NEW MEXICO DEPARTMENT OF TRANSPORTATION
SPECIAL PROVISIONS FOR

INTELLIGENT COMPACTION FOR HMA/WMA
SECTION 423/424-A

All pertinent provisions of the New Mexico Department of Transportation's Standard Specifications for Highway and Bridge Construction shall apply in addition to the following:

1.0 Description

This Work shall consist of the compaction of Hot Mix Asphalt (HMA) or Warm Mix Asphalt (WMA) utilizing Intelligent Compaction (IC) rollers within the limits of the work as described in the plans. IC is defined as a process that uses vibratory rollers equipped with a measurement/documentation system that automatically records various compaction parameters correlated to standard testing protocols in real time during the compaction process.

IC uses roller vibration measurements to assess the mechanistic properties and to ensure optimum compaction and position is achieved through continuous monitoring of the operations. Additional information may be found on the website www.intelligentcompaction.com.

The Contractor shall supply sufficient numbers of rollers and other associated equipment necessary to complete the compaction requirements for HMA or WMA operations. The Contractor will determine the number of IC rollers 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. Table 423/424-A "Known Manufacturers of Intelligent Compaction Rollers" lists manufacturers known to NMDOT and is for informational purposes only.

All Measurements and data derived from IC shall not be used for Acceptance of HMA or WMA Materials. The measurements and data will be compiled and given to the Project Manager for information purposes only. Acceptance of HMA or WMA Materials for the project will be done in accordance with Section 423 "Hot Mix Asphalt – Superpave (QLA and Non-QLA" and Section 424 "Warm Mix Asphalt" of the Standard Specifications.

2.0 EQUIPMENT AND CONSTRUCTION

Minimum operator qualifications: 5 years' experience demonstrated operating similar types of compaction equipment as approved by the Project Manager, i.e. roller operations.

The Contractor shall provide GPS point measurements of all cores taken for density to allow for correlation of data.

The IC rollers shall meet the following requirements:

1. IC rollers shall be self-propelled double-drum vibratory rollers equipped with accelerometers mounted in accordance with the original manufacturer's recommendation to measure the interactions between the rollers and compacted materials in order to evaluate the applied compaction effort. IC rollers shall also be equipped with non-contact temperature sensors for measuring pavement surface temperatures.

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. 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 stiffness response values, location of the roller, number of roller passes, machine settings, together with the speed, frequency and amplitude of roller drums. The display unit shall be capable of transferring the data by means of a USB port.

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

5. Roller mounted GPS units or Virtual Reference System (VRS) capable of survey grade accuracy shall be mounted on each IC roller. Survey Grade GPS is required to monitor the locations and track the number of passes of the rollers. The GPS system shall also meet the following requirements:
    a. All GPS devices to shall be on the same project coordinate system.
    b. Provide a GPS system that provides Real Time Kinematic (RTK) survey grade accuracy or VRS accuracy relative to the project control and coordinate system.
    c. Provide GPS/VRS units on IC rollers and GPS units. All GPS units shall utilize the same method to acquire real time corrections. (i.e. they shall receive corrections from the same GPS base station or VRS network) and

d. Provide the recorded GPS data from the IC rollers and other GPS rovers, in the following formats:
   i. The time stamp shall be in military format (HHMNMSS.SS) in either UTC or local time zone. 0.01 second is necessary to differentiate sequence of IC data points during post processing;
   ii. Provide GPS latitudes and longitudes in format that the IC requires. and
   iii. Provide grid coordinates in US survey feet with at least 2 digits of significance (i.e. 0.01 ft.) on predetermined coordinate system for the project.

GPS-Related Definitions:

- 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).

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

- 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 (4.8 Km) in radius without repeaters.

- Network RTK: Network RTK is a system that use multiple bases in real-time to provide high-accuracy GPS positioning within the coverage area that is generally larger than that covered by a ground-based GPS base station; e.g., VRS.

