SUPERSEDED BY EB 23-024
EFFECTIVE 8/3/23

New York State Department of Transportation
ENGINEERING INSTRUCTION

EI 14-017

Title: **SPECIAL SPECIFICATION FOR INTELLIGENT COMPACTION CONTROL OF SOIL**

Target Audience:
- ☐ Manufacturers (18)
- ☒ Local Govt. (31)
- ☒ Agencies (32)
- ☐ Surveyors (33)
- ☒ Consultants (34)
- ☒ Contractors (39)
- ☐ _____( )

Approved: Robert L. Sack
Robert L. Sack, P.E.
Deputy Chief Engineer (Research)
20AUG14
Date

ADMINISTRATIVE INFORMATION:

- This Engineering Instruction (EI) is effective beginning with projects submitted for the letting of January 8, 2015.
- This EI does not supersede any other issuance.
- Disposition of issued materials: The information transmitted by this issuance will reside in the Special Specifications directory of the Toolbox Server.

PURPOSE: The purpose of this EI is to issue special specifications for Intelligent Compaction Control of Soil and Training for Intelligent Compaction Control of Soil.

TECHNICAL INFORMATION:

- Intelligent compaction uses rollers equipped with an integrated measurement system consisting of a highly accurate Global Positioning System (GPS), accelerometers, and onboard computer monitoring/reporting system to:
  - Maximize compaction efficiency
  - Reduce compaction variability
  - Optimize labor deployment and construction time
  - Identify non-compactable areas
  - Identify weak spots
  - Achieve uniform compaction with 100% surface coverage
- PIN Approval: The Intelligent Compaction Control of Soil and Training for Intelligent Compaction Control of Soil special specifications are to be approved on a project-by-project basis. Designers must send their request for approval to the Geotechnical Engineering Bureau (GEB) through the Regional Special Specification Coordinator as per Highway Design Manual (HDM) Chapter 21.
- These special specifications will be used on a trial basis to acquire experience and gather data so that, in the future, Intelligent Compaction may be used as an alternative to traditional compaction (with the associated Quality Assurance procedures). While this work is in the experimental stage, projects will be selected based on discussions between the Geotechnical Engineering Bureau, Regional Design and Regional Construction Groups.

TRANSMITTED MATERIALS:

- The following new special specifications:
  Item 203.03600017 Intelligent Compaction Control of Soil (US Customary)
  Item 203.03610017 Training for Intelligent Compaction Control of Soil (US Customary)

Item 203.0360--17 Intelligent Compaction Control of Soil (Metric)
Item 203.0361--17 Training for Intelligent Compaction Control of Soil (Metric)

BACKGROUND:

- Compaction is one of the most critical processes associated with constructing a highway pavement that can provide good long-term performance. The densification of the various layer materials achieved through compaction gives them the strength and stiffness necessary to withstand heavy traffic loading and some of the damaging effects of the environment. The conventional rolling equipment and techniques for achieving the target levels of compaction have worked reasonably well over the years. However, they have not been without their difficulties. The typical associated problems include non-uniformity derived from variability in the materials (particularly in the natural soil), poor control of moisture content in the underlying layers, and a lack of tools that provide feedback to the roller operator so that the roller pattern can be continually achieved.
- These problems have, in turn, resulted in lower productivity and higher costs during construction as well as reduced pavement performance, shorter pavement lives, and higher maintenance and rehabilitation costs. Over the last 10 years, there have been several major innovations in technology for highway pavement construction that will greatly revolutionize pavement construction. One of these innovations, identified by the FHWA Every Day Counts initiative, is Intelligent Compaction (IC), which is intended to address some of the problems associated with conventional compaction methods.

CONTACT: Questions or comments regarding this issuance should be directed to Randall J. Romer, P.E., of the Geotechnical Engineering Bureau at (518) 457-4714, randy.romer@dot.ny.gov. Questions or comments regarding the technical aspects of the special specification should be directed to Don Dwyer, P.E., of the Geotechnical Engineering Bureau at (518) 457-4724, don.dwyer@dot.ny.gov.

