Comments and responses for proposed precision milling amendments to OPSS 510. Some similar comments have been combined.

C1: 510.04.02.01 f) Certification that the DDM meets the requirements of the Contract Documents, including cross fall.
- To the best of our knowledge, the contracts only stipulate an absolute cross fall and superelevation.
We suggest that a tolerance for each be stipulated because all would agree that an absolute 2% cross fall or 8% superelevation cannot be exactly satisfied in every instance.
We suggest a tolerance of +/- 0.3%.
- This would ensure that all boundary constraints such as residual asphalt thickness, drainage and appurtenance matching (curbs, catch basins etc.) could be achieved.
- this tolerance could be in this spec or elsewhere in the contract documents and drawings.

R1: Separate cross slope tolerance specification in development.

C2: 510.07.06.04.02 Operational Constraints
- The second paragraph we believe is intended to describe the crossfall at each station and not the smooth transition between stations that will be often required. Some clarification can be achieved with the following wording.
-The surface remaining after removal shall have a constant and continuous crossfall at each station with a smooth transition where crossfall transitions are required between stations.

R2: Agree with proposed wording, document updated.

C3: 510.07.06.04.03 Road Surface Survey
- This is a critical step that significantly affects the overall outcome of the DDM and the final surface achieved after milling
- The relationship between the survey registration points and the existing geodetic control monuments is appropriate at 4 mm in the vertical direction.
- The relationship between the adjacent registration points must be to a higher level of accuracy to ensure that an 8 mm error does not arise between adjacent registration points
- A+/- 2mm difference between adjacent registration points with a +/- 8mm difference per km between registration points is necessary. This can will be achieved/checked by running a closed leveling travers.

The definition of the vertical accuracy of Survey Registration as tolerance of +/- 4mm with respect to existing geodetic control is not sufficient. This definition would allow 8mm vertical difference between the adjacent registration points.
We propose this standard and commonly used definition among surveyors has to be added to existing definition: The accuracy of the differential leveling must be demonstrated by calculating a closed leveling traverse that must not exceed 8 mm per 1

km or/and +/- 2mm difference between adjacent registration points.
The selection of the locations (STA) where these quality "control cross section" measurements will be taken must be predefined and must not depend on the contractor's choice.
We suggest, for example, a midpoint between the survey registration points with a position tolerance STA +/- 10m; where maximum errors are assumed.
“An automatic machine guidance (AMG) system shall be installed on the milling equipment used for the work of removal of partial depth asphalt pavement removal. The AMG system shall be capable of precise three-dimensional control of equipment movement using satellite and local referencing.” Does this mean the need for base stations or something else?
“The AMG system and digital machine control file shall automatically control the milling equipment such that the existing asphalt pavement is partially removed over its entire surface to match the vertical dimension of the DDM milled surface to within a ±5 mm tolerance.”
Does MTO have data to confirm this is constructible?

“The Contract Administrator will carry out total station measurements of the milled surface to verify the ±5 mm tolerance is met.“
If the QC and QA measurements differ, will a referee system be available to the contractor to rectify?
“The survey registration points shall be referenced to the Owner’s geodetic control and benchmarks at the limits of the removal of asphalt pavement, partial depth. The geodetic control and benchmarks used shall be sufficiently distant from construction operations to be protected from disturbance.”
Will geodetic information be available, practical, and readily accessible for all MTO contracts where this specification is employed?
“A high-density survey of the existing asphalt pavement surface area using high accuracy methods shall be used to collect a minimum of 1000 measured points / m2 or of higher density as required to meet the standard deviation requirements specified herein. Each point shall be measured in three dimensions. The high-density survey shall be registered to the surveyed registration points.”
This is extremely high and will consume a huge amount of data with no advantage. A milling machine cannot change and react to even 1 point per m2. Why was this resolution selected? Check with manufacturers for verification.

