INDOT Guideline of Subsurface Condition Evaluation for Pavement Preservation Treatment

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DISCLAIMER

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1 GUIDELINE OVERVIEW

This guideline provides a project level tool for subsurface evaluation of asphalt pavements for the applicability of pavement preservation treatments (PPTs), including seal coat, microsurface, ultrathin bonded wearing course (UBWC), and 4.75 mm HMA overlay, etc. The evaluation defines severity of subsurface distresses, quantifies their coverage (extent) and distribution in a project using ground penetration radar (GPR) test or surface distress, and laboratory tests. An evaluation process developed through JTRP/SPR-3507 consists of five major steps, including preliminary assessment (checklist); analysis level selection and core location determination; layer determination, laboratory tests; and test result analysis, as shown in FIGURE 1-1. Details of each step are in the following chapters.

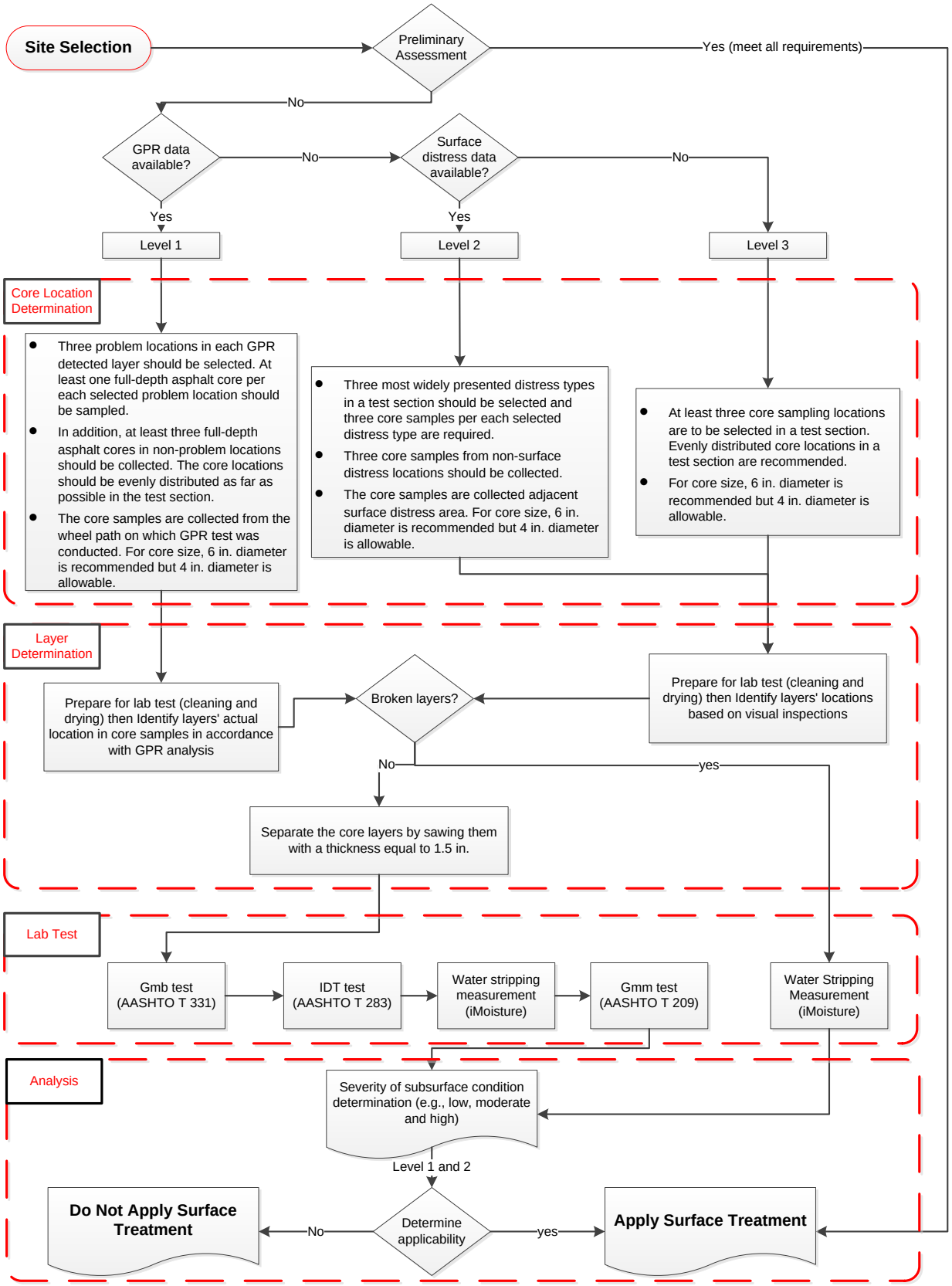

FIGURE 1-1 Schematic of evaluation process

2 EVALUATION PROCEDURE

2.1 SITE SELECTION

This step involves the collection of information regarding location, pavement history, design values, and any existing data upon the selection of test site. The specific portion or lane should be selected if the entire test section is not subject to subsurface condition evaluation. The length of a test section can be up to five miles long. A section longer than five miles should be divided by multiple subsections, where the length of each subsection should not be longer than five miles.

2.2 PRELIMINARY ASSESSMENT (CHECKLIST)

This preliminary assessment aids for assessing adequacy of pavement condition for the application of PPTs based on the information obtained from a visual inspection of surface distress on the test section. The pavement is considered to be a good candidate if it meets all categories as shown in TABLE 2-1**Error! Reference source not found.**. Otherwise, a further examination of the pavement is required to assess the adequacy.

TABLE 2-1 Preliminary assessment of pavement subsurface condition evaluation for pavement preservation treatment (Checklist)

Date		**Engineer**	
District		**Subdistrict**	
Road Name			
From Location		**From R. P.**	
To Location		**To R. P.**	
Lane Direction	**North, South, East, West**	**Lane Location**	**Passing Lane, Driving Lane**

No or little patching and other repairs (less than 10 % of area)	☐
No alligator cracking in wheel path	☐
No or little longitudinal cracking in wheel path (less than 265 ft / mile or 5 %)	☐
Transverse cracking spacing more than 120 ft	☐
No or little shoving in wheel path (less than 10 % of area)	☐
