Effectiveness of 2D and 2.5D FDTD Ground Penetrating Radar Modeling for Bridge Deck Deterioration Evaluated by 3D FDTD
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Abstract
Computational modeling effectively analyzes the wave propagation and associated interaction within heterogeneous reinforced concrete bridge decks, providing valuable information for sensor selection and placement. It provides a good basis for the implementation of the inverse problem in heterogeneous reinforced concrete bridge decks, providing valuable information for sensor selection and placement. It provides a good basis for the implementation of the inverse problem in

Bridge Deck Configuration

Asphalt Thickness: 2.4cm
Asphalt EM Properties: dielectric constant=5, conductivity=0
Concrete Thickness: 18.0cm
Concrete EM Properties: dielectric constant=9, conductivity=0
Transverse Rebar: diameter=1.8cm, spacing=4.8cm on center, concrete cover=4.8cm
Longitudinal Rebar: diameter=1.2cm, spacing=4.2cm on center, concrete cover=4.6cm
Air Void: Cylindrical air void with a 0.6cm thickness and 3.0cm diameter

Notes about 2D and 2.5D geometry
- Longitudinal rebar is not modeled in 2D
  - Cylindrical air void representation is analogous to an infinitely long transverse rectangular void
- 2.5D simulation is performed by scaling the horizontal geometry by the cosine of the angle of rotation from the x-axis

Excitation Reconfiguration
Filtering the 2D and 2.5D FDTD excitation signal to account for propagation variation at the deck surface

2D vs 3D Simulation Results
2D and 2.5D simulations adequately capture 3D observed scattering
• Noticeable difference is present for case with defect beneath rebars
• Accuracy of 2D and 2.5D model degrades for complex geometry and off-plane T/R locations

Computational Costs
• Easy, fast
• Invariant in the 3rd dimension left out off-plane interactions
• Cylindrical wave propagation → \( r \) \( \sqrt{r} \)

Simulation Configuration
Spatial Resolution: 0.6cm (satisfies 10 points per wavelength in concrete using center frequency)
Temporal Resolution: 5.9ps (satisfies Courant condition)
Simulation Duration: 12.5ns
TR Height: 30.6cm above the deck
TR Separation: 3.0cm in x-direction
Excitation Signal: Pulse with 1.0GHz center frequency and bandwidth
B-Scan Rate: 1 trace recorded every 1.5cm

Future Work
B-scans are continuing to be generated in 2.5D and 3D simulations for various delamination cases. A new physical model is being investigated that includes longitudinal rebar (creating a rebar mesh). Data are being generated using a Y-directed dipole in 3D simulations and a transverse electric wave in 2.5D simulations. It is also hypothesized that from these results we can develop a procedure for determining the rebar orientation angle relative to the direction of GPR model 0, which is unknown a priori in field-collected data.

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