R3: Section adjusted to address comments

C4: 510.07.06.04.04 Digital modelling
-The standard deviation of the calculated elevation difference for all the points at each cross section location shall not exceed 8mm.
- In general the tolerance is usually 2.5 times the standard deviation **https://en.wikipedia.org/wiki/68%E2%80%9395%E2%80%9399.7_rule**).
- This standard deviation is equal to a tolerance of +/- 20mm at a 98% confidence (and +/- 24mm at a 99% confidence)
- This tolerance can result in a 20mm elevation difference between the centre line and

the edge of pavement which translates into a 0.6 % cross fall error that will not meet the desired outcome but will satisfy this specification requirement. See diagram below.
-we recommend that the standard deviation be at 3 mm which has been demonstrated to be achievable and provides the desired outcome
- the tolerance will become 7.5 mm at the limit and the cross fall error will be reduced by more than half
- this was our original suggestion at the first drafting of the spec
- There must be a precise definition of the location of the control cross-section. This cross-section should also be approximated at the midpoint of the distance between survey registration points (where the maximum errors is assumption).

A check of the accuracy of the DRSM that is made by measuring the "control cross section" must meet a better criterion than the currently defined 8mm standard deviation of elevation differences, as this could lead to an error in slope of 0.7% or more out of the figure. Standard deviation of 8mm could result in elevation differences up to 24mm – please see attached drawing.
We suggest 3 mm standard deviation which is achievable with reasonable effort and reduce implementing of huge error from all beginning of entire process.
“The standard deviation of the calculated elevation differences for all the points at each cross-section location, σz, shall not exceed 8 mm.”
Does this coincide with the 4 mm tolerance in 510.07.06.04.03?
“A DRSM meeting the standard deviation accuracy requirement shall be used to create a digital design model (DDM) of the milled surface resulting from the removal of asphalt removal, partial depth work, and the subsequent layer(s) of asphalt materials to be placed.”

R4: Section adjusted to reflect comments

C5: 510.07.06.04.05 Automated Machine Guidance

6. This specification is new and when fully implemented after beta testing on several projects, contractors will be able to replace their millings fleets with equipment that can fully achieve the objectives and goals of this specification. In the mean time the specification should allow milling machines that use only local ground referencing systems.

High quality but older milling machines cannot be equipped with automatic milling depth control. For example, for accurate milling according to the 3D model, manual input is sufficient based on the milling depth information displayed on the tablet display depending on the GPS position (stationing). manual input can have the same accuracy as automatic input and should not disqualify such a system.

Suggested change: "... shall permit accurate compliance with the depths and slopes of milling in accordance with the DDM.

R5: Prefer to keep current wording as the NSSPs will be used only on trial basis in the short term. Equipment requirements will be revisited as experience is gained and the specification is more broadly used.

C6: Similarly, some manual intervention will be required on some milling machines that can still use the 3D model to achieve the precision milling. Until existing fleets can be replaced, the specification should just rely on the stipulated requirement to achieve a milling tolerance of +/- 5mm from the DDM.

The "3D Guidance" of the machine language needs revisited. The guidance for the machine should not be dictated by method but by accuracy. Machine control systems today provide "variable depth and slope", but don't steer the machine. If the intention of the spec is to say that the machine is controlled both vertically and horizontally, we think this is unachievable.

As a point of clarity, the depth and slope are controlled automatically, the horizontal position of the mill is still up to the operator and the design will reflect the mill position accordingly.

We suggest stating the expected accuracy of the system in both the horizontal and vertical and allow the contractor to select the guidance that will meet or exceed that specification.

R6: Further prescribing the capabilities of the milling machine would not be of great benefit as ultimately the contractor needs to be able to meet the 5mm tolerance on the milled surface.

C7: This section stipulates that “The Contract Administrator will carry out total station measurements of the milled surface to verify that the +/- 5mm tolerance from the DDM tolerance is met".

The location and number of measurements to be take are not specified. We recommend that the number of either individual shots or total cross sections be stipulated per kilometre. We also suggest that the location be selected on a random basis to eliminate any bias in the selection of the locations. This approach should reduce, if not eliminate any disputes between the CA and the contractor.

R7: Section updated to require a minimum of 12 locations on a contract to be surveyed, similar to QC requirements.

C8: 510.07.06.04.03: This section starts by stating that MTO survey specifications do not need to be met, but that the “work should be sufficient to achieve the specified accuracy requirements.” This could potentially lead to intended results, but what follows leaves too many questions and could result in unintended and unacceptable results.