- GPS Correction Service Subscription: A service that can be subscribed to receive VRS signals in order to achieve higher accuracy GPS positioning normally via cellular wireless data services; i.e., without the need for a ground-based base station. Examples of GPS Correction Service subscriptions are: OmniSTAR, TopCon, VRS NOW™ , Trimble VRS™, Trimble, etc.

- RTK-GPS: Real Time Kinematic Global Positioning Systems 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.

- UTM Coordinates: Universal Transverse Mercator (UTM) is a 2-dimentional Cartesian coordinates system that divides the surface of Earth between 80°S and 84°N latitude into 60 zones, each 6° of longitude in width and centered over a meridian of longitude. Zone 1 is bounded by longitude 180° to 174° W and is centered on the 177th West meridian. The UTM system uses projection techniques to transform an ellipsoidal surface to a flat map the can be printed on paper or displayed on a computer screen. Note that UTM is metric-based.

- Geodetic Coordinates: A non-earth-centric coordinate system to describe a position in longitude, latitude, and altitude above the imaginary ellipsoid surface based on a specific geodetic datum. WGS-84 and NAD83 datum are required for use with UTM and State Plans, respectively.

- ECEF XYZ: Earth-Centered, Earth-Fixed Cartesian X, Y, Z coordinates.

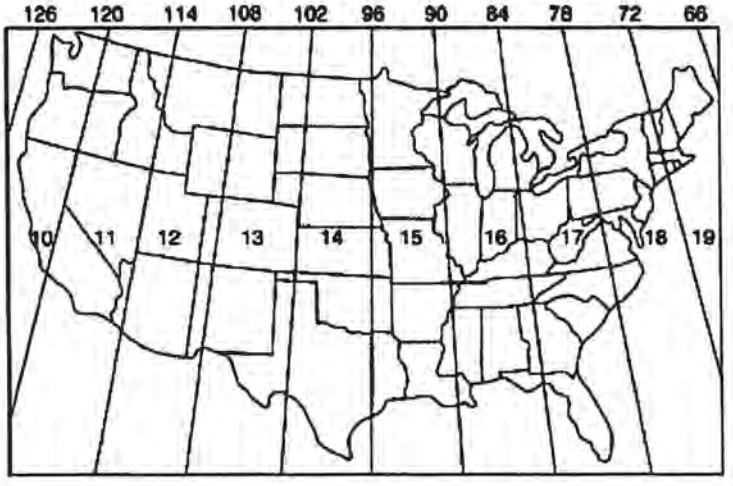
- Grid: Referred to ECEF XYZ in this specification.

- GUI Display: Graphical User Interface Display

- State Plane Coordinate: A set of 124 geographic zones or coordinate systems designed for specific regions of the United States. Each state contains one or more state plane zones, the boundaries of which usually follow county lines. The current State Plane coordinate is based on NAD83. Issues may arise when a project crosses state plane boundaries.

- UTC: Coordinated Universal Time (UTC) is commonly referred to as Greenwich Mean Time (GMT) and is based on a 24 hours' time scale from the mean solar time at the Earth's prime meridian (zero degrees longitude) located near Greenwich, England.

All GPS devices for this project shall be set to the same consistent coordinate datum/system no matter whether GPS or Grid data are originally recorded. UTM is the preference and shall be set to zone no. (xx) N for this project. *(NMDOT to fill in the appropriate zone number)* Zones outside of the continental United States can be acquired on the web at www.dmap.co.uk/utmworld.htm. The records shall be in meters. Use of UTM will facilitate GPS data checks onsite.



If UTM coordinates are not available, the State Plane Coordinate system can be used and set as (xx) for this project. *(NMDOT to fill in the appropriate State Plane designation)* Ad-hoc local coordinate systems should not be allowed.

Construction Requirements. 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.

