OHD L-57
GUIDE FOR FORENSIC EVALUATION OF DISTRESS IN HOT MIX ASPHALT AND PORTLAND CEMENT CONCRETE PAVEMENT

I. **INTRODUCTION.** Pavements are designed for a certain service life, usually 30 years for new construction, 15-20 years for rehabilitation projects, and 7-15 years for preservation projects. It is expected that the pavement section will perform satisfactorily during that period. When the pavement section does not meet that expectation, either by premature distresses or premature failure, it is recommended to review the type of distresses with a visual analysis and recommend a sampling and testing program; this could be called a forensic study. Finally, the cause, potential solution, and recommendation for rehabilitation need to be reported.

II. **SCOPE.** The intent of this document is to provide a guide for forensic investigation. It is not expected that every investigation would include each area listed or every item detailed in that area. It is expected that the depth of the investigation would increase as it moves from one level to the next. The investigation may begin at any level or be concluded at any level.

III. **FORMATION OF AN EVALUATION TEAM.** The Field Division Engineer, based on his initial information of distress, pavement conditions, and intensity of problem, will form an evaluation and forensic team and appoint a team leader. He or she may consult the Construction Engineer and the Materials and Research Division Engineer in the formation of this committee and decide the required level of investigation.

IV. **LEVELS OF INVESTIGATION.** Based on the degree of complexity and severity of the pavement distress and the urgency of the required response, the following three-tiered investigation levels are recommended:

A. **Level I (Division Level).** The team may consist of Division personnel with expertise in various areas of disciplines including Materials, Design, Construction, and Maintenance. Based upon preliminary information and data, the pavement distress appears to have a low degree of complexity and severity. Preliminary survey indicates the cause may be easily identified.

The investigation may include the following:

- Preliminary Investigation
- Visual Analysis

Complete the final report if the problem is resolved. If not, summarize the findings and proceed to Level II.

B. **Level II (Statewide Level).** Premature pavement failures on the NHS system and the Interstate system should be evaluated as Level II unless minor in scope. The team will consist of individuals from Level I and may include personnel from the Materials and Research Division, Pavement Design, FHWA, consultants, and local industry representation (ACPA, OAPA, etc.). Findings from the first level of investigation will be re-evaluated. The investigation may include the following:

- Preliminary Investigation
- Visual analysis
- Pavement core sampling and testing
- Non-destructive methods for evaluation
- Geotechnical investigation of base, sub-base, and subgrade.

Complete the final report if the problem is resolved. If not, summarize the findings and proceed to Level III, if deemed necessary.

C. **Level III (National Level).** The team will consist of individuals from Level I and Level II and may include national experts from FHWA, other government entities, and national industry representatives (NCAT, Asphalt Institute, ACPA, NAPA.) Findings from Level I and Level II will be re-evaluated again. The investigation may include the following:

- Preliminary Investigation
- Visual Analysis
- Pavement core sampling and testing
- Pavement slab samples by trenching may be obtained for further testing
- Geotechnical investigation of base, sub-base, and subgrade
- Non-destructive methods for evaluation (FWD, GPR, etc.)

Complete the final report.

V. PRELIMINARY INVESTIGATION. The available documentation about the project from the mix design to the construction procedure may be evaluated. These documents, depending on availability, include the following:

- Materials design and as-built/constructed material properties. This will include review of daily progress and QC/QA reports for information on mix design formulae, admixture and strength, use of polyphosphoric acid (PPA), fill material, etc.
- Construction procedure and witnessing. This will include review of equipment changes, weather impacts, materials moisture measurement, construction variables such as compaction, opening times, opening temperatures, tack coating application, etc.
- Pavement design and as-built/constructed information. This will include sample records documenting locations and possession during construction, QC/QA for construction variables such as thickness and material type, percent compaction in the field.
- Maintenance records to obtain surface treatment and drainage maintenance histories.
- Soil properties and geology maps to identify any subgrade soils or geologic conditions.
- Climate records to identify climatic events that may have contributed to the issues being investigated.
- Pavement management system data to examine past performance of the section, determine whether the issues are new, and/or determine whether past performance is a factor in the issues being investigated.
- Traffic data to identify changes in traffic patterns that may have contributed to the issues being investigated, including data on overload permits issued. Seasonal traffic variation will need to be taken into consideration.
- Information on underground services such as gas lines, cables, pipelines, etc., to determine if they contributed to the issues being investigated or if they will influence the forensic investigation in any way.
- Contract documents and geotechnical reports.

