**INTELLIGENT COMPACTION:** **(SPECIAL)**

**Description**

Intelligent compaction (IC) is a process that uses vibratory rollers equipped with a measurement/documentation system that automatically records various critical compaction parameters correlated to percent compaction and soil modulus obtained from plate load test in real time. IC shall be used for proof rolling test sections to develop correlations with plate load tests and proof rolling embankment lifts for Quality Assurance (QA) and compaction acceptance.

Develop correlations between IC measurements and soil modulus from test sections. Determine soil modulus from plate load tests for a vertical stress of 15 psi in accordance with AASHTO T- 221 as modified by the Department. These procedures can be obtained from the following website:
http:/www.ncdot.org/doh/preconstruct/highway/geotech/contractserv/geopavement/pdf/plate_load_test_procedures_NCDOT.pdf. Use Quality Control Construction Engineer Inspection (QCCEI) personnel trained by the GEU to perform plate load tests.

Construct embankments in accordance with the Contract. Compact and test embankment fill layers with equipment and methods chosen by the Contractor. After completing the first test section and developing initial correlations, fill layer compaction will be accepted based on proof rolling with IC rollers instead of AASHTO T 99 density testing specified in accordance with Article 235-3(C) of the *Standard Specifications*. Bridging lifts are exempted from IC Specifications.

**Preconstruction Requirements**

**Qualification of IC Vendor:** Use an IC Vendor approved by the Department Engineer that has successfully completed 3 IC projects within the last 5 years.

**Equipment**

1. IC rollers shall be self-propelled single smooth drum vibratory rollers equipped with accelerometers mounted in or about the drum to measure the interactions between the rollers and compacted materials.
2. The output from the roller is designated as the Intelligent Compaction Measurement Value (IC-MV). It represents the stiffness of the materials.
3. IC rollers shall include an integrated on-board documentation system that is capable of displaying real-time color-coded maps of IC-MV's, roller location, number of roller pass, machine settings, roller speed, frequency and amplitude of roller drums. The display unit shall be capable of transferring data by means of a USB port.
4. Real Time Kinetic Global Position System (RTK-GPS) radio and receiver units shall be mounted on each IC roller. RTK-GPS shall use the Universal Transverse Mercator (UTM) Coordinate system. The UTM for this project is Zone 17 North.
5. Base Stations: Ground mounted or virtual GPS base units that record values in northing, easting and the elevation data in feet using the UTM coordinate system along with the longitude/latitude of the measurement value shall be provided. The GPS base station shall broadcast updated correction data to the GPS receivers on the IC rollers and the hand held rovers during operation with a survey tolerance of not greater than 1.6 inches in both horizontal (x and y) directions.

6. Rover: A portable hand-held GPS radio/receiver for in-situ point measurements shall be provided.

7. Provide RTK-GPS and IC rollers that operate with the following tolerances:

| INTELLIGENT COMPACTION TOLERANCE REQUIREMENTS | |
|---|---|
| **Parameter** | **Tolerance (+/-)** |
| Roller Position (northing, easting and elevation) | 1.6" |
| Roller Speed (forward) | 0.5 mph |
| Frequency | 2 Hz |
| Amplitude | 0.0008" |

8. The Contractor needs to be aware that the range of IC-MV values from some IC vendors is very narrow and does not provide adequate spread to clearly distinguish the difference in stiffness between different compaction states which makes meeting soil modulus requirements difficult.

**Data Analysis Software:** Standardized data analysis software (Veda Alfa Vr.8.0 or later) shall be used. It is available on the website www.intelligentcompaction.com. Veda will utilize the IC-MV data from the IC roller for analysis of coverage, uniformity, and stiffness values during proof rolling of embankment lifts. At a minimum the following shall be available in either ASCII or text format for post processing.

(a) File name, section title or lot number,

(b) Date and time stamps,

(c) Machine manufacture, model, type and identification number,

(d) Drum width and diameter,

(e) Roller and drum weights,

(f) Roller RTK-GPS positions with northing, easting, elevation, longitude and latitude.

(g) Roller speed, pass count and travel direction (e.g., forward or backward),

(h) Drum frequency and amplitude,

(i) IC-MV, reporting resolution for independent IC-MVs in the roller moving direction and 90 degrees to the roller moving direction (mm),

(j) UTM Zone and offset to UTC (hrs) and

(k) Number of IC data points.

**(A) IC Plan**

Develop and submit the proposed IC plan for all embankments for acceptance. Provide 4 copies and a PDF of this plan at least 30 days before starting test sections. The IC plan shall be approved prior to construction of any test section. Provide detailed project specific information in the IC plan that includes the following:

(1) IC Vendor with representative contact information and experience details;

(2) List and description of IC rollers and documentation systems;

(3) Recommended drum weight, frequency and amplitude for proof rolling.

(4) Any historical correlation data between IC-MV and plate load tests from previous projects;

(5) Test section plan and details including test section locations and material sources and testing.

(6) IC training details and location and

(7) Names and qualifications of personnel that will develop correlations between IC-MV and soil modulus, conduct the plate load tests, monitor IC proof roll operations, GPS check testing, download and analyze IC-data from the rollers.

**(B) IC Training**

Provide 2 consecutive days of IC training, one day of classroom training and another day of field training, for up to 40 personnel (Department and QCCEI) prior to implementing IC operations. On the first day, hold the "Essential IC Workshop" (see http://www.intelligentcompaction.com) at a location local to the project. The second day, shall consist of the IC Vendor representative conducting field training on the project. The IC roller operators shall be included in the field component of the training.