ITEM 203.03600017 - INTELLIGENT COMPACTION CONTROL OF SOIL
ITEM 203.03610017 - TRAINING FOR INTELLIGENT COMPACTION CONTROL OF SOIL

DESCRIPTION

This work shall consist of the compaction of embankment in place, using Intelligent Compaction (IC) rollers within the limits of the work as shown on the plans. The work also includes the Contractor providing project-specific data based on roller compaction parameters, stiffness, number of roller passes and other roller parameters that will provide ongoing quality control (QC) data to the Engineer. This work supplements the requirements of §203-3.03. C. *Compaction*. This specification does not alter the acceptance criteria for Embankment-In-Place.

The Contractor shall supply a sufficient number of rollers and other associated equipment necessary to complete the compaction requirements for the specific materials. The Contractor will determine the number of IC rollers to use depending on the scope of the project. The IC roller(s) may be utilized during production with other standard compaction equipment and shall be used for the evaluation of the compaction operations.

Definitions

Intelligent Compaction (IC): A process that uses vibratory rollers equipped with a measurement/documentation system that automatically displays and records various critical compaction parameters including, but not limited to an Intelligent Compaction Measurement Value (IC-MV) that is related to the compaction of in-place material, and the location and number of roller passes in real time during the compaction process. IC uses machine feedback measurements to assess the compaction process and to ensure optimum compaction is achieved through continuous monitoring of the operations as well as documenting the locations by the use of Real Time Kinematic Global Positioning System (RTK-GPS).

Global Positioning System (GPS): A space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth to determine the location in geodetic coordinates. In this specification, GPS is referred to all GPS-related signals including US GPS, and other Global Navigation Satellite Systems (GNSS).

GPS Base Station: A single ground-based system that consists of a GPS receiver, GPS antenna, radio and radio antenna to provide L1/L2 differential GPS correction signals to other GPS receivers within a range limited by radio, typically 3 miles in radius without repeaters.

Hand-Held GPS rover: A portable GPS radio/receiver for in-situ point measurements.

RTK-GPS: Real Time Kinematic Global Positioning Systems are based on the use of carrier phase measurements of the available GPS signals where a single reference station or a reference station network provides the real-time corrections in order to achieve inch-level accuracy.

GPS Representative: A person from the staff of either the GPS manufacturer or the roller manufacturer who is qualified to operate and instruct others in the use of the GPS unit being used on the roller at the project.

CONSTRUCTION DETAILS

Work shall not begin until the Engineer has approved the IC submittals and the IC equipment.

Equipment.

IC Rollers. The Contractor shall only use IC rollers listed on the Department's Approved List of Materials and Equipment. IC Rollers shall be submitted to the Geotechnical Engineering Bureau for evaluation. To be included on the Approved List, IC rollers shall meet the following specific requirements:

1. IC rollers shall be self-propelled single-drum vibratory rollers equipped with accelerometers mounted in or about the drum to measure the interactions between the rollers and compacted materials in order to evaluate the applied compaction effort. IC roller drums may be smooth or pad footed.
2. The output from the roller is designated as the Intelligent Compaction Measurement Value (IC-MV) which represents the stiffness of the materials based on the vibration of the roller drums and the resulting response from the underlying materials.
3. GPS radio and receiver units shall be mounted on each IC roller to monitor the drum locations and track the number of passes of the rollers. RTK-GPS radio and receivers are required to monitor the location and track the number of passes.
4. The IC rollers shall include an integrated on-board documentation system that is capable of displaying real-time color-coded maps of IC measurement values including the IC-MV values, location of the roller, number of roller passes, roller speeds, together with the vibration frequency and amplitude of roller drums.
5. The display unit shall be capable of transferring the data by means of a USB port.
6. An on-board printer capable of printing the identity of the roller, the date of measurements, construction area being mapped, percentage of the construction area mapped, target IC-MV, and areas not meeting the IC-MV target values.

Global Positioning System (GPS): The Contractor shall provide the GPS system (including GPS receivers on IC rollers and hand-held GPS receivers (Rovers)) that makes use of the same reference system that can be a ground-based base station or network-RTK, to achieve RTK-GPS accuracy. Examples of combinations are:

1. GPS receivers on IC rollers and hand-held GPS rovers referenced to the same on-ground base station.
2. GPS receiver on IC rollers and hand-held GPS receivers referenced to the same network RTK.

The goal of GPS requirements is to achieve accurate and consistent GPS measurements among all GPS devices on the same project. Conversions of GPS data need to be minimized to avoid errors introduced during the process.

