Case history on the design, implementation, and conclusions of a study of haul roads associated with a wind farm development in Southwestern Ontario

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ABSTRACT

A wind farm consisting of 72 turbines is to be constructed in the Town of Lakeshore, in Southwestern Ontario. For the construction, turbine components will be hauled on a network of rural low-volume roads.

When these roads were designed and built, their use for the heavy haul required by the wind farm development was never envisaged. Consequently, the Town of Lakeshore commissioned a baseline study of the roads under their jurisdiction identified on the proposed haul routes. A total of 55 road segments, with gravel, surface-treated (chip-sealed) and asphalt surfaces was examined. The study included visual pavement condition assessment, falling weight deflectometer (FWD) testing, photographic work, and video recording.

The following are covered in the paper:

- the considerations that went into the design of a cost-efficient, successful field testing program;
- the methods used for the pavement condition survey;
- the arrangement of the FWD study;
- the results of the pavement condition survey;
- the results of the FWD study; and
- recommendations for follow-up study of the haul roads.

INTRODUCTION

Currently, a wind generation project comprising 72 turbines and a substation is under development south of Highway 401 in the Town of Lakeshore, in Southwestern Ontario (see Figure 1). The turbines will be distributed over an area of rural land of approximately 170 square kilometres. To support construction, the public rural road network is being used as haul routes to the turbine sites. Construction is expected to take at least a year.

As part of the agreement reached between the developer and the Town, a report which included the following was required:

- the identification of all highways that might be affected by the construction of the pole and line system, and/or the hauling of components to be used in the construction of the project; and
- an evaluation and photographs of the condition of the highways that have been identified, before construction begins.

The investigation and report provide a baseline study undertaken before construction. When construction is complete, a follow-up study will be carried out to compare to the baseline study, and to determine how much pavement deterioration should be attributed to the project's activities. This paper presents aspects of the design of the baseline study, its results, and conclusions.

