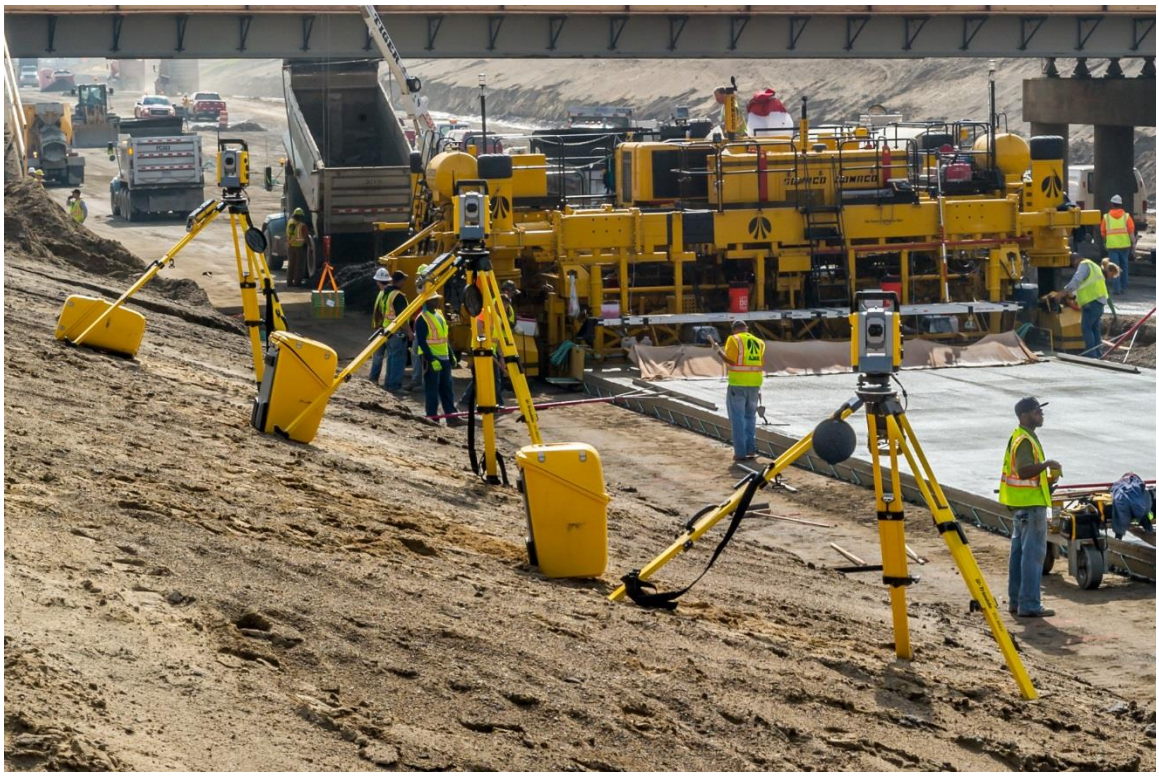

Automated Machine Guidance

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Glossary of AMG Terminology

AMG – Automated Machine Guidance (AMG) is the process of automatically adjusting the motion of a machine with an onboard computer that obtains its position from Global Positioning Systems (GPS), robotic total stations, lasers, or combinations of these technologies while referencing a digital model for the project.

BASE STATION – A stationary GPS receiver set up at a known location, used to derive correction information for nearby portable GPS receivers (rovers).

CONTROL

> **PROJECT CONTROL** – Survey monumentation with known three dimensional values relative to the project datum. This control is established by the Engineer prior to construction, per subsection 104.09.A of the Standard Specifications for Construction.
>
> **AMG CONTROL** – Survey monumentation with known three dimensional values relative to the project datum specifically established for AMG operations. This control is densified from the Project Control.

3D ENGINEERED MODEL – A digital model created by the design Engineer in conjunction with contract documents. This model is essentially an electronic version of the plans which can be used for validation of the contractor's model and for comparison to quality assurance measurements made by the Engineer. (Such models are also referred to as a 'surface' or 'digital terrain model' (DTM).

CONTRACTOR MODEL – A digital model created by the contractor to construct the project. This model is used to drive AMG systems and for comparison to quality control measurements made by the contractor.

GLOBAL POSITIONING SYSTEM (GPS) – A navigational system using satellite signals to determine precise locations on the surface of the earth. This technology is frequently used by AMG systems.

GRADE – A term used in general to define the elevation of a point. Often used in combination with other terms such as 'Plan Grade' or 'Finish Grade'.

