA). The design engineer may choose to use rubberized asphalt concrete-Type G (RAC-G) as an alternative. Based on *HDM Topic 635*, RAC-G overlay thickness is approximately equal to 50% of the HMA thickness when reflection cracks retardation is the governing design criterion. On the other hand, if the governing criterion is structural adequacy, the HMA is replaced by an equal thickness of RAC-G. Because it will not be possible to determine which criterion is governing the design without performing an actual pavement deflection testing, the procedure presented in this Tech Note is entirely probabilistic. It is based on the distribution of the data obtained for the statistical analysis of HMA overlay thicknesses. From the 2000 designed HMA overlays, 87% were controlled by reflective cracking retardation and 13% were governed by structural adequacy. By referring to the original report on which this Tech Note was based, the following equation were derived to enable the determination of a 10-year and 20-year RAC-G overlay thickness based on the corresponding estimated HMA thickness obtained from Tables 1 and 2, respectively:

$$h_{N\,(RAC-G)} \approx 0.60\, h_{N\,(HMA)}$$

where h denotes the overlay thickness, and subscript N refers to the desired pavement design life. The engineer should use proper judgment in rounding (up or down) the final value of the obtained thickness.

5.4 – ILLUSTRATIVE EXAMPLE ON ESTIMATING OVERLAY THICKNESS

This example will illustrate the use of the presented procedure for estimating the thickness of both HMA and RAC-G overlays. The following data for a highway segment is assumed:

- Traffic Index (TI) = 7.5
- Pavement design life (N) = 10 years, and
- Desired reliability of the estimated thickness (ρ) = 80%.

Since N=10 years, Table 1 is selected. To find the line with the correct TI range, examine the leftmost column. The first line, whose range is from 6.0 to 8.0, is the correct line. Then observe, on this line, under the column labeled 80% the value of 0.35 ft of HMA. Using RAC-G, from the Equation given in Section 5-3, the corresponding required RAC-G overlay thickness would be approximately equal to 0.6×0.35=0.21 ft (round to 0.20 ft).

5.5 – ADDRESSING RIDE QUALITY

Regardless of the values shown in Tables 1 and 2, if the existing International Roughness Index (IRI) obtained from the PCS for the pavement under consideration currently exceeds 150 in/mi, then it should be assumed that the IRI will deteriorate to a value greater than 170 in/mi. Thus, a minimum of 0.25 ft of HMA overlay should be estimated.

## 6.0 – MILL AND OVERLAY METHOD OR REMOVE AND REPLACE (PARTIAL DEPTH) METHOD

If it is required that the existing profile grade remains unchanged, or if the increase in the grade due to using an overlay is limited to a certain amount, a mill-and-overlay option should be used. Examples where these could be required are to maintain profile grade due to drainage or vertical clearance issues, or where barriers or curbs limit the amount of overlay that can be placed. Preparing an accurate estimate for milling and overlay is difficult without a deflection study because good data on existing conditions is needed to know how much structural strength is lost from the cold planing/milling and hence how much needs to be removed and replaced with new material to produce a structurally adequate pavement. For these reasons, a deflection study during a scoping phase is helpful in developing an accurate estimate. However, a procedure for estimating an approximate mill and replace depths is presented below.

Note, per HDM Index 635.1(6), if the existing pavement needs to be removed below the surface layer, the strategy is considered to be a remove and replace strategy. The method found in this section covers both mill/overlay and partial depth remove/replace. For full depth remove and replace, use the procedures for new flexible or rigid pavement in HDM Topic 633 or 623 respectively.

6.1 – METHOD

If a deflection study is not possible, a procedure is presented below for determining an estimate for the amount of milling that needs to be replaced with new hot mix asphalt to allow for a desired or a tolerable raise in the profile grade. This procedure is primarily based on structural strength equivalency. The tolerable increase could be set to zero for a mill/replace option that must maintain the existing profile grade. The procedure is summarized as follows:

1. For the given project TI, pavement design life, and design reliability (or reliability of estimate, ρ), determine the required basic overlay thickness ($y_1$) from Tables 1 or 2.
2. Decide on the increase in profile grade that is allowed for the pavement ($y_3$). Note that $y_3$=0 for a milling depth that is required to maintain the existing profile grade.
3. Determine a weighted average gravel factor, $G_f$* for the entire pavement structure above the subgrade. This can be determined as the product of the "reduced" gravel factors for the various layers times their corresponding thicknesses, divided by the total thickness of all layers (H). For a three-layer section, this is computed as:

$$G_f^{\ *} = \frac{G'_{f1} \times h_1 + G'_{f2} \times h_2 + G'_{f3} \times h_3}{H}$$