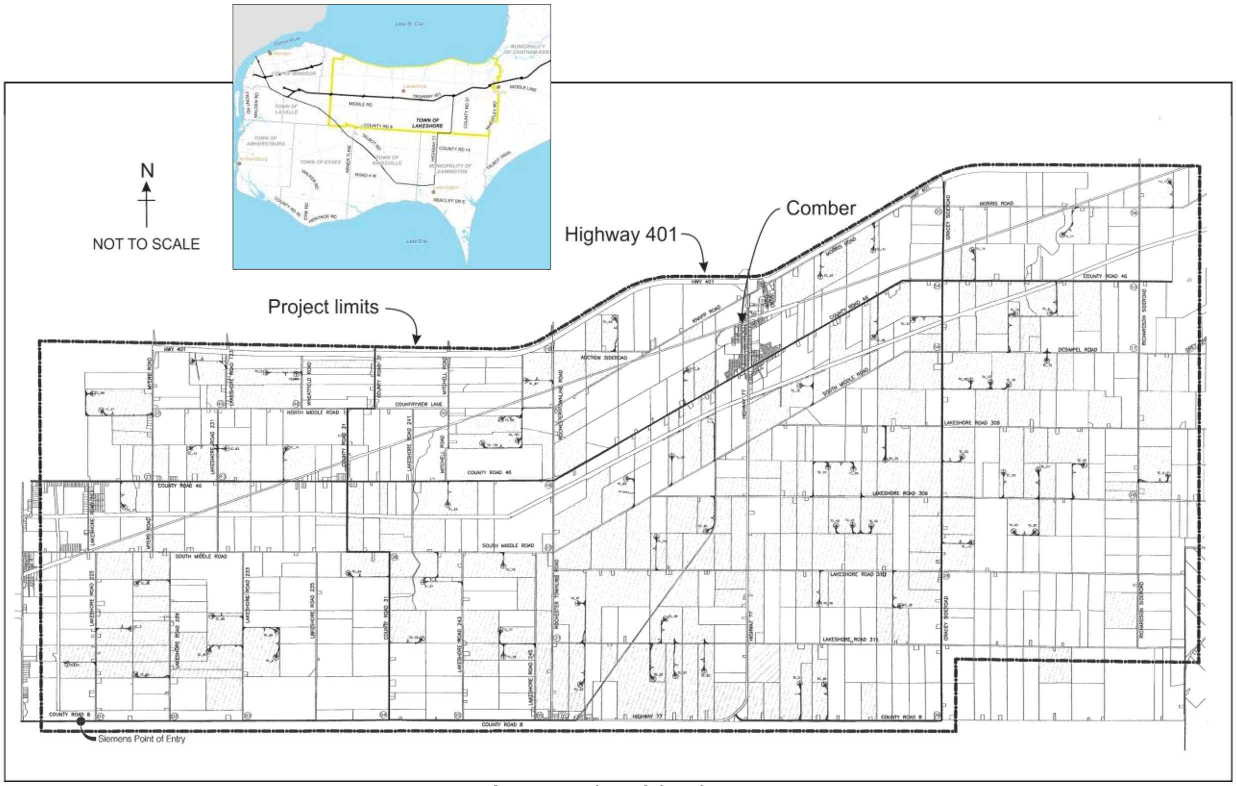


Figure 1. Plan of the site.

Context of the project

The terrain in the Lakeshore area is flat (Figure 2) and the rural road network is laid out predominantly on a rectangular grid, crossed by two rail lines (Figure 1). The site is bounded by Highway 401 to the north and County Road 8 to the south, and west to east, it extends from just east of the Town of Essex to just west of the Town of Tilbury. Of the roads designated for use to support construction and for hauling components to the turbine sites, a total of 55 segments was identified for analysis. Their surface types were as follows:

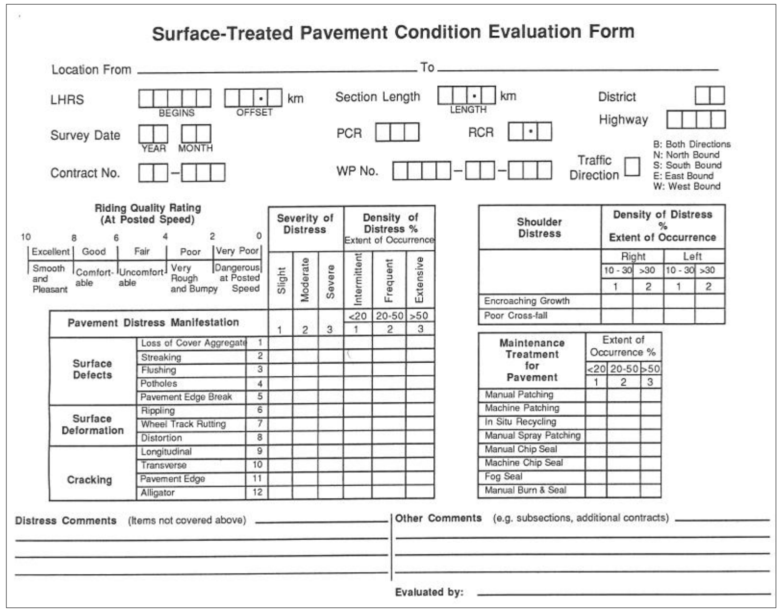
- Asphalt 15 segments
- Surface treated 21 segments
- Gravel surfaced 19 segments

Figure 2. The terrain is flat.

FIELD WORK PROGRAM

Pavement health is reflected in four aspects [1]: distress, structural capacity, roughness, and safety (usually taken as skid resistance). Any deterioration of the roads that might be attributed to the activities of the wind farm project would result in additional distress to the pavements, and/or a change in structural capacity. Distress was selected for the field evaluation of the roads over roughness and skid resistance because changes in roughness would also be reflected in certain distresses and skid resistance provides only a narrow view of pavement health.

Rather than perform an expensive detailed distress survey with randomly selected sample plots and measured distress severities and densities, a visual survey was considered sufficient. Procedures laid out in three Ministry of Transportation of Ontario (MTO) manuals [2], [3], [4], were followed in field work carried out in October of 2010. Each pavement section was evaluated for the severity (how bad) and density (how much) of each distress observed, and the results recorded on standard MTO forms (Figure 3). Examples of distresses are shown on Figure 4 (next page).



Surface-Treated Pavement Condition Evaluation Form

Location From ____________ To ____________

LHRS [BEGINS] [OFFSET] km   Section Length [LENGTH] km   District

Survey Date [YEAR] [MONTH]   PCR   RCR   Highway

Contract No.   WP No.   Traffic Direction   B: Both Directions, N: North Bound, S: South Bound, E: East Bound, W: West Bound

Riding Quality Rating (At Posted Speed)

10 – 8	8 – 6	6 – 4	4 – 2	2 – 0
Excellent	Good	Fair	Poor	Very Poor
Smooth and Pleasant	Comfortable	Uncomfortable	Very Rough and Bumpy	Dangerous at Posted Speed