LASER AUGMENTED GPS (LAGPS) – A combination of laser augmentation and GPS technology used to determine 3D location. Horizontal positioning is determined with GPS and vertical positioning by laser augmentation.

LOCAL TRANSFORMATION – The local transformation process establishes the relationship between WGS-84 data collected by GPS and local control points.

RESECTION – The method of fixing the position of a point by making angular observations to at least three fixed control points.

ROBOTIC TOTAL STATION – A total station that can operate independently and can automatically track and measure to a prism that is moving throughout the project.

ROVER – A mobile positioning tool used in conjunction with a stationary GPS base or total station to determine random positions. (Typically a mounted GPS receiver or prism that communicates with a base or total station to determine its coordinate values in real time.)

STRINGLESS PAVING – The operation of concrete slip form paving or bituminous paving that employs the use of a robotic total station and AMG equipment to eliminate the need of a string line to guide the paving machine for line and grade.

General

The Department has embraced the technological advancements of the construction industry and is constantly seeking to facilitate further advancements in technology. These advancements enhance the ability of the contractor to construct projects faster and with improved precision, which translates to more efficient use of resources. In order to meet the demands of advancing technology and to ensure uniformity in procedures, the methods and policies presented in this section should be followed.

Automated Machine Guidance (AMG) is the process of automatically adjusting the motion of a machine with an onboard computer that obtains its position from Global Positioning Systems (GPS), robotic total stations, lasers, or combinations of these technologies while referencing a digital model for the project. This procedure can be used to automate operations such as earth excavation, material placement, grading, trimming and/or paving.

AMG projects are often referred to as "stakeless" or "stringless" projects as these methods have the ability to eliminate the need for traditional stakes for a large portion of the project. Based upon the AMG Special Provision in use, the Contractor can eliminate staking required in subsections 824.03.C and 824.03.D of the Standard Specifications for Construction. The reduced need for physical stakes on the project offers significant efficiencies to the Contractor. The Contractor's ability to eliminate stakes is dependent upon the AMG methods that are being employed for the project. AMG methods can be task specific and can vary in accuracy, so it is necessary to understand the differences.

AMG Application Table

Table 1: MDOT AMG Accuracy Guidelines

AMG Operation	Obtainable Accuracies	
	Horizontal	Vertical
GPS Machine Guidance	0.04 foot	0.07 foot
Total Station Machine Guidance	0.02 foot	0.02 foot
Laser Augmented GPS (LAGPS) Machine Guidance	0.04 foot	0.02 foot
Total Station Stringless Paving	0.02 foot	0.02 foot

Construction

1. Contractor's AMG Work Plan

The Contractor will develop and provide a work plan for AMG operations. This is provided prior to, or at, the preconstruction meeting. This is an important communication tool to inform the Engineer where, when, and how AMG will be employed on the project. It also designates the primary AMG contact. The AMG Work Plan Checklist below lists the minimum items that must be addressed in the plan. A template and sample *AMG Work Plan* can be found by using the following links:

AMG Work Plan Template

AMG Work Plan Sample

The Engineer must review the work plan and request additional information to clarify any concerns. The Engineer is encouraged to use this as a communication tool with the contractor for understanding how AMG will be implemented on a project, coordinating verification activities, etc. The Contractor's AMG work plan must be in PDF format and filed in ProjectWise at the following path: (***project folder\Construction\200- Field Records\Survey-201-2)*** and be named **XXXXXX_AMG_Work_Plan_20XX-MM-DD.pdf**

AMG Work Plan Checklist

AMG Work Plan Checklist			
	Yes	**No**	**Remarks**
Are all work items that will utilize AMG identified?			
Are the locations where AMG will be employed clearly defined?			
Do the accuracies of the proposed AMG operations meet the tolerance requirements for the items of work?			
Does the contractor provide past experience?			
Does the contractor provide a description of AMG equipment?			
Does the contractor address how equipment calibration is performed and the frequency of calibrations?			
Has the contractor addressed control densification?			
Does the plan identify who the AMG primary contact is?			

2. Survey Meeting

It is recommended that the Engineer hold a survey meeting prior to commencement of AMG operations. The purpose of the meeting is to discuss the implementation of the AMG work plan. The Engineer should seek clarification on the Contractor's AMG operations and procedures. This communication will be used to solidify verification efforts and additional AMG control needs. In order to obtain the Contractor's model and additional AMG control, the method of data exchange should be discussed and agreed upon (See Section 3.4: Sharing and Maintenance). The Engineer should discuss any concerns with the AMG operations and steps that will be taken for compliance issues.

Key personnel for this meeting should include: Department project personnel, Contractor AMG contact, Contractor model creator, surveyors, inspectors, etc.