   where $h_1$, $h_2$, and $h_3$ are the layer thicknesses, $G'_{f1}$ , $G'_{f1}$, $G'_{f1}$ are their corresponding reduced gravel factors, and $H=h_1+h_2+h_3$. Because old materials can have lower gravel factors compared to virgin materials (for example due to HMA distresses, fines contamination of base), careful engineering judgment is required in selecting the appropriate reductions in gravel factors.
4. Calculate a strength-based estimate of the milling depth required ($y_2$) from the following derived equation:

$$y_2 = \frac{y_1 - y_3}{1 - \frac{G_f^{\ *}}{1.9}}$$

5. Check whether $y_2$ is less than or equal to H. If not, select a higher value for $y_3$ (if acceptable) in Step 2 and repeat Steps 3 through 5.

6.2 – ILLUSTRATIVE EXAMPLE ON MILL/REPLACE

Consider the same data as in Section 5-3 for a pavement section consisting of 0.5 ft of moderately fatigue-cracked HMA, over 1.0 ft of aggregate base (AB), over an R-value of 30 subgrade. Because of vertical clearance issues, no increase in the existing profile grade is allowed. Assume reduced values of $G_f$ for existing HMA and AB as 1.6 and 1.0, respectively.

According to the 5 steps summarized in Section 6-1, an estimate of the mill and replace depth is determined as follows:

- From Step 1, $y_1$=0.35 ft of HMA (also see Section 5.1).
- From Step 2, $y_3$=0.
- From Step 3, $G_f$*=[(0.5×1.6+1.0×1.0)/(0.5+1.0)]=1.20.
- From Step 4, $y_2$={(0.35-0)/[1-(1.2/1.9)]}=0.95 ft.
- From Step 5, $y_2 \leq 1.5$ ft (the total thickness of pavement, H).
- Result: the mill/replace strategy would require milling off 0.95 ft of the existing pavement and replacing with 0.95 ft of HMA.

6.3 – ISSUES FOR CONSIDERATION

The following should also be considered in estimating pavement rehabilitation costs for scoping documents where milling or removing the existing pavement is anticipated. These hints are based on experience with previous projects done in the State. However, good engineering judgment must still be used in developing a strategy that is realistic, maintainable, and constructible for the given location. Also, in order to have an accurate cost, it is essential that traffic management costs reflect the preliminary pavement strategy.

a) If the milling / cold planing is for a conform taper only to match an existing bridge, pavement, or other feature, and the proposed TI is less than 12.0, then use the thicknesses in Tables 1 and 2 to calculate the overlay thickness and add the cost of cold planing. If the TI is 12.0 or greater, assume full depth pavement replacement. Regardless of TI, if the milling / cold planing operation adversely impacts the integrity of the concrete pavement, lean concrete base, cement treated base, or any permeable base, these layers will need to be removed and replaced with an equivalent pavement structure, and included in the cost estimate. Refer to HDM Topic 673.3 and the guideline "Tapers and Transitions" for further information on conform tapers.

b) If milling / cold planing is limited to the shoulder (like for curbs and barriers), then add additional cost for cold planing the shoulders and use the thicknesses in Tables 1 and 2 to calculate the overlay thickness on the shoulders. Although in reality, the overlay thickness will likely be tapered across the shoulder in this application, reducing the thickness in the cost estimate is not recommended.

## 7.0 – ADDITIONAL COSTS TO BE CONSIDERED

a) If the mainline to be rehabilitated has portland cement concrete pavement, the designer should be reminded to estimate the cost of rehabilitation (with basic overlay or mill and overlay) for the ramps, which are usually hot mix asphalt.

b) If the rehabilitation (by basic overlay or mill/replace) will elevate the pavement surface sufficiently that existing barriers no longer extend the correct distance above the surface, then the cost of changing height of barriers may need to be added. Consult District Traffic Operations for further information.

c) If the engineer wishes to cover the new pavement surface with an open-graded friction course (OGFC), then the cost of that OGFC course must be added. OGFC is not considered to be part of the structural layer thicknesses in Tables 1 and 2.

d) If the rehabilitation (with basic overlay, mill/overlay, or remove/replace) will raise the existing highway profile, the cost of a corresponding amount of shoulder backing, if applicable, must be added. See the "Shoulder Backing Guidelines" for further information.

e) The cost of rehabilitation is also affected by the cost of the asphalt binder used to produce the HMA. The selection of the asphalt binder is dependent on the climate at the project site. Topic 632 (2) of the HDM should be used for selecting the appropriate binder.

**NOTE TO READER**

The full report that this Pavement Tech Note was based on titled *"New Criteria for Selecting Overlay Thickness for Scoping of Flexible Pavement Rehabilitation Projects"* can be obtained from the Department Pavement website