Intelligent Compaction (IC) Technology
Improvement of Construction Quality for Base and Soil

Jimmy Si, PE
Richard Williammee, PE
Soheil Nazarian, PE

Research Team
- Anjan Kumar: Field and Lab
- Cesar Tirado/Carrasco: Modeling
- Raed Aldouri: Geospatial Analyses
- Austin Marshall: Specifications
- Carlos Chang: Statistical Acceptance
- Anand Puppala: Geotechnical
Background

- IC is a fast-developing technology for quality control and acceptance
- Proof rolling using IC rollers can
  - Ensure appropriate coverage
  - Identify weak spots
  - Improve uniformity of compacted layers.
Benefits of IC Technology

- Improve Compaction (better performance)
- Improve Efficiency (cost savings)
- Increase Information (more informed QC/QA)
Components of IC

- **Roller equipped with**
  - Appropriate IC Sensor
  - Calibrated GPS Unit
  - Real Time Monitor
  - Data Storage/Transmission

- **Vendor’s Support Software to**
  - Translate IC data to appropriate format in real-time

- **Geospatial-Enabled Software to**
  - Generate maps in real-time to identity areas of concern
    - Adequate No. of passes
    - Areas with lower than required stiffness
  - Conduct Statistical Analysis for Acceptance/rework

- **Trained Personnel to**
  - Collect data properly
  - Analyze results rapidly
  - Interpret quality of work promptly
**Project 0-6740** *(UTEP with assistance from UTA)*

Develop practical test protocols and specifications to improve implementation of IC technology for subgrade, embankment, and base construction

1. Evaluate available instrumented rollers
2. Develop test protocols for application of IC technology
3. Develop specifications for use of IC technology with emphasis on retrofit kits

![IC Technology Equipment](image_url)
Document Strengths, Weaknesses and Limitations of IC Technology

Outcome: A list and description of specifications, processes and technologies with associated strengths and weaknesses

- Compile US and International information and specifications
  - Best practices for quality control and acceptance
- Develop a synthesis of available information
  - Advantages and disadvantages of methods
  - Past success/failure
- Focus study on areas of concern
  - Theoretical
  - Technological and
  - Practical

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<td>Rahman et al., 2007</td>
<td>Implementation of IC technology</td>
<td>Roller measurements are highly sensitive to moisture content variation</td>
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<td>Anderegg et al., 2006</td>
<td>Demonstrated compaction monitoring using Single drum vibratory intelligent compactor.</td>
<td>Strong correlation between plate bearing test and roller measurement values.</td>
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<td>Mooney et al., 2006</td>
<td>Investigated influence of heterogeneity on vibratory roller compactor response.</td>
<td>At higher frequencies roller parameters were insensitive to changes in underlying soil conditions.</td>
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<td>Hossian et al., 2006</td>
<td>Demonstrated intelligent compaction control concepts in identifying soft spots.</td>
<td>Target stiffness values needs to be function of dry density</td>
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Develop Prototype Specification

Outcome: A generic QC/QA specification that integrates best practices throughout the world. A list of items that have to be resolved for a practical and robust implementation in Texas.

First draft of specification based on information from Task 1 considering:

- What is the most effective timing after compaction for conducting IC-based testing?
- What kind of site preparation is needed before utilization of IC technology?
- What is the minimum thickness of the layer that should be considered for quality acceptance?
- What types of supporting tests for verification of IC values?
- What is the minimum amount of data needed to ensure manageability of data for a reliable acceptance process?
- What is the best way to share the results among TxDOT and contractors?

QUALITY MANAGEMENT OF BASE AND SOIL USING ROLLER INTEGRATED COMPACTION MONITORING

1. Description. Construct subgrade and base layers (collectively called compacted geomaterials) using a Roller Integrated Compaction Monitoring (RICM) system. RICM is the recording and color coded real-time display of roller-integrated measurement values (MV's) observed directly by the roller operator. Roller location is determined by a Real Time Kinematic-Global Positioning System (RTK-GPS). This work shall consist of compacting geomaterials with an approved RICM measurement and documentation system.

   Develop and implement a project specific Quality Control Plan (QCP) for the geomaterial construction that is based on the RICM roller compaction parameters, moisture content, density and modulus-based field measurements.