VI. VISUAL ANALYSIS. The first step in investigating the pavement distress is to perform a complete and comprehensive visual analysis of the entire project. Emphasis will be placed on the distressed areas. See Figure l Pavement Condition Evaluation Checklist (Rigid) and Figure 2 Pavement Condition Evaluation Checklist (Flexible) for Pavement Evaluation Checklists for both pavement types. Guidelines on how to perform the visual distress survey can be found in the Distress Identification Manual for the Long-Term Pavement Performance Program. This FHWA publication (2) includes a comprehensive breakdown of common distresses for both flexible and rigid pavements.

http://www.fhwa.dot.gov/publications/research/infrastructure/pavements/ltpp/reports/03031/

Information gathered may include:

- Date
- Reviewers
- Project location and size
- Traffic data
- Weather information
- Extent of distress
- Detailed information concerning each distressed area
- Photographs of the typical distress on the project will be included
- Any other problems that are visible (drainage, frost problems, dips or swells, roadside conditions) should be recorded.

In general, each individual distress type should be rated for severity and the extent (amount) of the distress noted. When determining severity, each distress type can be rated as low, medium (moderate), or high. This will not apply for some distresses, such as bleeding, which will be characterized in terms of number of occurrences.

When measuring and recording the extent or amount of a certain distress, each should be rated consistent with the type of distress. For example, alligator cracking is normally measured in terms of affected area. As a result, the overall amount of alligator cracking is recorded in terms of total square feet of distress. Alternatively, for quick surveys, the overall amount of alligator cracking can be recorded as a percentage of the overall area (i.e. 10%).

Other distresses, such as cracking, are recorded as total number of cracks or number of cracks per mile, and the overall length of the cracks. For example, for transverse or reflection cracking it is appropriate to record the amount of distress in terms of number of cracks per mile (for each severity level), while for longitudinal cracks it is appropriate to record the total length recorded.

Any assumptions made during the investigation should also be noted.

PAVEMENT EVALUATION CHECKLIST (RIGID)

PROJECT NO.:_____________________________ JOB PIECE (JP #):_________________

HWY:_____________________________________ DIRECTION: _____MP______TO MP___________

REVIEWED BY: ____________________________ TITLE: ______________________________

DATE: _________________________________

TRAFFIC
Existing AADT ____________________ (%TRUCK) _________________
Design AADT_____________________ (%TRUCK) _________________

EXISTING PAVEMENT DATA
Subgrade (type/thickness)
Base (type/thickness)
Pavement Thickness
Soil Strength (R/M_r)
Swelling Soil (yes/no)
Roadway Drainage Condition (good, fair, poor)
Shoulder Condition (good, fair, poor)
Joint Sealant Condition (good, fair, poor)
Lane Shoulder Separation (good, fair, poor)

DISTRESS EVALUATION SURVEY

Type	Distress Severity*	Distress Amount*
Blowup		
Corner Break		
Depression		
Faulting		
Longitudinal Cracking		
Pumping		
Reactive Aggregate		
Rutting		
Spalling		
Transverse and Diagonal Cracks		
OTHER		

* Distress Identification Manual for the Long-Term Pavement Performance Program, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-RD-03-031, June 2003.

PAVEMENT EVALUATION CHECKLIST (FLEXIBLE)

PROJECT NO.:_____________________________ JOB PIECE (JP #):_________________

HWY:_____________________________________ DIRECTION: _____MP______TO MP___________

REVIEWED BY: _____________________________ TITLE: ______________________________

DATE: _________________________________

TRAFFIC

Existing AADT ___________________ (%TRUCK) _________________

Design AADT_____________________ (%TRUCK) _________________

EXISTING PAVEMENT DATA

Subgrade (AASHTO)
Base (type/thickness)
Soil Strength (R/Mr)
Pavement Thickness

Roadway Drainage Condition (good, fair, poor)
Shoulder Condition (good, fair, poor)
Roadside Conditions
Overlay Thickness

DISTRESS EVALUATION SURVEY

Type	Distress Severity*	Distress Amount*
Alligator (Fatigue) Cracking		
Bleeding		
Block Cracking		
Corrugation		
Depression		
Joint Reflection Cracking (from PCC Slab)		
Lane/Shoulder Joint Separation		
Longitudinal Cracking		
Transverse Cracking		
Patch Deterioration		
Polished Aggregate		
Potholes		
Raveling/Weathering		
Rutting		
Slippage Cracking		
OTHER		

* Distress Identification Manual for the Long-Term Pavement Performance Program, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-RD-03-031, June 2003.