No sign of water stripping	☐
No Water bleeding or pumping	☐

2.3 ANALYSIS LEVEL DETERMINATION

The general approach for selecting or determining evaluation inputs for the evaluation is a hierarchical level system. The system is based on the philosophy that the level of engineering effort exerted in the pavement subsurface evaluation process should be consistent with the relative importance, size, and cost of the project. Level 1 is the most comprehensive procedure, involving laboratory and GPR tests. In case of Level 2, pavement distress surveys with the laboratory tests are conducted. In contrast, Level 3 requires only the laboratory tests to be conducted on randomly sampled cores and provides the most simplified results among 3 analysis levels.

2.4 CORE LOCATION DETERMINATION

2.4.1 LEVEL 1

- GPR data identifies problem locations in terms of layers in a test section utilizing relatively high discrepancies in their dielectric values measured between layers. It should be noted that the GPR data should be collected from the right wheel path.
- Three problem locations in each GPR detected layer should be selected. At least one full-depth asphalt core per each selected problem location should be sampled.
- In addition, at least three full-depth asphalt cores from non-problem locations should be collected. The core locations should be evenly distributed as far as possible in a test section.
- All core samples are collected from the right wheel path on which GPR test was conducted. For core size, 6 in. diameter is recommended but 4 in. diameter is allowed.

2.4.2 LEVEL 2

- Mapping surface distress by visual inspection or 3D laser scanner (available at the INDOT Research and Development) is required for Level 2 analysis. Types of distresses considered in the analysis are crack, pumping, potholes, and patch. Distress measurements should be presented as length (linear feet) in longitudinal direction.
- Up to three most widely presented distress types in a test section should be selected and three core samples per each selected distress type are required.
- Three core samples from non-surface distress locations should be collected.
- The core samples are collected adjacent surface distress area. For core size, 6 in. diameter is recommended but 4 in. diameter is allowed.

2.4.3 LEVEL 3

- At least three core sampling locations are to be selected in a test section. Evenly distributed core locations in a test section are recommended.
- For core size, 6 in. diameter is recommended but 4 in. diameter is allowed.

2.5 **LAYER DETERMINATION**

Once the collected core samples are cleaned and dried, visual inspection is conducted to identify layers and exam any broken layer existence in core samples.