TABLE 423/424-A
Known Manufacturers of Intelligent Compaction Rollers

Vendor	Bomag	Sakai	Wirtgen/Hamm
Model	Asphalt Manager	CIS (Sakai Compaction Information System	HCQ (HAMM Compaction Quality)
Model No.	BW190AD-4AM	SW8890/SW890	HD+90/HD+110 HD+120/HD+140
IC-MV	Evib (Vibration Modulus	CCV (Compaction Control Value)	HMV (HAMM Measurement Value)
IC-MV Units	MN/m^2	Unitless	Unitless

Documentation	BCM 05 Office	Aithon MT-A	HMV (HAMM Measurement Value)
Company Address	Bomag Americas, Inc. 200 Kentville Road Kewanee, Il. 61443	Sakai America, Inc. 90 International Parkway Adairsville, Ga. 30103	Wirtgen America, Inc.
Contact Information	Dave Dennison (309) 852-6217 Dave.dennison@bomag.com	Ed Conlin (301) 807-6800 e-conlin@sakaiamerica.com	Tim Kowalski (615)5010600 tkowalski@Wirgenamerica.com

In addition to the acceptance criteria described in Section 423.3.6.2.1.1 "Acceptance of Pavement Density" for Non-QLA HMA, Section 423.3.6.2.1.2.1 "Acceptance of Pavement Density" for QLA HMA, Section 424.3.6.2.1.1.1 "Acceptance of Pavement Density" for Non-QLA WMA and Section 424.3.6.2.1.2.1 "Acceptance of Pavement Density" for QLA WMA of the Standard Specifications, a minimum coverage of 90 percent of the individual construction area shall meet the optimal number of roller passes and 70 percent of the target IC-MV determined from the test sections or uniformity. Construction areas not meeting the IC criteria shall be evaluated prior to continuing with the operations in that area.

When importing the IC-MV data into the data analysis management program, store the GPS data and associated IC measurements with minimum data conversions and minimum loss of precisions so that uses can then select unit of preference to allow real time unit conversion for the graphical user interface display.

Follow the original roller manufacture specific instructions for exporting the IC-MV data to Veda-compatible formats. Import the IC roller data in Veda and enter GPS point measurements from the rover and visually inspect the IC map and point measurements on the Veda display screen for consistency.

Standardized data analysis software (Veda) shall be utilized and is available for downloading from the website www.intelligentcompaction.com. The software program will use the IC-MV data from the IC roller for analysis of coverage, uniformity and stiffness values during the HMA/WMA construction operations. At a minimum, provide the essential IC data information and data elements (shown in Table 304-B and Table 304-C) either ASCII or text format for post processing.

Table 423/424-B
Essential Intelligent Compaction (IC) Data

Item No.	Description
1	Section Title
2	Machine Manufacturer
3	Machine Type
4	Machine Model
5	Drum Width (feet)
6	Drum Diameter (feet)
7	Machine Weight (ton)
8	Name index of intelligent compaction measurement values (IC-MV)
9	Unit index for IC-MV
10	Reporting resolution for independent IC-MV's – in the roller moving direction (inches)
11	Reporting resolution for independent IC-MV's – 90 degrees to the roller moving direction (inches)
12	UTM Zone
13	Offset to UTC (hrs.)
14	Number of IC data points

Table 423/424-C
Essential Intelligent Compaction (IC) Elements

Item No.	Date Field Name	Example of Data
1	Date Stamp (YYYYMMDD)	e.g. 20080701
2	Time Stamp (HHMMSS.SS – military format)	e.g.090504.00 (9 hr. 5 min. 4.00s.)
3	Longitude (decimal degrees)	e.g. 94.85920403
4	Latitude (decimal degrees)	e.g. 45.22777335
5	Easting (ft)	e.g. 354048.900
6	Northing (ft)	e.g. 5009934.900
7	Height (ft)	e.g. 339.9450
8	Roller pass number	e.g. 2
9	Direction index	e.g. 1 forward, 2 reverse
10	Roller speed (mph)	e.g. 4.0
11	Vibration on	e.g. 1 for yes, 2 for no
12	Frequency (vpm)	e.g. 3500.00
13	Amplitude (in)	e.g. 0.6
14	Surface temperature (^{o}F)	e.g.120

15	IC Measurement Values	e.g. 20

In addition to the responsibilities described in Section 901.2 "Contractor Quality Control", the contractor is responsible for the following:

1. Daily GPS check testing for the IC roller(s) and rover(s).

2. Monitoring the IC rollers during production and final evaluation operations.

3. Daily download (twice per day) and analysis of the IC data from each roller. Provide the Project Manager and/or his or her representative with the daily downloads and analysis of the IC data from the rollers within one day (24 hours) following that days production.