Pavement Distress Manifestation			Severity of Distress: Slight	Moderate	Severe	Density of Distress % Extent of Occurrence: Intermittent	Frequent	Extensive
						<20	20-50	>50
			1	2	3	1	2	3
Surface Defects	Loss of Cover Aggregate	1						
	Streaking	2						
	Flushing	3						
	Potholes	4						
	Pavement Edge Break	5						
Surface Deformation	Rippling	6						
	Wheel Track Rutting	7						
	Distortion	8						
Cracking	Longitudinal	9						
	Transverse	10						
	Pavement Edge	11						
	Alligator	12						

Shoulder Distress	Density of Distress % Extent of Occurrence: Right 10 - 30	Right >30	Left 10 - 30	Left >30
	1	2	1	2
Encroaching Growth				
Poor Cross-fall				

Maintenance Treatment for Pavement	Extent of Occurrence %: <20	20-50	>50
	1	2	3
Manual Patching			
Machine Patching			
In Situ Recycling			
Manual Spray Patching			
Manual Chip Seal			
Machine Chip Seal			
Fog Seal			
Manual Burn & Seal			

Distress Comments (Items not covered above) ____________

Other Comments (e.g. subsections, additional contracts) ____________

Evaluated by: ____________

Figure 3. Field data collection form for surface treated road condition survey [3].

To assess the structural capacity of the roads, falling weight deflectometer (FWD) testing was performed. A Jils 20 FWD unit was used to measure pavement deflection at a typical interval of 200 m in each lane, staggered by 100 m. Loads of 30, 40, and 50 kN were used, and the results normalized to 40 kN at 21°C according to the MTO MERO-019 FWD Testing Guideline. Gravel roads were not tested with the FWD apparatus.

A visual record of the road sections was collected, using still digital photography and video. Care was taken to identify each image's road, location, and orientation.

Figure 4. Typical distresses.
(a) flushing in surface-treated pavement
(b) rutting in asphalt pavement
(c) alligator cracking in asphalt pavement.

(a)

(b)

(c)

RESULTS

For the purposes of this paper, the visual distress results were extended into the calculation of the pavement condition index (PCI). The PCI is essentially a normalized weighted average of the distresses' severity and density ratings. Equations 1 and 2 [2] were used to calculate PCI for asphalt, surface-treated, and gravel-surfaced roads:

Eq. 1

$$DMI = \sum_{i=1}^{N} [(S_i + D_i) \times W_i]$$

Eq. 2

$$PCI = 100 \times (0.1 \times RCR)^{1/2} \times \frac{A - DMI}{A} \times 0.92 + 8.9$$

Where:

DMI	=	damage manifestation index
S_i	=	severity of the i^{th} distress
D_i	=	density of the i^{th} distress
W_i	=	weighting factor for the i^{th} distress
PCI	=	pavement condition index ($0 \le PCI \le 100$)
RCR	=	ride condition rating
A	=	a constant (= 260, 135, and 75 for asphalt, surface-treated, and gravel surfaces)

The RCR is a measure of road roughness, rated on a scale of 0 to 10. It is rated by staff driving the road at the posted speed limit. During the fieldwork, no RCR data was recorded; in order to estimate PCI for this paper, RCR has been assumed to be 10 in all cases. As a result, all calculated PCI values will be slightly high compared to the value that would be calculated with the inclusion of an RCR value. Table 1 provides a summary of the calculated PCIs.

Table 1. PCI and FWD deflection data.

Pavement surface type	Distress			Structural capacity: FWD measurements		
	Number of observations	Mean PCI	Standard deviation of PCI	Number of observations	Mean normalized deflection (mm)	Standard deviation of the mean normalized deflection (mm)
Asphalt	15	83	12	7	0.38	0.16
Surface-treated	21	69	13	14	0.93	0.27
Gravel-surfaced	19	78	10	Gravel-surfaced roads were not tested for FWD deflection		

The FWD data is summarized in Table 1.

DISCUSSION

The visual distress data is summarized on Figures 5, 6 and 7. The results are expressed as the observations of each stress, normalized as a percentage of the total number of observations for that road surface. Severity and density were not accounted for – one observation was counted for a distress of any severity or density.