Data Analysis Software: Standardized data analysis software shall be used for data analysis. The software program will utilize the exported IC-MV data from the IC roller for analysis of coverage, uniformity, temperature, and compaction values during construction operations. As a minimum, the following Essential IC Data Information and IC Data Elements shall be exported from the raw IC data by using IC vendors' software in either ASCII or text format for post processing.

IC Training.

The IC vendor must provide two consecutive days of IC training for the appropriate Department and Contractor staff. One day of classroom training at a location in the close proximity of the project as approved by the Engineer, and one day of field training within the limits of the project is required prior to commencing IC operations. At a minimum, the following staff shall be offered IC training:

1. Department or Consultant Inspection staff:
    a. Earthwork inspectors
    b. Engineer and assistants
2. Contractor staff
    a. Roller operators
    b. QC field representative
    c. Field grading superintendent

The training requirement may be reduced or waived by the Engineer based on the trainee's recent prior experience with IC operations.

The Contractor must arrange the training location and all instructional materials. The training must cover at a minimum the following topics:

1. General background information on IC and GPS.
2. Hands-on operation of the IC system including the on-board documentation system, use of the software and setup.
3. Roller certification.
4. Verification of IC GPS accuracy.
5. Details on the system relevant to both the Contractor and the Department. At a minimum:
    a. Data transfer
    b. Data backup
    c. Recommended operator settings
    d. Data storage capacity of the on-board documentation system
    e. Base station and GPS use

Submittals.

IC Quality Control Plan.

The Contractor shall prepare and submit a written IC Quality Control Plan (QCP) for the project. As a minimum, the QCP shall contain the following information:

- Detailed Procedure for correlating and verifying GPS for the IC roller(s) and rover(s).
- Detailed Plan and Procedure for the construction of the Test Section to establish target compaction pass counts and target IC-MV values by correlating the density of the materials using standard testing devices, e.g. nuclear density gauges and IC rollers(s).
- Procedures for monitoring the construction operations and the IC roller(s) during production and Procedures to monitor the ongoing IC data including IC-MV stiffness, number of roller passes and the required level of compaction.
- Density/Compaction. Identification of the standard testing device(s) and frequency for monitoring and measuring the in-place density of the soil materials.

- Process and procedure for downloading and analysis of the IC data from the roller(s). The frequency of obtaining the data from the roller shall be at a minimum of twice per day during fill construction operations. The data is date/time stamped which permits for external evaluation at a later time.
- Ensure the IC roller manufacturer provides a knowledgeable representative on the project to provide the required IC training and until such time as outside consultation is no longer required, but for a minimum of three days to ensure proper operation of the equipment.
- The QCP shall include an organizational chart showing all quality control personnel and how these personnel integrate with other management/production and construction functions and personnel.
- The QCP shall be signed and dated by the Contractor's representative at the time the QCP is submitted to the Engineer. The QCP shall be submitted no later than 15 days prior to commencing the embankment operations.
- The QCP shall contain the name, telephone number, duties, and employer of all quality control personnel necessary to implement the QCP. Staff shall include the QCP Field Manager, the Quality Control Technician (QCT), and the IC roller operator(s).
- The QCP shall be maintained to reflect the current status of the operations, and revisions shall be provided in writing prior to initiating the change. The QCP revision shall not be implemented until the revision has been accepted.

Construction.

Verify the proper setup each day prior to the start of IC work. For the first three days and in the presence of the Engineer, the Contractor, GPS representative and IC roller manufacturer must verify the proper setup and accuracy of the GPS, IC roller(s) and the rover(s) using the same datum as follows:

- At a location nearby or within the project limits, the GPS base station must be established and the IC roller tied into the base station.
- Verification that the roller and the rover are working properly and that there is a connection with the base station.
- The coordinates of the roller from the on-board display must be recorded.
- Remove the receiver from the rover and place on top of the roller receiver and record the coordinates shown on the rover display.
- Compare the roller and rover coordinates. If they are within 1½ inches, the comparison is acceptable. If not, corrections must be made as needed and the above steps repeated until verification is acceptable. Work must not begin until proper verification has been achieved.

Verification subsequent to the first three days may be made between the Contractor and the States Inspection Staff.