2.5.1 LEVEL 1

- Based on GPR analysis and visual inspection, identified layers are located and marked on the surface of each core sample.
- Each core sample is then inspected for broken layers. If found, record the core sample and layer number. Only water stripping severity test is conducted for core layer specimen containing broken layer.
- Test specimen, 6 in. or 4 in. of diameter with1.5 in. of thickness, should be obtained from middle of each layer. A specimen thickness range from 1.0 in and 1.5 in. is acceptable in case of a layer thickness shorter than 1.5 in. and thicker than 1 in. For a layer thickness shorter than 1in., a specimen should be prepared with combining an adjacent layer (e.g., a combination of microsurface layer with surface course) to meet the thickness requirement.

2.5.2 LEVEL 2 AND LEVEL 3

- By visual inspection of each core sample, interface(s) should be located first. Available construction documents can be a good reference in identifying different layers.
- Thickness of each layer should be recorded.
- Each core sample is then inspected for broken layers. If found, record the core sample and layer number. Only water stripping severity test is conducted for core layer specimen containing broken layer.
- Test specimen, 6 in. or 4 in. of diameter with1.5 in. of thickness, should be obtained from middle of each layer. A specimen thickness range from 1.0 in and 1.5 in. is acceptable in case of a layer thickness shorter than 1.5 in. and thicker than 1 in. For a layer thickness shorter than 1in., a specimen should be prepared with combining an adjacent layer (e.g., a combination of microsurface layer with surface course) to meet the thickness requirement.

2.6 **LABORATORY TEST**

2.6.1 ASPHALT MIX BULK SPECIFIC GRAVITY TEST (AASHTO T 331)

The bulk specific gravity test should be conducted for each core layer specimen according to AASHTO T 331. AASHTO T 209 can also be used for the measurement of bulk specific gravity only if CoreLok® is not available (1) (2).

2.6.2 INDIRECT TENSION TEST (AASHTO T 283)

The tensile strength of each core layer specimen is tested according to AASHTO T 283 without conditioning (3). The loading rate is 2 in. per min. Upon completion of IDT test, digital image of split surface should be taken.

2.6.3 WATER STRIPPING SEVERITY MEASUREMENT (IMOISTURE)

The water stripping severity is measured on core layer specimen using iMoisture. For additional information regarding the usage of software, refer to the iMoisture user's manual.

2.6.4 ASPHALT MIX THEORETICAL MAXIMUM SPECIFIC GRAVITY TEST (AASHTO T 209)

The maximum specific gravity should be determined from the materials of at least two replicates from the same core sampling location.

2.6.5 LABORATORY TEST DATA RECORD (ISUB)

Laboratory test results as well as general information of the test section for each specimen should be recorded for analysis. TABLE 2-2 represents the form which may be used in recording data. The test data can be recorded using iSub explained in later chapter.

TABLE 2-2 Laboratory testing results form

Date		**Engineer**		**From Location**		**From R. P.**	
District		**Subdistrict**		**To Location**		**To R. P.**	
Road Name				**Lane Direction**		**Lane Location**	

□ Level 1	**□ Level 2**	**□ Layer 3**
□ Problem Location	□ Problem Location	
□ Non-problem Location	□ Non-problem Location	
	Distress Type	

		1						**2**						**3**					
		R. P.						**R. P.**						**R. P.**					
Layer No.		**TS[1] [psi]**	**WS[2] [%]**	**AV[3] [%]**	**G_{mb}**	**G_{mm}**	**B[4]? [y/n]**	**TS[1] [psi]**	**WS[2] [%]**	**AV[3] [%]**	**G_{mb}**	**G_{mm}**	**B[4]? [y/n]**	**TS[1] [psi]**	**WS[2] [%]**	**AV[3] [%]**	**G_{mb}**	**G_{mm}**	**B[4]? [y/n]**
1	**Mid Layer Depth (in.)**																		
2	**Mid Layer Depth (in.)**																		
3	**Mid Layer Depth (in.)**																		
4	**Mid Layer Depth (in.)**																		
5	**Mid Layer Depth (in.)**																		

TS[1]: Tensile Strength, WS[2]: Water Stripping Severity, AV[3]: Air Voids, B[4]: Broken Sample

2.7 **ANALYSIS**

2.7.1 SCORING SYSTEM FOR SUBSURFACE DISTRESS SEVERITY

In order to understand the subsurface condition in a test section, lab test results are converted to scales using poor, fair, and good based on their distress severities as shown in TABLE 2-3. It should be noted that the poorest severity rating should be assigned for a broken sample from the core sampling process.