3. Contractor Model

3.1 Professional Involvement

The Department requires a Professional Engineer or Professional Surveyor, licensed by the State of Michigan to provide oversight on AMG projects. This involvement is required to ensure that the designer's intent is captured in the Contractor's model and is an additional measure of quality control required for the project. Subsequently, any concerns relative to the design must be brought to the attention of the Engineer and resolved prior to the commencement of any AMG operations. The Contractor is required to provide a documented certification sealed by the Professional Surveyor/Engineer stating that the Contractor's model(s) accurately represents the contract documents. The Professional Surveyor/Engineer

is encouraged to provide additional detail regarding any areas of concern encountered during the creation and review of the Contractor's model.

3.2 Contract Documents and Reference Information Documents (RID)

The Contractor model should be based upon contract documents. If RID information is available for the project, it can be used or referenced for creation of the model. The Contractor is not prevented from utilizing RID information provided they agree to the liability disclaimer when accepting the information.

The Contractor must bring any differences found between the contract documents and the RID documents to the attention of the Engineer to seek clarification and/or resolution prior to working in the affected area. The following steps listed in **Figure 1** should be followed to resolve differences.

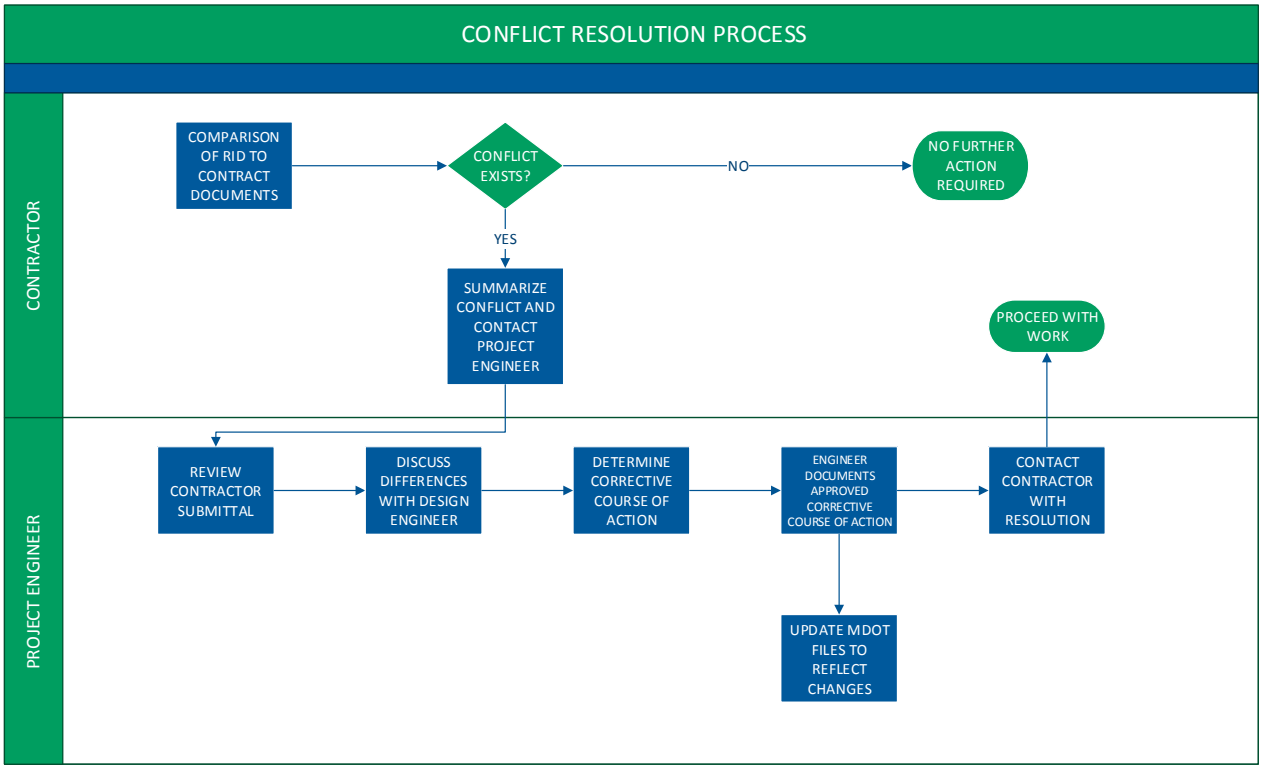

Figure 1: Conflict Resolution Process

3.3 Liability and Verification

The Contractor is solely responsible and assumes all liability for the creation of the Contractor's model. As such, the Contractor must verify the model reflects contract documents and field conditions.