Asphalt

Distresses:

1 Ravelling and coarse aggregate loss
2 Flushing
3 Rippling and shoving
4 Wheel track rutting
5 Distortion
6 Longitudinal wheel track cracking – single and multiple
7 Longitudinal wheel track cracking - alligator
8 Centreline cracking – single and multiple
9 Centreline cracking - alligator
10 Pavement edge cracking – single and multiple
11 Pavement edge cracking - alligator
12 Transverse cracking – half, full and multiple
13 Transverse cracking - alligator
14 Longitudinal, meandering and midlane cracking
15 Random cracking

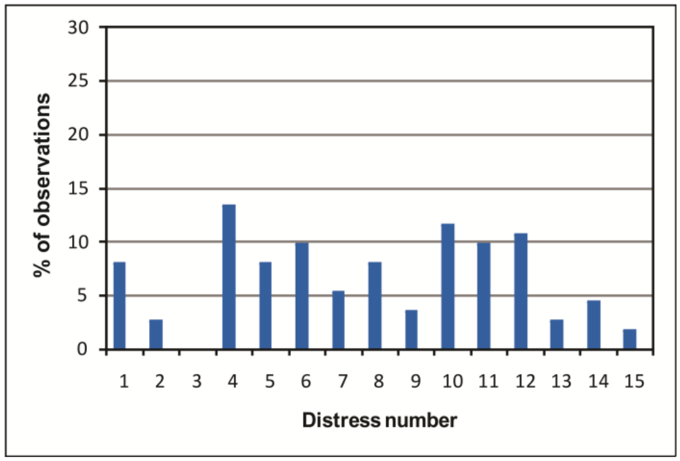


Figure 5. Distress observations, asphalt-surfaced roads.

For the asphalt-surfaced roads, Figure 5 indicates that wheel track rutting, single and multiple pavement edge cracking, transverse cracking, single and multiple longitudinal cracking, and alligator edge cracking were dominant distresses. Missing or infrequently observed were rippling and shoving, random cracking, flushing, transverse alligator cracking, and centreline alligator cracking.

Surface-treated

Distresses:

1 Cover gravel loss
2 Streaking
3 Flushing
4 Potholing
5 Pavement edge break
6 Rippling and shoving
7 Wheel track rutting
8 Distortion
9 Longitudinal cracking
10 Transverse cracking
11 Pavement edge cracking
12 Alligator cracking

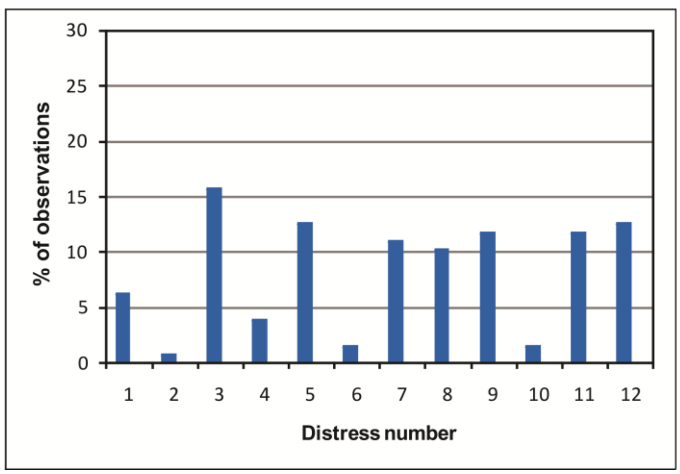


Figure 6. Distress observations, surface-treated roads.

Surface-treated pavement distress data is presented on Figure 6. A significant number of observations of all distresses were made with the exception of streaking, rippling and shoving, transverse cracking, and potholing.

Gravel

Distresses:

1	Loose gravel
2	Dust
3	Potholes
4	Breakup
5	Washboarding
6	Rutting
7	Flat or reverse crown
8	Distortion

Figure 7 shows the distress observation data for gravel-surfaced roads. Significant numbers of observations of loose gravel, washboarding, potholes, dust, and distortion were made, while little or no flat or reverse crown, breakup, or rutting were observed.

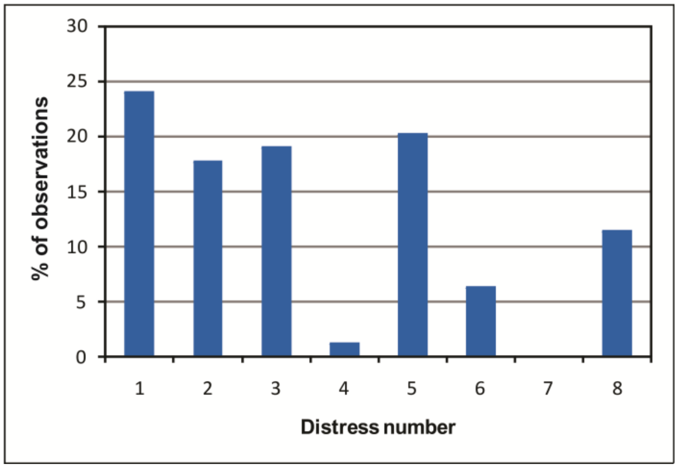


Figure 7. Distress observations, gravel-surfaced roads.