2. Materials. Furnish uncontaminated materials of uniform quality that meet the requirements of the plans and specifications in accordance with Item 132, "Embankment;" Item 247, "Flexible Base;" Item 251, "Reworking Base Courses;" Item 260, "Lime Treatment (Road-Mixed);" Item 263, "Lime Treatment (Plant-Mixed);" Item 265, "Fly Ash or Lime-Fly Ash Treatment (Road-Mixed);" Item 275, "Cement Treatment (Road-Mixed);" and Item 276, "Cement Treatment (Plant-Mixed)." Notify the Engineer of the proposed material sources. Notify the Engineer before changing any material source. The Engineer may sample and test project materials at any time throughout the duration of the project to assure specification compliance. Use Tex-100-E for material definitions.

3. Equipment. Furnish machinery, tools, and equipment necessary for proper execution of the work in accordance with the plans and the applicable Specification Items listed in Article 2, Materials. Provide self-propelled RICM rollers in accordance with the Department's Approved Product List, "Intelligent Compaction Rollers."
Address Limitations of IC Technology

Outcome: Documentation of theoretical limitations of IC Technology

- Numerical analyses to establish
  - depth of influence of a roller
  - minimum layer thickness and modulus contrast
  - realistic goals for most suitable pavement sections

- Data Processing and Analyses
  - best scheme for data processing and analysis
  - managing data provided by contractors
  - best method for reporting processed data
  - minimum frequency at which field data should be collected

Diagram:
- IC Data collected
- SVO exported as CSV
- Data is imported into ArcGIS
- Geostatistical analyses
- Passes are separated
- Data cleanup
Geospatial/Geostatistical Analyses

- Select data with CMV values
- Run Kriging analysis for each pass using model builder
- Extract CMV values from grid data to compare with Spot data
Evaluation of Prototype Specification: Sites

Outcome: Documentation of practical applications of the IC Technology

- Two sites in Fort Worth District
  - Rural vs. Urban
  - New vs. Used Rollers
  - Embankment, Subgrade, Lime-Treated Subgrade, Base
  - Placement Moisture Content (dry of OMC vs. OMC vs. wet of OMC)

Site near Dublin-SH 267

Site near Fort Worth-IH 35
1. Construct three test beds at moisture contents of 80% OMC to 120% OMC
2. Determine variability of different test methods under field condition
3. Establish the effectiveness of using test strips for developing target values
4. Develop correlation between roller measurement values with spot test measurements
5. Monitor actual compaction process at site
Evaluation of Prototype Specification: Results

IC values are representative of the quality
**Evaluation of Prototype Specification: Results**

**Dry of OMC Subgrade**
Good Quality

**Close to OMC Subgrade**
Good Quality

**Wet of OMC Subgrade**
Lower Quality

*IC values are representative of the quality*
Evaluation of Prototype Specification: Results

Dry of OMC Subgrade

Close to OMC Subgrade

Wet of OMC Subgrade

IC values are not strongly related to Spot Tests
Evaluation of Prototype Specification: Practicalities

- **IC Rollers**
  - Some rollers cannot control the speed, frequency and amplitude as specified

- **IC Roller Values**
  - Different vendors report different parameters; some are more sensitive than others to compaction quality

- **GPS Unit Data**
  - GPS coordinates reported should be calibrated frequently
  - Data collected should use a standard projection and datum (UTM or State Plane)

- **Utilization of IC Data**
  - A more efficient protocol for timely storage, sharing of data, and utilization of data for acceptance by TxDOT is desirable

- **Test Pad for Setting Target**
  - Even though pragmatic, a faster way of setting the target is desirable.

- **IC Data Collection vs. Production**
  - Not all rollers that are effective for compaction can be used as IC rollers
  - It may be pragmatic to focus on testing finished product as opposed to focusing on the compaction process
Path Forward

• **Training**
  – All parties involved to understand the big picture
    • Roller operators for best method of data collection
    • Contractors for best ways to incorporate the IC Technology to reap the benefits
    • TxDOT personnel for best practices to achieve quality product

• **Certification**
  – Personnel
    • Roller Operators
    • QC/QA Representatives
  – Equipment
    • IC roller
    • GPS-based Station
    • GPS rover

• **Improvement of Data Processing**
  – A uniform real-time output data format from different manufacturers
  – A more integrated real-time data presentation and analysis algorithm