VII. INVESTIGATION REQUIREMENTS: DESTRUCTIVE AND NON-DESTRUCTIVE. After the visual analysis report has been evaluated, the second step of this procedure requires the determination of the investigational requirements. The requirements will depend on the type and extent of the pavement distress. It is recommended to obtain samples of the pavement adjacent to the distress area for comparison and control purposes. A minimum of 5 samples per lane is required outside of each end of the distress area.

A list of investigational requirements may include:

- Non-destructive methods for evaluation (FWD, GPR, etc.)
- Pavement core sampling and testing plan
- Slab sampling of pavement (trenching
- Geotechnical investigation of base, sub-base, and subgrade

A. Non-destructive methods for evaluation (FWD, GPR, etc.). The FWD is a nondestructive testing device that can be used in structural testing for pavement rehabilitation, investigations, design, and research. The FWD imparts a dynamic load to the pavement surface that is similar to that of a single heavy moving wheel load. The resulting pavement deflection can then be measured. This deflection data combined with the pavement layer thickness can be used to determine the in-situ resilient modulus of layers within a pavement structure and analyze the remaining service life of a pavement. A small number of cores will be required to confirm layer thickness. FWD measurements are highly influenced by the test location and temperature; these factors must be considered when correlating test measurements to performance.

GPR is an electromagnetic sounding method in which a transducer (transmitter/receiver) is passed over the surface of a pavement. Short duration pulses of radio energy are transmitted into the pavement and reflections from within are detected by the receiver. Changes in the dielectric properties are used (in conjunction with positional [GPS] information) to assess layer thickness, presence of moisture, voids, and other anomalies.

B. Core Sampling and Testing Plan. The precise location of destructive testing will be determined by the forensic team after the visual assessment. Cores for testing should be taken in both distressed and non-distressed areas to allow for comparison and to aid in identifying key contributing factors to the problem. The quantity of cores taken will depend on the extent of the damages being measured. Figure 1 from NCHRP Report 747 shows an example for core locations depending on distress.

