MODELLING OF A ROAD INFRASTRUCTURE ADAPTED FOR DYNAMIC INDUCTIVE RECHARGING FOR MAINTENANCE AND MONITORING

Presentation:

SHMI II CONFERENCE


POLITECNICO DI TORINO
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Electric vehicles (EVs) has recharged while travelling without the need to stop for short or long periods

Car’s battery would need to have approximately 1/5 of capacity than a traditional EV’s battery, reducing the weight and the price of EVs

Frequent charging of batteries prevent battery depletion and longer life
TECHNOLOGY PROVIDERS

- KAIST -

-KAIST 4G-
(Chun, 2013)

-QUALCOMM-
(Boys and Covic, 2012)

- BOMBARDIER -

-SCANIA & BOMBARIDER -
Primove
(Viktoria Swedish ICT, 2013)
# Feasibility

## Optimal Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electromagnetic field (μT)</td>
<td>&lt; 6.25</td>
</tr>
<tr>
<td>Power transferred (kW)</td>
<td>&gt; 20 - 30</td>
</tr>
<tr>
<td>Operational frequency (kHz)</td>
<td>≈ 20 - 100</td>
</tr>
<tr>
<td>Vertical air-gap (m)</td>
<td>&gt; 0.2 - 0.3</td>
</tr>
<tr>
<td>Misalignment (m)</td>
<td>&gt; 0.2 - 0.3</td>
</tr>
<tr>
<td>Efficiency of WPT (%)</td>
<td>&gt; 80 - 85</td>
</tr>
</tbody>
</table>
WHY MODELLING AND MONITORING?

- Infrastructure could be very expensive to implement
- Stress concentration in the proximity of technology
- Calibrate structural assessment and prediction of maintenance tasks
THE MODELS

Layered model on elastic soil with linear elastic behavior of all materials

Road stratigraphy

Recharging Unit
THE MODELS

<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
<th>Thickness [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wearing + Binding layer</td>
<td>Bituminous Conglomerate</td>
<td>0.12</td>
</tr>
<tr>
<td>Base course layer</td>
<td>Granular mixture stabilized</td>
<td>0.15</td>
</tr>
<tr>
<td>Sub-base course layer</td>
<td>Compacted granular material</td>
<td>0.35</td>
</tr>
<tr>
<td>Sub-grade layer</td>
<td>Semi-infinite elastic soil</td>
<td>Springs</td>
</tr>
</tbody>
</table>
## THE MODELS

### Applied loads

<table>
<thead>
<tr>
<th>Type of analysis</th>
<th>Value [MPa]</th>
<th>Area [m$^2$]</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>1</td>
<td>0.3x0.3</td>
<td>Centre of the model, over coil-box</td>
</tr>
<tr>
<td>Harmonic</td>
<td>3 (0 - 100 Hz)</td>
<td>0.3x0.3</td>
<td>Centre of the model, over coil-box</td>
</tr>
<tr>
<td>Transient</td>
<td>3 (δt=0.015 s)</td>
<td>0.3x0.3</td>
<td>Centre of the model, over coil-box</td>
</tr>
</tbody>
</table>
INFLUENCE OF CONTACT
(Static analysis - von Mises Stress [Pa])

Without contact behavior

With contact behavior
INFLUENCE OF CONTACT
(Static analysis - Horizontal $\sigma_x$ [Pa])

Without contact behavior

With contact behavior
INFLUENCE OF CONTACT
(Dynamic analysis - Horizontal $\sigma_x$ [MPa] in the wear layer)

Horizontal $\sigma_x$ in the wear layer with and without contact behaviour
INFLUENCE OF CONTACT
(Static analysis - von Mises Stress [Pa] on ferrite core)

Without contact behavior

With contact behavior
INFLUENCE OF CONTACT
(Dynamic analysis - Horizontal $\sigma_x$ [MPa] on ferrite core)

Horizontal $\sigma_x$ on ferrite core with and without contact behaviour
COMPARING E-ROAD AND TRADITIONAL INFRASTRUCTURE
(Static analysis - von Mises Stress [MPa] in the wear layer)

The values of stresses, in the wear layer, are lower in a rail solution than in a traditional infrastructure for distance about 0.5 m from the charging devices.

von Mises Stress at 0.04 m from the road surface.
MODELING & MONITORING

MAINTENANCE

Probability to hit each path of lane

Creep averaged model

\[ \text{Equiv. Slope} = \frac{\sigma \cdot \Delta t}{\eta T} \]

\[ \eta_{eq} = \frac{T}{\Delta t} \]
Creep analysis highlights the critical areas; in these areas the cycles to failure are evaluated.

From phenomenological laws is obtained $N=210,000$.
There are different types of sensors that can be introduced in order to evaluate all the trends of the infrastructure, e.g. in terms of strains, stresses, accelerations, temperatures, and humidity.
Example of strain and stress sensors positioning in a traditional infrastructure [*]

Most critical areas predicted by Finite Elements Model in ANSYS
COMPARASION WITH EXPERIMENTAL DATA

From 6 years of experimental data [*]

[*] "Measurement of strain at the bottom of asphalt layers showed that the strain value is independent of asphalt type, but highly dependent on asphalt layer temperature."

Values of transverse strain at the bottom of wear layer:

50 - 150 µstrain

[*] Computer-Aided Civil and Infrastructure Engineering 00 (2014) 1-12; Monitoring the Mechanical and Structural Behavior of the Pavement Structure Using Electronic Sensors
From a numerical model

7 DOF vehicle model, loaded with road roughness

The output forces are the input of F.E.M.
Average values of transverse strain at the bottom of wear layer:

30 - 80 µstrain

Comparable with the experimental data

(50 - 150 µstrain)
CONCLUSIONS

• The model with contact elements supplies a realistic representation of the stress in the pavement;

• High transversal strain concentrations are highlighted by rutting analysis in the areas closed to the charging-unit. These areas can be chosen to implement monitoring devices or other sensors;

• The e-road rail solution, more apparently performs better in terms of stress, in assumption that, the fatigue life of the pavement is defined at the instant when the elastic modulus "E" reaches 50% of the initial value [...].

[**] European Standard (EN 12697-24, 2004)
CONCLUSION

PERSPECTIVES

• Perform nonlinear analysis that take into account the appropriate degradation laws of materials (with particular attention to the temperature effect) in order to better estimate local damages and lifetime of entry system;

• Adapting and developing special monitoring devices in order to not interfere with the wireless electromagnetic power transfer;

• Evaluate the effects of the introduction of technology in the bridges.
THANK YOU FOR THE KIND ATTENTION
Inside the pavement flows an electric current $i(t)$ that produces a magnetic field $B(t)$. The magnetic field $B(t)$ is intercepted by a coil installed at the bottom of the vehicle. Consequently, in that coil arise a voltage and an induced current $i(t)$ capable to provide the necessary power to recharge the vehicle.