Intelligent Compaction

CCV IC

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Compaction Meter History

- Compaction meters to measure stiffness or modulus of soil and subbase materials were developed in Europe in the late 70’s and 80’s.
- Trials over many years show that the technology is fully field functional.
- Testing based on modulus provides compaction results in real time and 100% roller coverage.
- Not widely used in the USA.
“CCV” Operating Principle

- Measuring drum acceleration
- Soil test section at SAKAI tech center

Soil: Sandy loam
Accelerometer
Change of Drum Acceleration

- Acceleration of drum becomes more irregular as it encounters stiffer material.
Changes in Amplitude Spectrum and Condition of Ground

Filtered with band pass filters which correspond to 6 frequencies
From Acceleration to Compaction Value

**CCV formula:**

\[
CCV = \left\{ \frac{(A_1 + A_3 + A_4 + A_5 + A_6)}{(A_1 + A_2)} \right\} \times 100
\]

**Other formulas:**

\[
CMV = \left\{ \frac{(A_4)}{(A_2)} \right\} \times 100
\]

\[
CCV_2 = \left\{ \frac{(A_3 + A_4 + A_5 + A_6)}{(A_1 + A_2)} \right\} \times 100
\]

\[
PWIR^* = \left\{ \sqrt{(A_3^2 + A_4^2 + A_5^2 + A_6^2)} / \sqrt{(A_1^2 + A_2^2)} \right\} \times 100
\]

\*PWIR : Public Works Research Institute in Japan
Simulation Results

- Comparing acceleration output data using four formulas.

Type of soil: Sandy Loam
Type of Roller: SV160DV

Comparing acceleration output data using four formulas.
CCV System

CCV System

A/D input and D output

CCV display unit

Controller

Battery: 12 or 24 V
Wisconsin State Highway 77

Sakai SV510D with CCV

• Good correlation between nuclear density gauges and CCV for aggregate subbase.

• CCV crucial to identifying soft areas prior to paving on warranty project.
Real Time Moving Display

- **VALUE** directly under the vibrating drum
- **Soft spot**
- **Moving display**
- **Vibration Frequency in Hz**
- **Target value indicates specified compaction level**
- **Stiff spot: No more compaction is needed.**
- **Adjusts CCV range from 30 to 100**
- **Adjusts time range from 6 to 60 sec**
Density/Stiffness Correlation

CCV is correlated with target density or stiffness using calibration switch

\[ y = 143.47x - 193.91 \]

\[ R^2 = 0.9302 \]

Required density

**CAL-CCV value**

**Density**: \( \gamma_d \text{ (g/cm}^3\text{)} \)
RTK GPS
gives centimeter accuracy
GPS Receiver & Radio
CCV & GPS

Signal from the roller
* Direction
* Vib. On/Off
* Vib. Hi/Lo

Radio modem receiver

I/F unit

Computer

Power source

GPS Antenna

GPS receiver

Battery

RTK GPS

Radio modem transmitter

Base

Roller
New Views of the Compaction Process
True Real Time Digital Data
### IC(GPS+CCV) Software

**For Larger Projects**

1. Make a PLAN file
   - Input Job Coordinates
   - Input Roller Information
   - System setting ;Comm.,

2. Roller Operation and Recording
   - Real Time visual display
   - Recording all data.

3. Documentation
   - System can display automated data models
   - Database

**Basic CCV Software for Smaller Projects**

1. Make a PLAN file
   - Input Job Coordinates
   - Input Roller Information
   - System setting ;Comm.,

2. Roller Operation and Recording
   - Real Time visual display
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3. Documentation
   - System can display automated data models

**Roller Soft + Office Soft**

**Roller Soft + Office Soft (AutoCAD Add-In)**
CCV for HMA
Number of Roller Passes during Breakdown Rolling

- NRP is not uniform.
**Number of Roller Passes during Finish Rolling**

- NRP is not uniform.

Longitudinal Joint

Shoulder (Median) side

Number of roller passes

1 2 3 4 5 6 7 8
Stiffness of Pavement during Breakdown Rolling

1. The stiffness at the final roller pass in each location.
   Variation: 30 to 90 MN/m² (4,350 to 13,055 PSI)
1. Better correlation between stiffness measured during breakdown rolling and core density.

2. All cores were cut after finishing rolling was done.

3. Coordinates of core locations were measured by GPS.
Stiffness of Pavement during Finish Rolling

1. The stiffness at the final roller pass in each location.
2. Variation: 30 to 60 MN/m² (4,350 to 8,700 PSI).
Temperature of Pavement Surface during Breakdown Rolling

1. The surface temperature at final roller pass in each location.
2. Variation: 270 °F to 180 °F.
Number of Roller Passes

Displays the number of passes and shows compaction coverage
Compaction Control Value
CCV

CCV gives the roller measured compaction value.
The dots indicate the location of cores drilled from the pavement.
Correlation between CCV and Percent of Theoretical Maximum Density

\[ R^2 = 0.69 \]
Surface Temperature

Surface Temperature °C at compaction

- 0 - 80
- 80 - 90
- 90 - 100
- 100 - 110
- 110 - 160
Intelligent Compaction, Does It Exist?

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Relationship between CCV, Density (core) and Surface Temp

Graph 1: CCV vs. Number of Roller Passes
- Area1
- Area2
- Area3
- Area4

Graph 2: Degree of Compaction (%) vs. Number of Roller Passes

Graph 3: Temperature (℃) vs. Number of Roller Passes
- Area1
- Area2
- Area3
- Area4
Distribution of CCV

Test Section 3

Test Section 4

Time (s)
Realities of the Paving Job Site
To get good information on HMA
Monitor the initial conditions

- Smoothness should be measured before and after the test strip especially when paved over a milled surface.
- Thermal and Material segregation should be measured after lay down.
- Create new index to evaluate uniformity of compaction
HMA Factors

- Temperature affects stiffness, not a linear relationship.
- Uniformity of mat placed by paver
  --Material Segregation, Temperature variations
  --Consistent paver speed and lift thickness
- Subbase condition
- Longitudinal Joint
Thank you
Compaction Area: from STA516+40 to STA517

Name of Construction: Highway
Contractor: SAKAI
Work Day: Dec. 20, '02

Number of Roller Passes

Operator: 
Weather: Shine
Layer No.: 2
Material No.: 8
Start Time: 9:00
End Time: 16:00
Work Time: 6.0 h
Mean Speed: 3.55 km/h

Machine: SV505
Centrifugal Force: 118 kN
Drum Width: 2.13 m
Mesh Size: 0.5 m