- The accuracy requirement state that “The registration points shall have a horizontal accuracy of 30 mm and a vertical accuracy of 4 mm established by digital differential leveling with respect to existing geodetic control at 95% confidence.” Some problems result with this.

o 1. Given the poor state of control monumentation in Ontario, the chances of finding two existing geodetic control monuments that agree with each other within a few cm is slim. Given that these projects benefit from high accuracy, and there seems to be no useful benefit to force control to fit all control points, the specifications should state that one geodetic benchmark should be held as fixed, and elevations should not be adjusted to fit other benchmarks. The surveyor establishing the original control points should provide a report outline what points were held to constrain the coordinates of the control points along with the adjusted coordinates, accuracy (95%) and a sketch or drawing showing their locations.

o 2. The way the accuracy requirement is currently stated (“horizontal accuracy of 30 mm and a vertical accuracy of 4 mm established by digital differential leveling with respect to existing geodetic control at 95% confidence”) could suggest the accuracy is defined as either absolute accuracy or perhaps relative accuracy relative to a benchmark that may be far away. Potentially one point could be 4 mm high and the next point (less than 150m away) could be 4 mm low. Having such large differences in a short span could potentially have a significant detrimental effect on the project outcomes. Given that the requirement is to establish the elevations with a digital level, a better method is suggested to state the accuracy as something like 8mm per km. This would be easy to demonstrate in each level loop closure and ensure that any elevation errors between adjoining survey registration points are kept small.

o 3. Despite the preceding point, section 510.07.06.04.04 (Digital Modelling) includes “The standard deviation of the calculated elevation differences for all the points at each cross section location, σz, shall not exceed 8 mm.” Is the actual intent here to refer to the elevation difference defined earlier as Δz? Assuming normal distribution, specifying a standard deviation of 8mm could result in elevation differences up to 24mm.

- 4. The third paragraph starts with “The survey registration points shall be referenced to the Owner’s geodetic control and benchmarks at the limits of the removal of asphalt pavement, partial depth.” The meaning of the bold text should be made clear.

- 5. Given that this paragraph is about the survey control that will be relied upon in subsequent stages, it would likely be better to state the accuracy requirements here. Otherwise, if any accuracy questions come up with the registration points, high density survey, or quality control cross sections, one could potentially question the accuracy of the control points used. Perhaps it would be good enough to use

redundant/independent RTK or NRTK GNSS surveys to establish the horizontal locations and to use a digital level in closed loops with to establish elevations. The vertical accuracy requirement should be specified at a higher level than the accuracy for the survey registration points. (e.g., if the survey registration points accuracy is specified to be 8mm/km, the control points should be specified at 4 mm/km).

- 6. There are no details about how the quality control cross sections will be done other than that they can be done with a total station. It is suggested that it be stated that these total station surveys will be tied to multiple points from the original survey control points, and each cross section identify the survey control points used and any observed residuals. This will provide confidence in the validity of the data produced by the total station surveys.

- 6. As indicated on multiple points above, the specifications around the survey cross sections are confusing. It has been considered that section 510.07.06.04.04 uses standard deviation because it may be acceptable if a cross section is consistently offset from the DRSM. If that is indeed acceptable, one would expect the maximum permitted standard deviation to be close to 2 or less. Also, if a consistent offset between cross sections is potentially acceptable, one would expect that there would be an additional test to ensure that adjoining cross sections give similar results. If one cross section is consistently 6mm high and the next is 6mm low, then the overall accuracy of 8mm/km could not possibly be met.

- The following points may capture the intent of the cross sections. (Accuracy specifications are included as examples only and may not represent the real accuracy requirement.)

  - QC cross section measurements will be made (at specified intervals) by total station measurements. The total station setup coordinates and orientation will be established from 2-face resection observations to 3 or more control points. Maximum allowable residuals for station coordinates will be 2 mm vertical and 20 mm horizontal.

  - Measurements will be taken along the cross section at 100 mm or less spacing.

  - Cross sections will be taken roughly halfway between survey registration points. (Given that the DRSM is constrained by these points, it would be better to check areas where errors could be higher)

  - The elevation differences between each measured point and the interpolated elevation at the corresponding point of the DRSM (Δz) will be labelled on a plot of the cross section. The plot will use sufficient vertical exaggeration to clearly show any difference in the sections.

  - The average elevation difference (Ave Δz) and standard deviation (σz) will be shown for each cross section.

o The maximum permitted average elevation difference at a cross section is 2 mm, and the maximum allowable average standard deviation is 2 mm.