4. Daily set-up, take down, and secure storage of GPS and IC roller components.

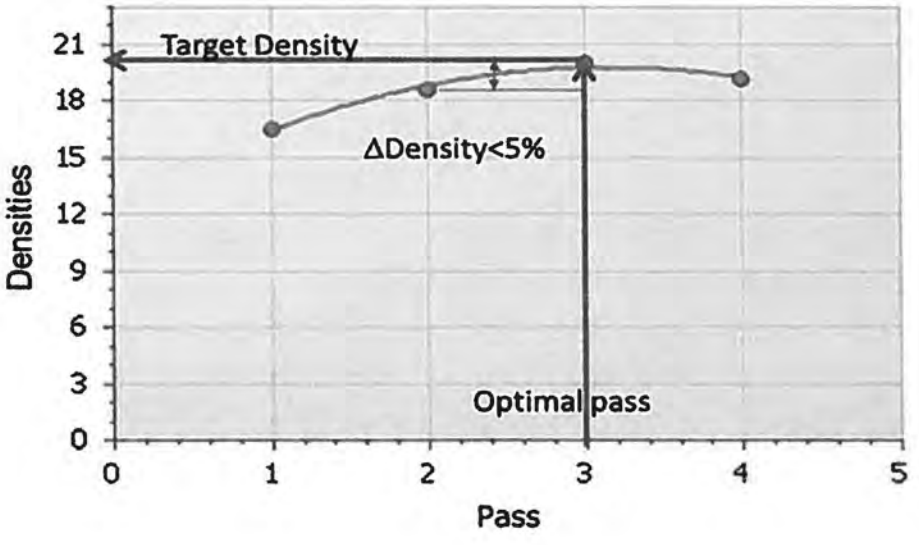
Test Sections. Test section evaluations are intended to verify the mixture volumetric of mixtures and determine a compaction curve of the asphalt mixtures in relationship to number of roller passes and to the stiffness of mixture while meeting the NMDOT in-place compaction requirements.

All HMA/WMA 'shakedown' and JMF adjustments shall be completed prior to starting the IC test sections.

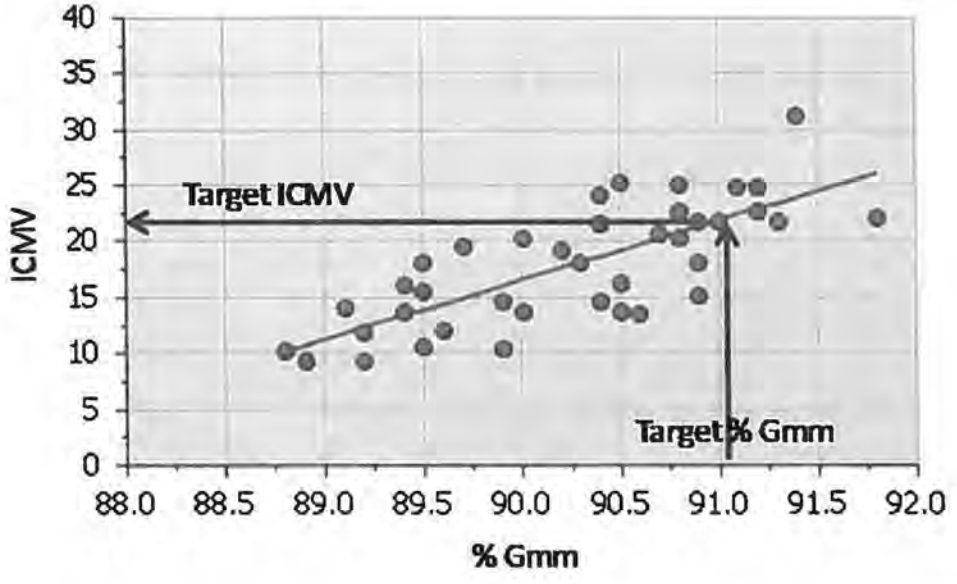
The evaluations shall be conducted every lift and be approximately 300 tons of mixtures. The IC roller in the initial phase shall use low vibration amplitude and the same settings (speed, frequency) throughout the section. After each roller pass, a nondestructive density device shall be used to estimate the density of the asphalt mixture at five (5) locations uniformly spaced throughout the test section. The density readings and the number of roller passes that takes to achieve the desired compaction will be recorded. Rover data measurements will be recorded and inputted into Veda,