TABLE 2-3 Lab test result conversion to severity

Air Voids (AV)	**Tensile Strength (TS)**	**Water Stripping Severity (WS)**	**Condition**	**Score (s)**
≤ 8 %	> 80 psi	≤ 18 %	Good	2 (S_{max})
8 < AV ≤ 10 %	50 < TS ≤ 80 psi	18 < WS ≤ 40 %	Fair	1
> 10 %	≤ 50 psi	> 40 %	Poor	0

The converted severities from lab data are utilized in determination of the overall subsurface condition using a condition scoring system: 2 for good condition; 1 for fair condition; and 0 for poor condition. Among the scores from air voids, tensile strength, and water stripping severity, the lowest score (**s**) is selected for each cut core sample. Then, the overall score (**S**) for each location can be calculated using EQUATION 1. It should be noted that subsurface condition for "problem locations" in Level 1 and surface distress locations in Level 2 are separately processed from non-problem locations and non-surface distress locations. **S** can be interpreted as shown in TABLE 2-4. **S** accepting for PPTs should be higher than 40.

$$\boldsymbol{S = \frac{\sum_{l=1}^{m}\sum_{r=1}^{n} s_{rl}}{m \times n \times S_{max}} \times 100} \quad \textbf{EQUATION 1}$$

Where**,**

S: overall score ($\mathbf{S_p}$ for "problem locations" and surface distress locations; $\mathbf{S_n}$ for "non-problem locations and non-surface distress; $\mathbf{S_a}$ for all locations in case of Level 3 analysis)

m: total number of layers

n: total number of replicates

$\mathbf{S_{max}}$**:** the maximum value of converted severities

s_{rl}: the lowest **s** for each cut sample (**s_{prl}** for "problem locations" and surface distress locations; **s_{nrl}** for "non-problem locations and non-surface distress; **s_{arl}** for all locations in case of Level 3 analysis)

$_r$: denotes the replicate number

$_l$: denotes the layer number

TABLE 2-4 Score interpretation for subsurface condition

S (S_p, S_n, or S_a)	**Condition**
≥ 81	Excellent
61 ≤ S ≤ 80	Good
41 ≤ S ≤ 60	**Fair**
21 ≤ S ≤ 40	**Poor**
S ≤ 20	**Very poor**

2.7.2 APPLICABILITY OF PAVEMENT PRESERVATION TREATMENTS (PPT)

The GPR analysis result or surface distresses are strongly related to the material properties measured in lab. However, in reality, some of GPR detections and surface distresses cannot be explained by the limited lab test results only. Therefore, if a difference between the lab test results from non-problem locations and from non-surface distress locations is insignificant, those locations are treated as problem and surface distress locations. Thus, the test section has uniformly distributed subsurface condition. Subsequently, the acceptable **S_n** and **S_p** in Level 1 and Level 2 are used for determining the PPT applicability as shown TABLE 2-5. The non-uniform condition (i.e., Sp ≤ 60 and Sn > 60) requires a further analysis and is explained following chapters. Since an assumption in Level 3 analysis is the uniform distribution of subsurface distress, the allowable **S_a** is only a factor for the PPT determination as shown in TABLE 2-6.

TABLE 2-5 PPT applicability for subsurface conditions (Level 1 and Level 2)

S_p	**S_n**	**PPT Applicability**	**Distribution**
> 60	> 60	Yes	Uniform
≤ 60	≤ 60	No	Uniform
≤ 60	> 60	No or partial yes	Non-uniform

TABLE 2-6 PPT applicability for subsurface conditions (Level 3)

S_a	PPT Applicability	Distribution
> 60	Yes	Uniform
≤ 60	No	Uniform

2.7.3 ANALYSIS FOR NON-UNIFORM DISTRIBUTION

Evaluating the subsurface condition coverage (%) and the distribution along a test section is an important process for determining PPT applicable lane length, For example, a 5-mile long pavement section with uniformly distributed 20% coverage of problem locations may not be a good candidate for the PPT. However, if all problem locations are located within 1-mile, the PPT can be applicable for the rest of 4-mile section.