Test Section.

Construct a test section using IC technology. The results of the test section shall be used by the Contractor to correlate the IC-MV results to density requirements. At a location agreed upon by the Engineer and the Contractor, construct at least one test section to establish a rolling pattern for each lift necessary to achieve the required level of compaction. Each test section should be

approximately 100 feet long and 20 feet wide. Construct additional test strips when a change is made to the source, gradation, type of material, or lift thickness. Each test section may be left in place to become part of the work.

An example of a test section construction and analysis procedure follows:
Initiate the test section with two passes of the IC roller. After two passes, mark and take three density and moisture content measurements at randomly selected locations at least 2 feet from the edge of the test section. Record the test locations using the rover. Take additional density and moisture content measurements at the three original locations after every 2 subsequent passes of the roller. Continue to compact the test section until the target maximum density is achieved. Determine the moisture content and density of the soil in accordance with Departmental procedures.

Quality Assurance.

The State reserves the right to verify the results of the IC operations and/or the Contractor's density testing by conducting its own tests and overseeing the Contractor's operations.

Verification Rolling.

Verification-roll the final soil lift over the full width of the lift using the same IC roller(s) used throughout the project. Record all information. Conduct verification rolling with IC rollers moving in the forward direction only at a speed of 3 mph and using the vendor recommended drum weight, frequency and amplitude. Turn mapping off when not performing measurement passes. Provide to the Engineer immediate viewing of the measurement pass data as requested. After completion of the measurement pass, provide to the Engineer both printed and electronic copies of the compaction data files.

BASIS OF ACCEPTANCE

Acceptance will be based on the receipt of IC-MV results, submitted electronically and on paper as described in this specification, that show compaction results for each lift.

METHOD OF MEASUREMENT

IC Control of Soil.
This work performed on the areas shown on the plans will be the number of cubic yards of material compacted using IC technology, measured in its final position.

Training for IC Control of Soil.
The training for the IC work will be measured on a lump sum basis.

ITEM 203.03600017 - INTELLIGENT COMPACTION CONTROL OF SOIL
ITEM 203.03610017 - TRAINING FOR INTELLIGENT COMPACTION CONTROL OF SOIL

BASIS OF PAYMENT

IC Control of Soil.
The unit price bid shall include the cost of developing and implementing the project-specific Quality Control plan, performing testing on the test section(s), and furnishing all labor, materials, and equipment necessary to satisfactorily complete the work.

Training for IC Control of Soil.
The lump sum bid shall include the cost of providing training as required by this specification.

ITEM 203.0360 17- INTELLIGENT COMPACTION CONTROL OF SOIL
ITEM 203.0361 17- TRAINING FOR INTELLIGENT COMPACTION CONTROL OF SOIL

DESCRIPTION

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Hand-Held GPS rover: A portable GPS radio/receiver for in-situ point measurements.

RTK-GPS: Real Time Kinematic Global Positioning Systems are based on the use of carrier phase measurements of the available GPS signals where a single reference station or a reference station network provides the real-time corrections in order to achieve centimeter-level accuracy.

GPS Representative: A person from the staff of either the GPS manufacturer or the roller manufacturer who is qualified to operate and instruct others in the use of the GPS unit being used on the roller at the project.

CONSTRUCTION DETAILS

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6. An on-board printer capable of printing the identity of the roller, the date of measurements, construction area being mapped, percentage of the construction area mapped, target IC-MV, and areas not meeting the IC-MV target values.

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1. Department or Consultant Inspection staff:
    a. Earthwork inspectors
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2. Contractor staff
    a. Roller operators
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2. Hands-on operation of the IC system including the on-board documentation system, use of the software and setup.
3. Roller certification.
4. Verification of IC GPS accuracy.
5. Details on the system relevant to both the Contractor and the Department. At a minimum:
    a. Data transfer
    b. Data backup
    c. Recommended operator settings
    d. Data storage capacity of the on-board documentation system
    e. Base station and GPS use

Submittals.

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- Procedures for monitoring the construction operations and the IC roller(s) during production and Procedures to monitor the ongoing IC data including IC-MV stiffness, number of roller passes and the required level of compaction.
- Density/Compaction. Identification of the standard testing device(s) and frequency for monitoring and measuring the in-place density of the soil materials.