**(C) Test Sections**

Prior to the start of IC work, the Contractor, GPS representative and IC roller manufacturer shall conduct the following to check the proper setup of the GPS, IC roller(s) and the rover(s) using the same datum:

1. On a location nearby or within the project limits, the GPS base station shall be established and the IC roller and the GPS rover tied into the base station.
2. Verification that the roller and the rover are working properly and that there is a connection with the base station.
3. The coordinates of the roller from the on-board color-coded display shall be recorded.
4. The receiver from the rover shall be removed and placed on top of the roller receiver and the coordinates shown on the rover display recorded.
5. The roller and rover coordinates shall be compared. If they are within 1.6 inches, the comparison is acceptable. If not, corrections shall be made as needed and the above steps repeated until verification is acceptable. Work shall not begin until proper verification has been obtained.

6. The project plan file provided by the department shall be uploaded into the IC Data analysis software and depending on the manufacturer, the on board IC computer.
7. GPS check testing shall be conducted prior to every IC proof roll operation.

Construct the first test section within 14 days of beginning earthwork operations. Perform the following test procedures for each of the test sections:

| **Property** | **Test Method** |
|---|---|
| Soil Classification | AASHTO M 145 |
| Moisture-Density Curve | AASHTO T 99 as modified by the Department |

Preform, at minimum, one test section for granular materials and one test section for silt-clay materials as defined by AASHTO M 145 for materials consistent with that anticipated for embankment construction. Additional test sections may be necessary when adequate stiffness is not achieved, earth materials varies, IC equipment changes and/or whenever directed. Additional test sections may be beneficial when earth materials vary in order to develop better correlations.

Locate test sections at least 4 feet above existing ground unless the Department waives this requirement based on subsurface conditions underlying test section locations. Test sections may remain in place for embankments provided the test section will be at least 6 feet below subgrade IC compaction requirements. Notify the Department at least 5 days before establishing the initial test sections in order for the Department to prepare for associated field QA testing. Construct test sections using the proposed construction/compaction techniques. Construct test sections a minimum of 30 feet wide and 500 feet long, and no more than 24 inches thick.

Proof roll test sections with IC rollers moving forward at a speed of 3 mph, using the vendor recommended drum weight, frequency and amplitude in the presence of both QCCEI personnel and the Department and in accordance with the accepted IC plan. Perform plate load, in-situ moisture and percent compaction density tests within 24 hours of proof rolling with IC rollers. Use the IC, plate load and density test results from the test sections to develop correlations between IC-MV vs. soil modulus and IC-MV vs. percent compaction. Establish a Target IC-MV in accordance with Department *Guidelines for Construction of IC Test Sections*. These guidelines are available at the following website:

http://www.ncdot.org/doh/preconstruct/highway/geotech/contractserv/geopavement/pdf/Intelligent_Compaction_Test_Section.pdf

Submit IC, plate load, in-situ moisture and percent compaction density test data and results, IC-MV and soil modulus correlations for acceptance. Do not disturb or allow any equipment on or near the initial test sections until the Department completes QA field testing, which shall occur within 5 working days.

**Construction Methods**

After completing the initial test sections and developing initial correlations, place and compact embankments in accordance with Section 235 of the *Standard Specifications* except for the following:

(A) Place each fill layer with a thickness of no more than 24 inches instead of 10 inches.

(B) Maintain moisture content of embankment fill materials within 3% of optimum moisture content as defined by AASHTO T 99 as modified by the Department. Visually monitor moisture content daily using the judgment procedures described in the latest edition of the Conventional Density Manual provided by the Materials and Tests Unit. If the judgment factors indicate the soil may deviate from optimum moisture more than 3 % as defined by AASHTO T 99 as modified by the Department, obtain a sample to determine the in-place moisture content. As a minimum, determine in-place moisture content at a frequency of once per day of earthwork operations for the full compacted state and develop a plot of IC-MV versus in-place moisture content. Alternate locations of in-situ moisture tests between areas of high and low IC-MV. In-place moisture content can be determined either by following procedures provided in the Conventional Density Manual or by using the Speedy Moisture apparatus as defined in AASHTO T 217.

(C) Compact each fill layer to meet the Target IC-MV. The Target IC-MV must have a corresponding soil modulus of at least 6,000 psi at a vertical stress of 15 psi, or a corresponding percent compaction of 95% of AASHTO T-99 density, whichever is greater.

(D) Proof roll each fill layer with IC rollers moving forward at a speed of 3 mph, using the vendor recommended drum weight, frequency and amplitude in the presence of the QCCEI Personnel to determine soil modulus in accordance with the appropriate accepted test section correlation. Use accepted correlations from test sections constructed with embankment fill materials representative of fill layers. An embankment section shall be defined as a fill layer of 2,500 cubic yards or portion thereof. Compaction shall be accepted when a minimum of 70% of the embankment section meets or exceeds the Target IC-MV requirements defined above. If the next embankment lift is not placed soon after proof rolling with IC rollers, the Engineer may require proof rolling again for acceptance of fill layer compaction before placing the next layer. If a section repeatedly fails compaction, the soil modulus may be determined from plate load tests for a vertical stress of 15 psi in accordance with AASHTO T 221 as modified by the Department. Perform 4 plate load tests per section at random locations. For each section of a fill layer tested with plate load tests, compaction is acceptable if the average soil modulus is at least 6,000 psi and each of the 4 soil modulus values has a minimum result of 4,500 psi. Submit 4 hard and electronic copies of the IC data, per the IC Plan, and plate load test data/results for each section within 48 hours of proof rolling with IC rollers and/or performing plate load tests.