R8: Section updated to address above concerns.

C9: 510.07.06.04.05 This section contains specifications on accuracy but lacks details on how the accuracy is to be determined other than “The Contract Administrator will carry out total station measurements of the milled surface to verify the ±5 mm tolerance is met”.

- The “Contract Administrator” is not defined. If it is important that this requirement be met, I would suggest that an Ontario Land Surveyor be specified.
- A similar method to the method suggested for the total station cross sections is suggested. Given that the milled surface will be grooved and potential for “noise” in the resulting data, an additional requirement could be made that the top of the milled surface be used for elevations. (This can be easily achieved by using a “boot” on the bottom of a standard prism pole.)

R9: Additional wording provided to address concerns. Contract Administrator is defined in the General Conditions.

C10: The NSSP is a step in the right direction because it will reduce emissions due to construction ion by reducing milling time and hauling away cuttings from the milling.

It will also lead to better rehabilitated highways.

The specification requires the contractor to perform surveying and design prior to undertaking milling. These activities require time during the contract. The amount of time is a function of the highway complexity, 2 lane rural hwy, 4 lane divided highway urban or rural freeway with interchanges etc.

Designers and the Ministry must recognize that the survey and design requirements will inherently add time to the duration of the contract. The additional time must be considered when determining contract working days or completion dated as well as the actual advertising and award dates. The notes to designers should include this comment.

R10: Comment noted.

C11: 510.07.06.04.05 The final definition for checking the correct milling depths (510.07.06.04.05) according to the DDM, which must meet +/-5mm, should be better described and should include checking the milled slope to match the design slope according to the DDM at that location. The DDM check of cross slopes is very important because it involves not only checking the AMG function and milling machine calibration, but also checking that the DRSM has been well measured and that the slope correction has been correctly designed in DDM.

R11: Wording added to address comment

C12: 510.04.02.01: “The DSRM shall be digitally sealed and signed by an Ontario Land Surveyor or Engineer with specialist training in Geomatics”.
Can this not be sealed and signed by a P. Eng. instead?

R12: This is not a design document so engineer should not seal

C13: Will MTO be developing and providing contractors a list of licensed Ontario Land Surveyors qualified for this work who are acceptable to the MTO?

R13: We do not intend to do this.

C14: 510.07.06.04.02: “After partial depth removal, the gap between the top of milled surface and the bottom of a 3 m straightedge placed anywhere in any direction on the milled surface shall not exceed 6 mm.”
Top of milled groove, correct? What about the distance between the bottom and top of milled groove?

R14: Wording clarified, should be top of milled groove

C15: “The surface remaining after removal shall have a constant and continuous crossfall matching the design milled surface crossfall. The milled surface shall have an even texture and be free of significantly different grooves and ridges in all directions.”
To what tolerance?

R15: Tolerance is not required to be specified. Any visible inconsistencies would likely indicate that the 5mm surface tolerance is not being met.

C16: It doesn’t seem the spec., considers the road scanning requirement of a tripod mounted total station, why?
Perhaps this should be spec'd as an accuracy and not a method. If mobile scanning can meet or exceed the intended accuracy (both in terms of horizontal and vertical accuracy, but also in point density) then it should also be allowed, right?

R16: Addressed in updated language in 510.07.06.04.03

C17: Will the MTO be performing preliminary design prior to tender to ensure the final design is achievable?

R17: Yes, projects will be screened for suitability of use of this special provision

C18: How will MTO determine whether the contract will be a contractor-provided survey or MTO provided survey?

R18: On Design Bid Build contracts survey info will be provided by MTO. On Design Build contracts obtaining survey information will be responsibility of the contractor.

C19: What type of contracts will MTO be utilizing this specification on? Ie. freeway, 2 lane rural, etc. Will line of sight to geodetic benchmarks be consistently available?

R19: Locations will be evaluated for suitability of the use of this special provision.

C20: Finally, re. “INSTRUCTIONS TO DESIGNERS”
Warrant: “Sufficient pavement depth to limit risk of “punch-through” to granular base by variable depth / optimized milling”
This is very critical! There have been many historical contracts where the existing HMA thickness was not sufficient to accommodate the specified milling depth.

R20: Noted