The estimated target density will be the peak of the nondestructive readings within the desired compaction temperature range for the mixture. The IC roller data using the IC data analysis software will create an IC compaction curve for the mixture. The target IC-MV is the point when the increase in the IC-MV of the material between passes is less than 5 percent on the compaction curve. The IC compaction curve is defined as the relationship

between the IC-MV and the roller passes. A compaction curve example is as follows:



Linear regression relationships between the GPS rover point results and the IC-MV results will be used to establish the production target IC-MV as the target density (% Gmm) that meets the *NMDOT* in-place compaction requirements. A linear regression curve example is as follows.



GPS Check Testing. Prior to the start of production, the Contractor and representatives of the GPS 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 (if required by the GPS) shall be established and the IC roller and the GPS rover tied into the same base station.

2. Verification that the roller and rover are working properly and that there is a connection with the base station.

3. Production shall not begin until proper GPS verification has been obtained. IC vendors' recommended verification process can be used to augment the following procedure.

   Move the IC roller around until the GPS header computation is initialized. Move the IC roller and park at a selected location. Record the GPS measurements from the IC roller ensuring the distance offsets are applied so that the GPS coordinate is at the center or at left/right edges of the front drum. Mark two locations on the ground adjacent to the right and left edges of the front drum contact patch. Move

the IC roller from the marked locations. Use a hand-held rover to measure at the marked locations. Average the rover GPS measurements if the roller GPS measurement is at the center of the front drum. The differences between the roller GPS and rover measurements shall be within 6 inches (150 mm) for northing and easting.

4. The project plan file provided by NMDOT shall be uploaded into the IC Data analysis software and depending on the roller manufacture, the on-board IC computer.

5. GPS check testing shall be conducted daily during production operations to ensure consistency and accuracy of GPS measurements for all GPS devices prior to the paving and compaction operations.

Post-Process GPS Check. Follow the vendor-specific instructions to export IC-MV data to Veda-compatible formats. The Contractor shall import the IC roller data in to Veda and enter GPS point measurements from the rover and visually inspect the IC map and point measurements on the Veda display screen for consistency.

Mapping. Pre-paving mapping with an IC roller of the underlying materials is recommended to be completed using low amplitude/frequency prior to tacking operations to identify weak areas and may be part of the test section evaluations on the project or independently run. Pre-construction mapping should be approximately 500 ft (150 m) in length and conducted on identified plan paving sections. Underlying materials includes treated or non-treated subgrades, treated or non-treated aggregate bases, or on milled or non-milled asphalt pavements. Mapping operations are intended to provide the Contractor and understanding of the stiffness of the existing roadway being paved. Subsequent mapping may be conducted at any time to understand the changes in the roadway that affects the target IC-MV or the density verification testing. The stiffness of the underlying materials should increase with subsequent lifts of asphalt mixtures. The Contractors procedures for mapping should be included.

Response to Test Results. The response to quality control tests for the test sections and during production compaction shall include as a minimum the following:

1. Temperature. The procedure for corrective action when the QC or IC temperature readings are not within the recommended laydown values for the mixtures.