2.7.3.1 COVERAGE (EXTENT) OF PROBLEM LOCATION

The coverage (extent) of subsurface condition can only be determined when either Level 1 or Level 2 was selected for the evaluation. In case of Level 3, only the severity rating of the test section is reported. The guideline for the extent level of subsurface distresses is the following:

2.7.3.1.1 LEVEL 1

The GPR analysis results should provide the coverage of problem locations for each identified layer. In case multiple layers are determined to have problematic subsurface condition, the total coverage is determined by adding the coverage of all layers while excluding the overlapped area. The overlapped locations are a certain section which was determined to be problematic in more than one layer. Consequently, overlapped locations should only be counted once in the calculation of total coverage of problem locations.

2.7.3.1.2 LEVEL 2

The coverage of surface distresses types selected for determining core sampling locations are only used in the analysis. The length-based coverage can be defined as the longitudinal length covered with distress in a given test section and add effective length for the length-based calculation of transverse crack and pothole. The length-based coverage is uniformly used in order to add up the extents of all distress types and a single coverage value representing a pavement condition can be used. Consequently, the length-based coverage calculation of longitudinal crack remains the same. In case of fatigue crack, pumping, potholes, and patch, only the effective longitudinal length of each distress area is included and divided by the total length instead of the area. It is assumed that each distress has an effective length of 20 ft. For example, 10 potholes are converted into 200 ft (10 × 20 ft). In case more than one pavement sections with surface distresses are included in the analysis, the total coverage should be determined by adding the coverage from all types of distresses excluding the overlapped area. The overlapped locations

are in a certain section which was determined to be covered with more than one type surface distress.

2.7.3.2 DISTRIBUTION ANALYSIS

The analysis process reviews the problem locations and their influence length in order to find any PPT applicable locations in a section. The process includes 1) determination of Distress Coverage of Unit Analysis Length (DCUAL); 2) application of allowable DCUAL; and 3) determination of PPT applicable locations.

The distress coverage for each unit analysis length UAL (1 mile) is calculated using EQUATION 2. For example, if the frequency of data collection is 10 ft., the first distress coverage of UAL is for a section is between 0 ft to 5280 ft (1 mile) away from the beginning of the section. Accordingly, the second UAL for the section is between 10 ft to 5290 ft away from the beginning of the section. The allowable $DCUAL_i$ for the PPT applications varies by the type of a test section. Any locations with $DCUAL_i$ equal or less than the allowable coverage is determined to be adequate for the application PPT as shown in TABLE 2-7.

$$\boldsymbol{DCUAL_i = \frac{\sum_i^{i+j} S_i}{j} \times 100} \quad \text{----------EQUATION 2}$$

Where,

$DCUAL_i$ (i=0, 1, …, n-1-j) = distress coverage of unit analysis length at i^{th}

i = 0, 1, …, n-1-j, where n is the total number of data for a test section

j = total number of data in unit analysis length (UAL, 1 mile long)

S = distress index (i.e., presence of distress for 1 and non-presence of distress for 0)

TABLE 2-7 Allowable DCUAL for road type

DCUAL	**PPT Applicability**
≤ 5 %	Interstate
≤ 10 %	US Highway
≤ 20 %	State road / Others

3 ISUB OVERVIEW

The evaluation software "INDOT Pavement Subsurface Condition Evaluation (iSub)" was developed as part of the JTRP/SPR-3507: Subsurface Condition Evaluation for Asphalt Surface to aid the pavement subsurface condition evaluation. The software is entirely based on the "Guidelines of subsurface condition evaluation for pavement preservation." Thus, iSub provides user-friendly system which helps to follow the hierarchy of evaluation steps. Furthermore, iSub automatically calculates the overall condition of the pavement subsurface as severity rating for each laboratory test result was implemented into the software. However, it should be noted that iSub does not determine core sampling location nor analyze GPR and surface distress survey data. The guideline should be used in core sampling location determination and iSub aids the subsurface condition determination process based on laboratory test results. For additional details, a user manual of iSub should be referred.