3.4 Sharing and Maintenance – Contractor's Model

3.4.1 Sharing

The Contractor's model must be provided to the Engineer at least 10 work days prior to the start of any AMG operations. The Engineer should discuss with the Contractor how the model will be transferred. The finalized digital model will be submitted in a GEOPAK compatible format and also be provided in LandXML format. It is suggested that the Engineer and the Contractor use ProjectWise to exchange data. The data should be stored in the following location in the project folder: ***(Project Folder\Construction\200 - Field Records\Survey-201-2)***. The submitted model files will be named with the same naming

convention as the Model files in the RID documents. The standard naming convention can be found in Chapter 3 of the Development Guide. The Survey Support area is also a good source of information and can be contacted at MDOT-Survey_Support@michigan.gov

3.4.2 Maintenance

If there is a change in the Contractor's model then it is the responsibility of the Contractor to provide the updated data to the Engineer by posting it to the designated project path. It will be the responsibility of the Engineer to ensure that the updated data has been received and filed in the correct location. The exchange of data should be made as described above. The time frame for this submittal is established in the AMG Special Provision, however, a different time frame may be accepted by the Engineer depending on the scope of changes required.

4. Control

Project control is a network of physical control points with known X, Y, Z values relative to the project datum. It is comprised of vertical control points, also known as benchmarks, and horizontal control points. These points are necessary to construct any project. The Department is responsible, regardless of utilization of the AMG Special Provision or a *Contractor Staking* pay item, for providing control in accordance with subsection 104.09.A of the Standard Specifications for Construction prior to the start of the project. This work will be completed by Departmental staff or a consultant prequalified in construction staking. Horizontal and vertical control must be verified and/or established in accordance with the Department's current Design Survey Standards of Practice. The *Control Verification and Establishment Summary* form should be completed as part of this process. This form is used to summarize the procedures, instrumentation, monumentation, and results utilized during the establishment and verification of the project control.

For AMG projects, it is likely that additional AMG control will be needed to supplement the project control provided by the Engineer under subsection 104.09.A of the Standard Specifications for Construction. The level of densification and precision of AMG control is determined by such factors as the AMG equipment, associated pay items, accuracy requirements, and field conditions to name a few. Although variable, AMG control spacing will usually be in the range of 300 feet to 500 feet apart along both sides of the area where AMG is being utilized. Dependent upon the width of the road section and project staging, AMG control may need to be established multiple times throughout the course of the project. The responsibility of providing AMG control is dependent on whether or not the pay item of *Contractor Staking* is included in the contract. If AMG control is established by the Contractor, it is still the responsibility of the Engineer to verify the AMG control if the Department intends to use it for quality assurance operations. The *Responsibility Matrix* below is provided to assist in determining who is responsible for this task. If the densification of AMG control is completed by Department staff or a consultant prequalified in construction staking then the *Control Verification and Establishment Summary* form must be used in the process.

Control Establishment – Responsibility Matrix

	104.09.A Project Control	AMG Control Densification
CONTRACTOR STAKING (Pay Item Included in Project)	Engineer	Contractor
ENGINEER STAKING (No Contractor Staking Pay Item)	Engineer	Engineer

5. Contractor Responsibility

The Contractor's AMG operations can only eliminate staking required under subsections 824.03.C and 824.03.D of the Standard Specifications for Construction, provided that the Contractor's proposed AMG operation is specific to the requirements defined in those sections. Subsection 824.03.C covers slope stakes, subgrade stakes, undercut stakes, and clearing stakes and subsection 824.03.D covers pavement stakes. The Contractor's work plan must lay out the use of AMG operations to eliminate conventional staking for these items. A Contractor that is utilizing only GPS machine guidance may be able to eliminate staking items covered under subsection 824.03.C, but will still need conventional staking to cover subsection 824.03.D. A Contractor that is only performing stringless paving operations, which could cover subsection 824.03.D and portions of 824.03.C, will still need conventional staking for items not covered under subsection 824.03.C. Based on current AMG methods, a combination of AMG operations will be needed to completely eliminate conventional staking for both subsections 824.03.C and 824.03.D.

5.1 Contractor Quality Control

The Contractor is responsible for all necessary quality control during AMG operations to meet the prescribed tolerances for each associated pay item. The Contractor must follow the equipment calibration, frequency of calibrations, and methods that were identified in the submitted work plan. Normally, the Contractor will perform independent checks during and after AMG operations to ensure compliance. If tolerances are not met, the Contractor will suspend AMG operations and evaluate the areas of concern.