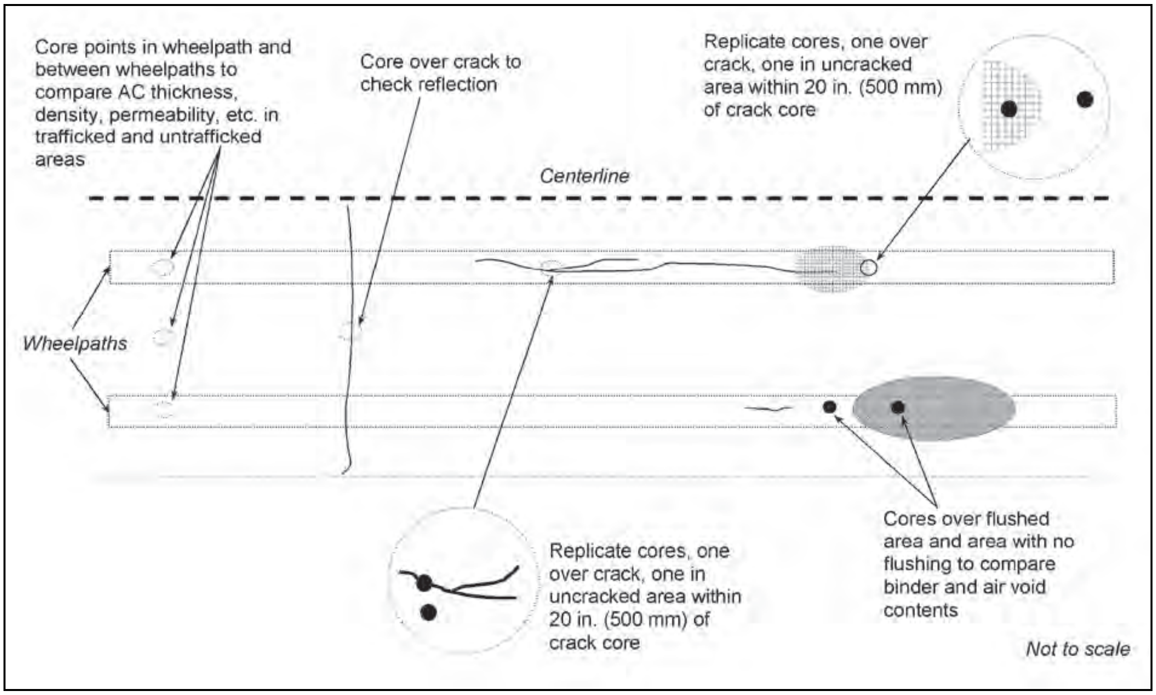

Figure 1: Example of core locations (NCHRP Report 747)

The following key issues should be considered when coring:

- Log each core and core hole.
- Core at an angle of 90o to the surface to ensure the recovery of straight intact smooth-surface samples suitable for layer analysis and laboratory testing.
- Observe the core hole to identify problems that may be contributing to the issues being investigated.
- Measure the core hole to account for discrepancies in height/layer thickness due to the core recovery procedure.
- Photograph the core with the core ID.
- Record initial observations such as moisture, layer debonding, breakage, etc. after extracting the cores.

The Materials and Research Division representative will be responsible for the proper management of cores that are going to be used for laboratory testing.

C. **Slab sampling of pavement (trenching).** Along with core samples the team may decide, depending on the scope of the investigation, to make trench pit excavations to obtain bigger samples and to detect other issues that cannot be obtained from cores. During the trench pit excavation the team will observe and look for issues such as debonding, stripping, moisture, pitting, etc. Once the excavation is completed, thickness measurements of the layers will be made. Special attention should be taken to irregular variations on layer thickness, which can be the result of poor or over compaction. Figure 2 from NCHRP Report 747 shows an example of a test pit layout.

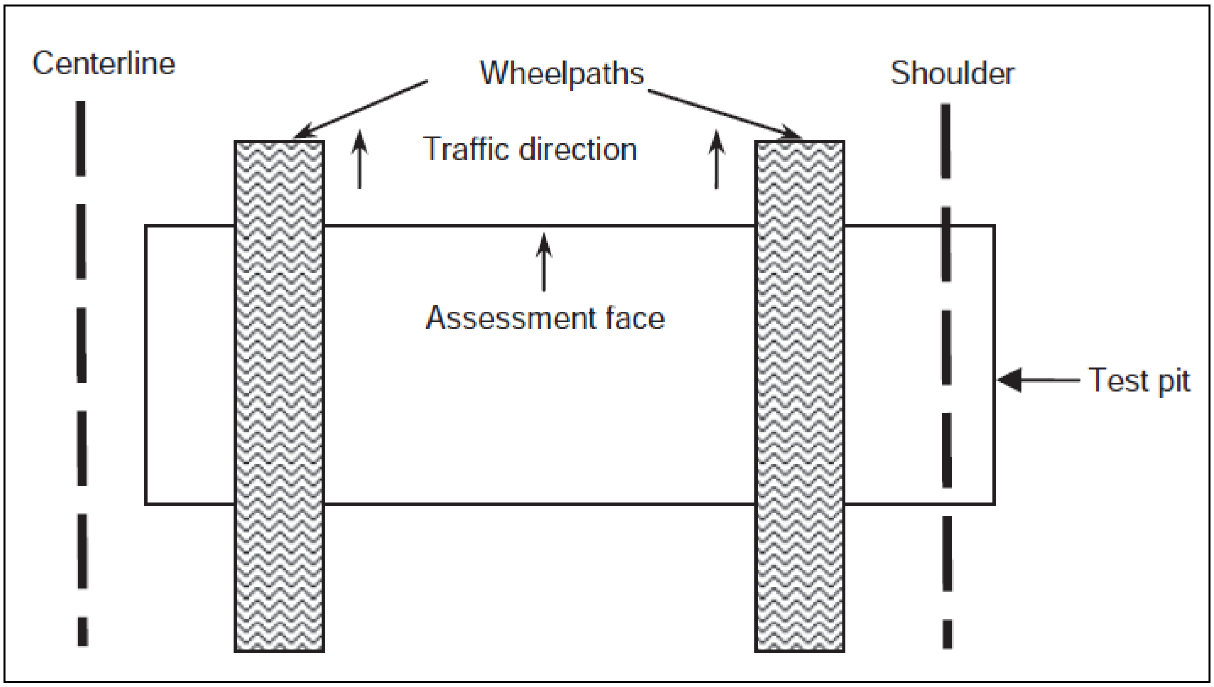

Figure 2: Test pit layout

The following key issues should be considered when excavating a trench pit:

- Saw the pavement to the full depth of the wearing course and bound layers to the specified overall dimensions and into smaller pieces as necessary for removal.
- Minimize the use of cooling water during sawing to reduce water contamination, especially when moisture damage is one the issues in consideration.
- If material samples from the pit are required for laboratory testing, the Materials and Research Division representative will be responsible for the proper handling of them.

D. Geotechnical Investigation of Base, Sub-base, and Subgrade. Insitu and laboratory methods may be used to characterize base and subgrade materials. Goals and methods of investigation are generally the same as those for pavement design: to determine the horizontal and vertical variations in subsurface soil types, moisture contents, densities, water table depth, and location of rock strata; to identify expansive, dispersive, organic, or other problem soils; to determine whether water may drain, accumulate, or erode subgrade soils (3,4). When obtaining samples of the base and subgrade materials, a sufficient area of the pavement surface should be removed for adequate testing and sampling of each layer of material. When base and subgrade materials are required for testing (i.e. moisture), proper handling must be taken to prevent contamination from other sources when separating each layer. Sufficient material should be obtained to do the required laboratory testing. Testing may include but not limited to:

- Nuclear gauge density and moisture determination
- Dynamic cone penetration
- Soil classification
- Monitoring of ground water levels
- Proctor testing

Testing and sampling shall be conducted according to applicable AASHTO, ASTM, or Oklahoma OHDL standards.

VIII. FINAL REPORT. A summary of the entire forensic process including document reviews, visual findings, laboratory and in-situ testing, etc. should be documented in a final report. The report should include the following:

A. Project Overview

- Type of pavement (HMA, PCCP, CRCP, DJPC)
- Highway location MP reference and size of project
- Traffic data
- Weather conditions
- When distress developed
- Historical distresses
- General site description listing specific issues (quarry, bat cave, gypsum, etc.)

B. Visual Inspection

- Type, extent and location of distress
- Photographs

C. Summary of Construction Records

- Mix design
- Central laboratory (Material & Research Division) evaluation tests (TSR, Hamburg test, LA abrasion test, soundness, etc.)
- Quality Control/ Quality Assurance test results (density, VMA, air voids, gradation, asphalt, air content, compressive strength, etc.)
- Project diaries
- DWRs

D. Core Sampling and Testing Results*

- Thickness
- Core location and map
- Density and air voids
- Asphalt content
- Gradation
- Vacuum extraction and asphalt cement penetration
- Geologic analysis of aggregates
- Portland cement chemical tests
- Petrographic analysis
- Alkali-Silica Reactivity (ASR) tests
- Modulus of Elasticity
- Resilient Modulus

*All testing evaluating should be done in each pavement lift thickness.

E. Slab Sample

- Thickness
- Areas of deformation
- Stripping
- Determination of subsurface deformation
- Any other items of note

F. Results of Sampling and Testing of Base and Subgrade

- R-value
- Classification testing

G. Moisture and density

- Gradation
- Proctor results

H. Deflection Analysis

- Layer modulus and extent
- Joint load transfer

I. Conclusions and Recommendations

- Apparent cause of failure
- Potential solutions to prevent future problems with other pavements
- Recommendations for rehabilitation of the distress location

References

1. Rada, G.R., Jones, D.J., Harvey, J.T., Senn, K.A. and Thomas, M. 2013. NCHRP Report 747: *Guide for Conducting Forensic Investigations on Highway Pavements*. Washington D.C.: Transportation Research Board of the National Academies.
2. *Distress Identification Manual for the Long-Term Pavement Performance Program,* U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-RD-03-031, June 2003.
3. *AASHTO Guide for Design of Pavement Structures,* American Association of State Highway and Transportation Officials, Washington, D.C. 1993.
4. *Mechanistic-Empirical Pavement Design Guide, Interim Edition,* American Association of State Highway and Transportation Officials, Washington, D.C. 2008.