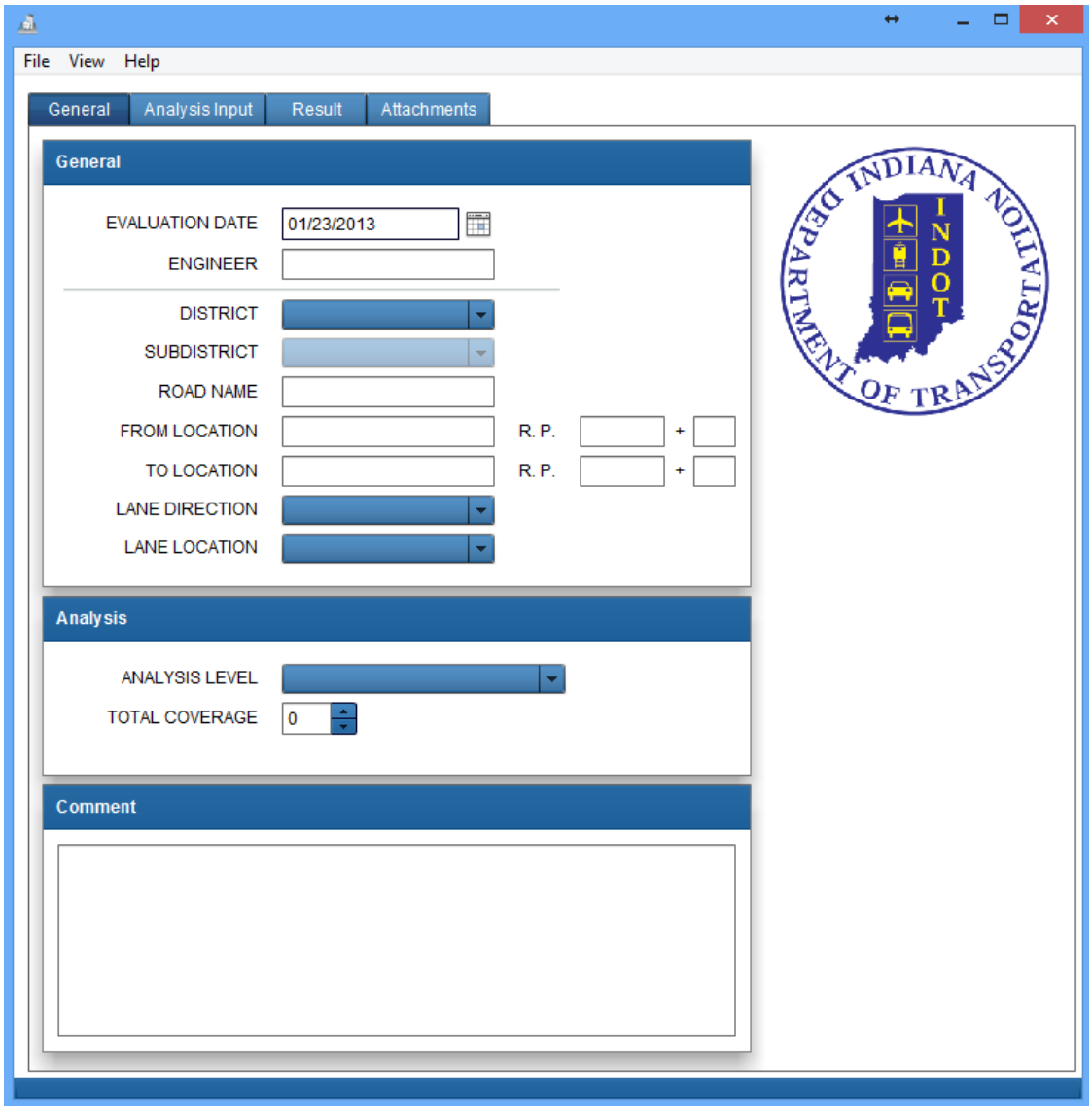

FIGURE 3-1 iSub: INDOT Subsurface Condition Evaluation Software

4 IMOISTURE OVERVIEW

The evaluation software "INDOT Water Stripping Severity Evaluation (iMoisture)" was developed to aid the water stripping severity evaluation and incorporate INDOT subsurface condition evaluation process. Asphalt mixture is primarily composed of asphalt and aggregate. Aggregates should be completely coated by asphalt. Thus, the uncoated aggregate is an index of water stripping, iMoisture detects uncoated aggregates and quantifies the area in a sample by employing the digital image analysis technology. For additional details, a user manual of iMoisture should be referred.