2. Density/Compaction. The procedure for corrective action when the maximum specific density (Gmm) results fall below the NMDOT specification limits shall require corrective action. Corrective action shall be per NMDOT Specification 423/424.

3. IC Coverage Area and Uniformity Criteria. The procedures to be taken when the IC criteria for coverage or the minimum IC-MV targets criteria are not being met.

Documentation. A statement that the test results for quality control and documentation of equipment and IC roller data shall be provided to the Project Manager and/or his or her representative

The documentation shall include the following.

1. Equipment. Documentation of the manufacture, model, type of paver, and rollers used each day of asphalt materials operations. The positioning of the IC roller(s) in the paving operations shall be noted.

IC Roller Data: the electronic data and analysis from the IC rollers for each day of HMA/WMA operations. Save the IC roller data as Time History Data and Post-Processed Data. Import the Post-Processed data using the all-passes and proofing-data formats. The all-passes data includes the data from all of the passes and the proofing data is the data from just the last pass within a given

2. IC Roller Analysis. The Contractor will analyze the IC roller data for conformance to the requirements for coverage area and uniformity and will submit the results to the Project Manager at the completion of the individual IC Construction Area operations. IC data shall be exported from the vendor's software in both all passes data and proofing data files. All passes data includes the data from all of the passes and proofing data is the data from just the last pass within a given area.

3. Construction Area. The limits of and total tons of the asphalt mixtures being placed within each construction area.

IC CONSTRUCTION

Technical Assistance. The Contractor shall coordinate for on-site technical assistance from the IC roller representatives during the initial seven (7) days of production and then as needed during the remaining operations. As a minimum, the roller representative shall be present during the initial setup and verification testing of the IC roller(s). The roller representative shall also assist the Contractor with data management using the data analysis software including IC data input and processing.

On-Site Training. The Contractor shall coordinate and provide for on-site training for Contractors and Agency project personnel related to operation of the IC technology. Contractor's personnel shall include the paving superintendent, QC technician(s), and roller operator(s). Agency's personnel shall include the project engineer and field inspector(s). (*Appropriate personnel to attend the training to be modified/expanded as applicable by the NMDOT*) Arrangements shall be provided that

includes an enclosed facility with electrical availability and a projector for presentations and should be 4-8 hours in duration.

Minimum training topics shall include:

1. Background information for the specific IC system(s) to be used
2. Setup and checks for IC system(s), GPS receiver, base-station and hand held rovers
3. Operation of the IC system(s) on the roller; i.e., setup data collection, start/stop of data recording, and on-board display options
4. Transferring raw IC data from the rollers(s); i.e., via USB connections
5. Operation of vendor's software to open and view raw IC data files and exporting all-passes and proofing data files in Veda-compatible format
6. Operation of Veda software to import the above exported all-passes and proofing data files, inspection of IC maps, input point test data, perform statistics analysis, and produce reports for project requirements
7. Coverage and uniformity requirements

3.0 METHOD OF MEASUREMENT

This item will not be measured as it will be paid as an allowance for providing the Intelligent Compaction for HMA/WMA on the project.

4.0 BASIS OF PAYMENT

Pay item	Pay Unit
Intelligent Compaction HMA/WMA	Allowance

This item includes all costs related to providing the Intelligent Compaction Data Collection including an IC plan, IC roller(s) with the fuel, roller operator, GPS system and rovers(s), or any other equipment, training, manufacturer representative presentations and on-site support, computer, printers, software, and manpower required for, and the implementation of, the IC process. All quality control procedures including the IC rollers and GPS systems

representatives support and testing shall be included in the contract allowance price.

Intelligent Compaction will be paid for the actual cost incurred.

Provide the Project Manager with a detailed cost breakdown, including receipts and invoices of actual costs incurred.

For the purpose of bidding, the Department will enter into the Bid Schedule a fixed amount for Intelligent Compaction.