Advanced Methods to Identify Asphalt Pavement Delamination (R06D) Ground Penetrating Radar (GPR)

Caltrans

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Introduction

- How We Got Here
  - Strategic Highway Research Program, (SHRP2)
- History of GPR at Caltrans
- A Little GPR Background
- A Bit More Inertial Aided GNSS Background
- Results So Far
- Possible Follow-Ups
History of Caltrans GPR

- **1998**: PE IV and PE 1000
  - Utilities, NDT, Geotech

- **2000**: Tow Cart
  - Pavements

- **2001**: 2-½ D Applications
  - Void mapping
  - Pavement research

- **2006**: 3-D Visualization

- **2008**: Upgrades (PE Pro)
  - Improved tow cart, larger grids, high sample density

- **2009**: Pavement Management
  - 58,000 Lane Miles (2009-2012)

- **2011**: SUE

- **2015**: Multichannel Radar
  - Product Demos (IDS, 3D Radar)
  - Bridge Deck Pilot (3D Radar)
  - SHRP2 Round 6 (R01B-SUE)

- **2016**: SHRP2 Round 7
  - R06D (Pavement)
  - R06A/G (Bridge decks/Tunnels)
  - R01B (SUE)
SHRP2 Technology Overlap

- No single grant provides full funding
- Leverage multiple grants for technology acquisition

IE – Impact Echo
IR – Infrared (Thermal Imaging)
TDEM – Time Domain Electromagnetics
SASW – Spectral Analysis of Surface Waves
MCGPR – Multichannel GPR
Caltrans SHRP2 Goals

- Validate GPR technology for diverse applications
- Bring high-speed GPR technology to Caltrans for pavements & bridge decks
- Improve testing methodology and reporting
- Training and technology transfer
- Develop appropriate roles, responsibilities and business practices for collaboration
2D GPR Rendering
3D Radar Implementation

• Collaboration at State & National Level
  – Funding through FHWA & AASHTO
  – Design and Fabrication through CT-GS and CT-DOE
  – Installation and Testing through CT-GS and UC Davis

• Implementation Challenges
  – Short Delivery Schedule
  – Rigid Mounting System
  – Reliable Power Supply
  – I/O From Multiple Data Streams
• Critical Design Criteria
  - 48” Antenna/Vehicle Separation
  - <24” Antenna Height
  - Use All Four Mounting Brackets
Final Assembly
Energy Loss vs. Antenna Height

![Graph showing energy loss vs. antenna height. The graph plots the ratio A/A₀ on the y-axis against antenna height in inches on the x-axis. Two lines are plotted: one for A/A₀ and another for loss (17"), with the loss line showing an increasing trend as antenna height increases.](image-url)
POS LV - GNSS Aided Inertial Navigation

- Dual Antenna GNSS
  ✓ position, attitude & heading
- Three-axis IMU
  ✓ Accelerometer & gyroscope
  ✓ 100 Hz output
- DMI Odometer
  ✓ Up to 20,000 pulse/m
- Integrated processor
- PC interface
  ✓ Real-time output
  ✓ User parameter controls

https://www.applanix.com/img/gallery/pos_lv_imu_ant_dmi.png
Real-Time Onboard Processing

- Kalman filter -- raw pseudorange & carrier phase
- IMU -- resolution of initial ambiguities, maintains accuracy during “cycle slip” or GNSS outage (solution from last known position)
- GNSS Azimuth Measurement Subsystem (GAMS) -- heading & attitude
- Distance Measurement indicator (DMI) -- constrains velocity error and IMU drift

Scherzinger & Hutton, Applanix IN-Fusion Technology Explained
Post-Processed Inertially-Aided Kinematic Ambiguity Resolution

Post-processed tightly coupled inertial and GNSS data using POSPac MMS software

Smoothed Best Estimate Trajectory (SBET) solutions computed using forward and reverse-time processing of data

Advantages
✓ Eliminates need for radio link
✓ cm-accuracy maintained with base distance up to 20 km
  (decimeter up to 70 km)
✓ Maintains position accuracy during GNSS outages

Disadvantages
✓ Range from base station limited to 20 km using single base
✓ Decreased accuracy occasionally occurs with SmartBase solution
Base Station Network

ATIRC Test Section

5 km
Static Start Position

Static Start Location

2.2 cm

2 mm
Examiner Image Correction, 20 MPH
Examiner Image Correction, 50 MPH
GNSS Post-Processing

SBAS Differential Only

Post-Processed

Error (m)

Relative Time (s)
Examiner Image Quality vs. Position Sample Output

100 Hz (0.3 ft)

1 Hz (30 ft)
Types of Outputs

Analysis Outputs

- Total pavement thickness
- Intra-layer (Overlay) thickness
- Overlay delamination
- Void distribution
- Rebar location/condition
- Concrete degradation
- Subsurface utility location

QC Outputs

- Gridding accuracy
- Intra-layer accuracy
- Georeferencing accuracy
- Depth/thickness correlation
SR 247, Total HMA Thickness
SR 247, Overlay Thickness
QC: SR113 Grid Residuals
QC: SR247 Intra-layer Residuals
Going Forward

- Verification of GPR thickness and overlay delam. Analysis
- Process Improvement
  ✓ QA/QC
  ✓ Automation of data processing/analysis
- Integration with Laser Scanner and thermal imaging systems
  ✓ Full synthesis with existing systems
  ✓ “One-Pass” acquisition
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