5.2 Contractor Suspension of Work and Investigation

Should the work be suspended due to failure to meet prescribed tolerances, the Contractor must provide a documented plan addressing the concerns to the Engineer. The plan must outline the reason the tolerances were exceeded and what is being done to resolve the problem. This plan must be filed accordingly and reviewed to ensure the problem has been addressed. Considering that an issue has been encountered, the Engineer must also document any deviations from the submitted work plan in case subsequent failures are encountered. Upon satisfaction, the Engineer must provide approval to the Contractor to resume AMG operations. It may be suggested to increase the frequency of quality control checks until confidence is fully restored in the AMG process. If subsequent failures are experienced, the Engineer must assess the need to suspend the Contractor's AMG operations and request conventional staking at no cost to the Department.

6. Quality Assurance

The Engineer is responsible for performing continuous and independent quality assurance. The Contractor's work plan must indicate which items of work contained within subsections 824.03.C and/or

824.03.D will be performed with AMG operations, as previously mentioned. This will dictate the items (slope stakes, subgrade stakes, undercut stakes, clearing stakes, and pavement stakes) where stakes will not be provided during construction due to AMG operations. The AMG operations may eliminate the need for the Contractor to place stakes for these activities, but it does not eliminate the need for quality assurance (QA) by the Engineer. It is strictly prohibited for the Engineer to use the Contractor's equipment during the QA process. Prior to field verification, the Engineer must first review the Contractor's model to independently verify that the model matches the contract documents. The Engineer does not provide approval to the Contractor based upon this review but this is a necessary step of the QA process. A list of the required elements that must be checked are listed in the RID Review Checklist which can be found in the Development Guide.

6.1 Reference Information Documents (RID) – Intended Use (By Department)

Considerable effort is made by Design staff to generate RID information, models and electronically engineered data. The Department intends that this information be used to aid in efficiency at the time of construction. RID data should be used by the Department and/or its direct representatives in performing QA and for understanding design intent. The user must verify the RID for correctness prior to use. The MDOT Survey Support Unit can assist Department staff in employing modern surveying technology and utilizing RID for verification.

6.2 Engineer Quality Assurance and Acceptance

The Engineer will ensure compliance of the finished surfaces with corresponding specifications for the material being placed or removed. The Contractor's AMG operations do not change current QA verification requirements. The Engineer must rely on the 2012 Documentation Guide (Minimum Acceptance Requirements for Materials Approvals and Documentation), contract documents, Standard Specifications for Construction, and the MDOT Construction Manual to determine the required frequency and accuracy for materials being placed or removed.

6.3 Quality Assurance – Team Composition

The approach to performing quality assurance on projects with AMG operations will be dependent upon the complexity of the project and AMG operations employed. Team composition will be unique for each project. Please contact the MDOT Survey Support Unit for further guidance.

6.4 Quality Assurance – Field Procedures and Reporting

6.4.1 Field Tool Selection

Different types of survey equipment and the methods selected to employ their use will have a profound effect on the level of accuracy attained. Therefore it is essential to select the proper equipment and apply the correct methods when utilizing survey technology for QA; see Table 2 for available tools and associated accuracies.

Table 2: MDOT Field Tool Selection

Field Tool	Obtainable Accuracies	
	Horizontal	Vertical
GPS Rover	0.04 foot	0.07 foot
Total Station	0.02 foot	0.02 foot
Laser Augmented GPS (LAGPS)	0.04 foot	0.02 foot

For assistance, please contact the MDOT Survey Support Unit.

6.4.2 Reporting

QA reports must be prepared electronically by the Engineer. The Engineer will make QA checks based at current requirements and will prepare daily reports of the QA results. The report must contain at a minimum the following information: station, offset, plan elevation, as-built elevation, and description of material checked. For sample forms and assistance please contact the MDOT Survey Support Unit.

6.5 Measurement and Payment - Electronic Model Revisions

In the event that a design change is required warranting a plan revision by the Engineer, the Contractor will have to update the Contractor's model. In order for compensation to occur, a work order must be approved by the Engineer. Note that not all plan revisions will constitute an update to the electronic engineered data / model used by the Contractor.

References

1.1. Web Based Training

The Federal Highway Administration provides self-paced introductory training course available at the following link:

http://www.fhwa.dot.gov/construction/3d/wbt.cfm

This training is the minimum required baseline for Department construction staff.

1.2. Modern Survey Technology for Quality Assurance

The MDOT Survey Support Unit provides the following training as part of the MDOT Technical Training Curriculum.

- Introduction to Surveying
- Introduction to Survey Equipment
- Construction Surveying