- Process and procedure for downloading and analysis of the IC data from the roller(s). The frequency of obtaining the data from the roller shall be at a minimum of twice per day during fill construction operations. The data is date/time stamped which permits for external evaluation at a later time.
- Ensure the IC roller manufacturer provides a knowledgeable representative on the project to provide the required IC training and until such time as outside consultation is no longer required, but for a minimum of three days to ensure proper operation of the equipment.
- The QCP shall include an organizational chart showing all quality control personnel and how these personnel integrate with other management/production and construction functions and personnel.
- The QCP shall be signed and dated by the Contractor's representative at the time the QCP is submitted to the Engineer. The QCP shall be submitted no later than 15 days prior to commencing the embankment operations.
- The QCP shall contain the name, telephone number, duties, and employer of all quality control personnel necessary to implement the QCP. Staff shall include the QCP Field Manager, the Quality Control Technician (QCT), and the IC roller operator(s).
- The QCP shall be maintained to reflect the current status of the operations, and revisions shall be provided in writing prior to initiating the change. The QCP revision shall not be implemented until the revision has been accepted.

Construction.

Verify the proper setup each day prior to the start of IC work. For the first three days and in the presence of the Engineer, the Contractor, GPS representative and IC roller manufacturer must verify the proper setup and accuracy of the GPS, IC roller(s) and the rover(s) using the same datum as follows:

- At a location nearby or within the project limits, the GPS base station must be established and the IC roller tied into the base station.
- Verification that the roller and the rover are working properly and that there is a connection with the base station.
- The coordinates of the roller from the on-board display must be recorded.
- Remove the receiver from the rover and place on top of the roller receiver and record the coordinates shown on the rover display.
- Compare the roller and rover coordinates. If they are within 4 cm, the comparison is acceptable. If not, corrections must be made as needed and the above steps repeated until verification is acceptable. Work must not begin until proper verification has been achieved.

Verification subsequent to the first three days may be made between the Contractor and the States Inspection Staff.

Test Section.

Construct a test section using IC technology. The results of the test section shall be used by the Contractor to correlate the IC-MV results to density requirements. At a location agreed upon by the Engineer and the Contractor, construct at least one test section to establish a rolling pattern for each lift necessary to achieve the required level of compaction. Each test section should be

approximately 30 m long and 6 m wide. Construct additional test strips when a change is made to the source, gradation, type of material, or lift thickness. Each test section may be left in place to become part of the work.

An example of a test section construction and analysis procedure follows:
Initiate the test section with two passes of the IC roller. After two passes, mark and take three density and moisture content measurements at randomly selected locations at least 0.6 m from the edge of the test section. Record the test locations using the rover. Take additional density and moisture content measurements at the three original locations after every 2 subsequent passes of the roller. Continue to compact the test section until the target maximum density is achieved. Determine the moisture content and density of the soil in accordance with Departmental procedures.

Quality Assurance.

The State reserves the right to verify the results of the IC operations and/or the Contractor's density testing by conducting its own tests and overseeing the Contractor's operations.

Verification Rolling.

Verification-roll the final soil lift over the full width of the lift using the same IC roller(s) used throughout the project. Record all information. Conduct verification rolling with IC rollers moving in the forward direction only at a speed of 5 km/hr and using the vendor recommended drum weight, frequency and amplitude. Turn mapping off when not performing measurement passes. Provide to the Engineer immediate viewing of the measurement pass data as requested. After completion of the measurement pass, provide to the Engineer both printed and electronic copies of the compaction data files.

BASIS OF ACCEPTANCE

Acceptance will be based on the receipt of IC-MV results, submitted electronically and on paper as described in this specification, that show compaction results for each lift.

METHOD OF MEASUREMENT

IC Control of Soil.
This work performed on the areas shown on the plans will be the number of cubic meters of material compacted using IC technology, measured in its final position.

Training for IC Control of Soil.
The training for the IC work will be measured on a lump sum basis.

BASIS OF PAYMENT

IC Control of Soil.
The unit price bid shall include the cost of developing and implementing the project-specific Quality Control plan, performing testing on the test section(s), and furnishing all labor, materials, and equipment necessary to satisfactorily complete the work.

Training for IC Control of Soil.
The lump sum bid shall include the cost of providing training as required by this specification.