PCI – FWD correlation

It was of interest whether pavement distress, indicated by PCI, correlated well to structural capacity, measured by FWD deflection. If there is a good correlation, relatively inexpensive and low-technology distress surveys could provide the needed pavement condition information, and FWD deflections then estimated via the correlation.

The FWD-PCI data was paired up and graphed, Figure 8. To pair up the data, mean FWD deflections were calculated for the lengths of road sections identified in the distress survey. FWD testing was not performed on gravel surface roads. A total of 36 points was plotted.

The combined set of data for the asphalt and surface-treated pavements is plotted on Figure 8. The asphalt pavement points extend the trend set by the surface-treated pavements into the low-deflection, high-PCI region of the graph. Linear regression results in an r^2 value of 0.23, indicating weak correlation. The trend does go the expected way (greater deflection, lower PCI), however. It must be recalled that the PCI values are artificially high, because with no RCR data recorded, RCR was arbitrarily set at 10.

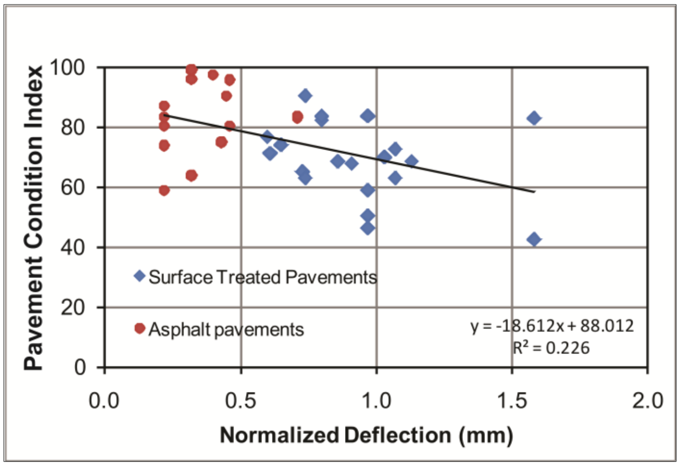


Figure 8. Correlation of PCI to FWD deflections.

THE NEXT STEPS

At the time of writing this paper, turbine construction activities had just begun. It is anticipated that construction will take approximately a year. Once hauling is complete, a distress survey should be performed again, and FWD testing carried out after the spring thaw. Comparisons should be made between the baseline data and the final data. The comparison can be made in a number of ways:

- qualitative assessment made by comparing still and video photography;
- quantitative comparison of PCI values (recall that the before-hauling PCI values were calculated with an assumed RCR = 10);
- quantitative comparison of normalized FWD deflections; and

- quantitative and qualitative comparisons of distress observation plots such as Figures 5, 6, and 7.

An important issue to note, particularly if hauling for construction extends over greater time, is that there would have been some deterioration of the roads even had there not been hauling for the project over them. This is particularly true of the gravel-surfaced roads, less so for the surface-treated roads, and even less for the asphalt roads, based on their respective service lives. The application of deterioration models can be used to assist in sorting out the "natural" deterioration from that caused by the heavy hauling operations.

CONCLUSIONS

Based on the work done to prepare the baseline data for the project, the following can be concluded:

- well-planned, inexpensive field programs can provide the required background needed for such a project;
- distress and structural capacity are reasonable indicators of pavement health to use, more so than safety (skid resistance) and roughness – they give a more complete picture of whether the condition of the pavement has been affected by the hauling activities;
  in future, RCR should be recorded during the pavement condition survey to enable the calculation of the PCI for each road segment;
- a comparison of the PCIs on each road segment before and after construction activities can be used as an indication of any deterioration caused by project traffic;
- the background deterioration that would have occurred if there had been no project traffic should be taken into account when determining how much of the deterioration of the roads should be attributed to project traffic; and
- PCI and FWD deflections correlate weakly (r^2 = 0.23) – this potential relationship should be investigated further.

ACKNOWLEDGEMENTS

The permission of the Town of Lakeshore to publish the results of the investigation is gratefully acknowledged.

DISCLAIMER

Any opinions expressed in this paper are solely those of the authors, not Golder Associates Ltd.

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