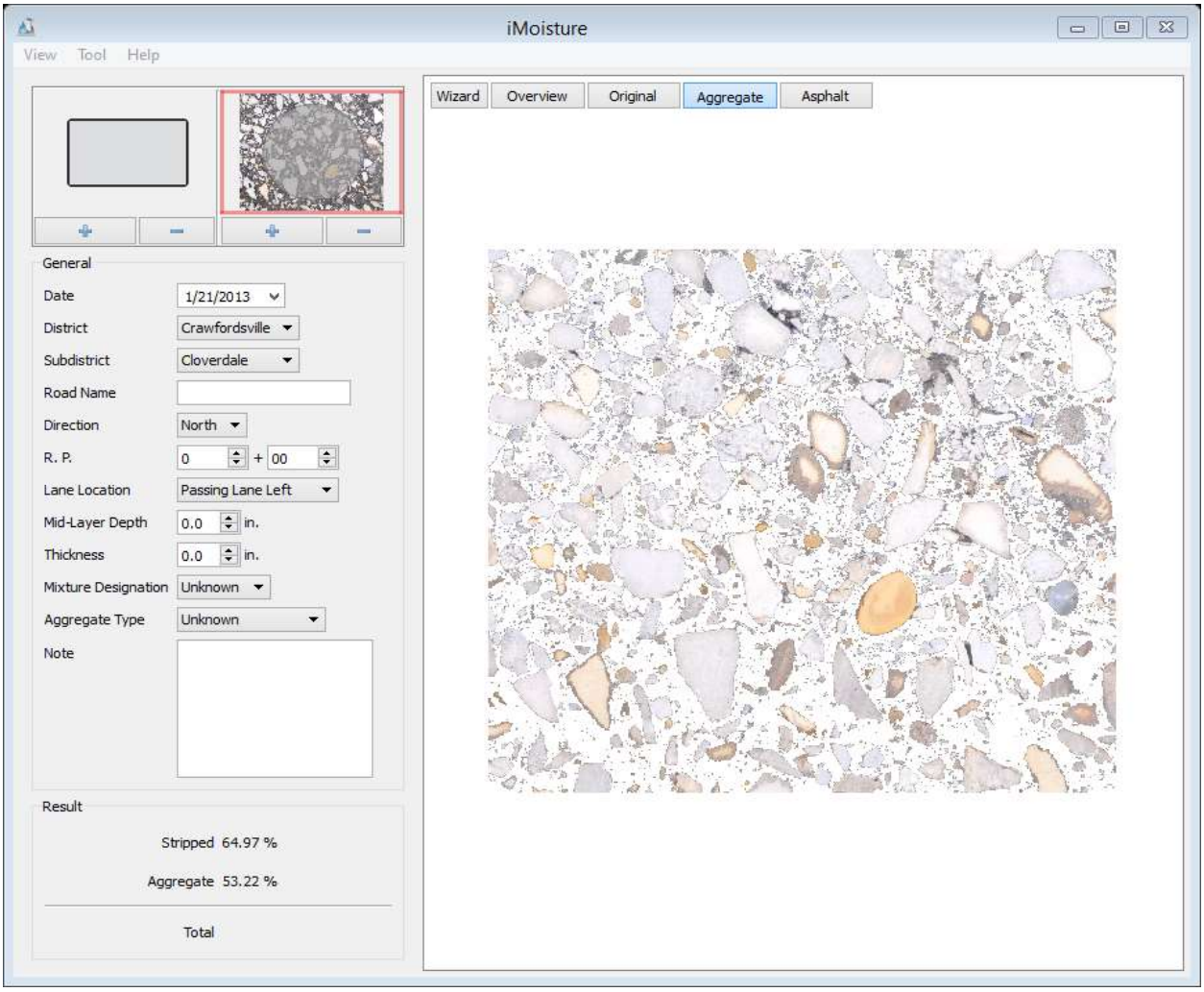

FIGURE 4-1 iMoisture: INDOT Water Stripping Severity Evaluation Software