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

Presentation:

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POLITECNICO DI TORINO
Turin, Italy

July – 1, 2015

FRAMING

This project is funded by the EC, FP7

Feasibility analysis and development of on-road charging solutions for future electric vehicles

A) INTRODUCTION

Technology Providers and Feasibility

B) LIFE-CYCLE

Modelling and Monitoring

C) CONCLUSION

Conclusions and Perspectives

FRAMING

WHY DYNAMIC INDUCTIVE RECHARGING ?

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

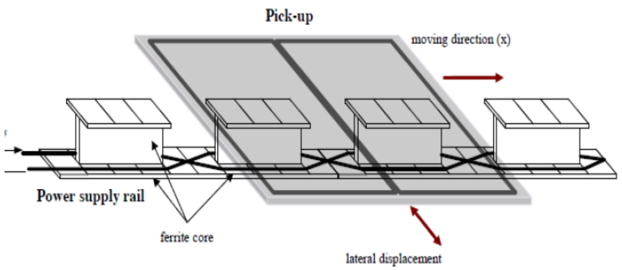
Car’s battery would need to have approximately 1/5 of capacity than a traditional EV’s battery, reducing the weight and the price of EVs

Frequent charging of batteries prevent battery depletion and longer life

TECHNOLOGY PROVIDERS

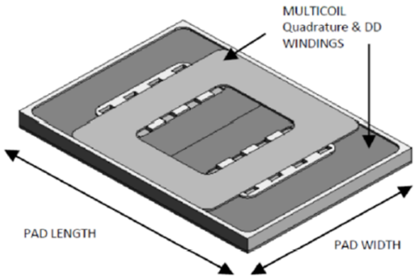
_A

-KAIST-



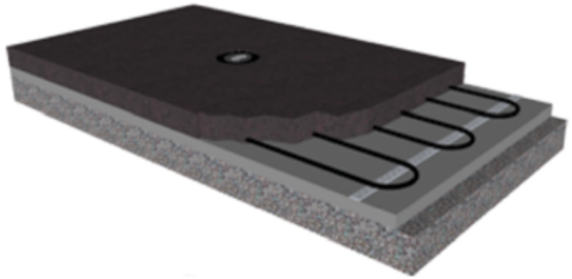
KAIST 4G
(Chun, 2013)

-QUALCOMM-



QUALCOMM
(Boys and Covic, 2012)

-BOMBARDIER-



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

FEASIBILITY

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OPTIMAL PARAMETERS

Electromagnetic field (μT)

< 6.25

Power transferred (kW)

> 20 - 30

Operational frequency (kHz)

≈ 20 - 100

Vertical air-gap (m)

> 0.2 - 0.3

Misalignment (m)

> 0.2 - 0.3

Efficiency of WPT (%)

> 80 - 85

LYFE-CYCLE

B

WHY MODELLING AND MONITORING ?

Infrastructure could be very expensive to implement

Stress concentration in the proximity of technology

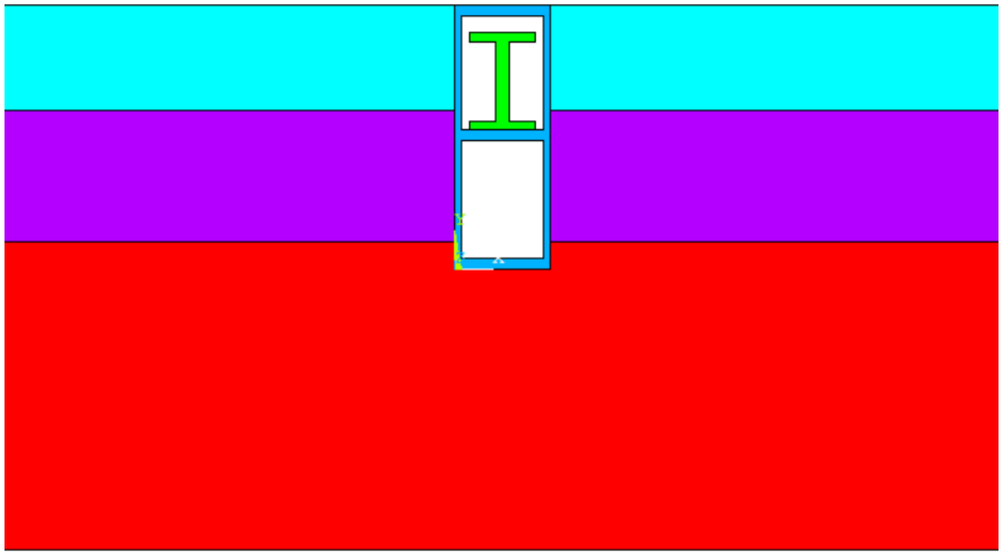
Calibrate structural assessment and prediction of maintenance tasks

MODELING & MONITORING

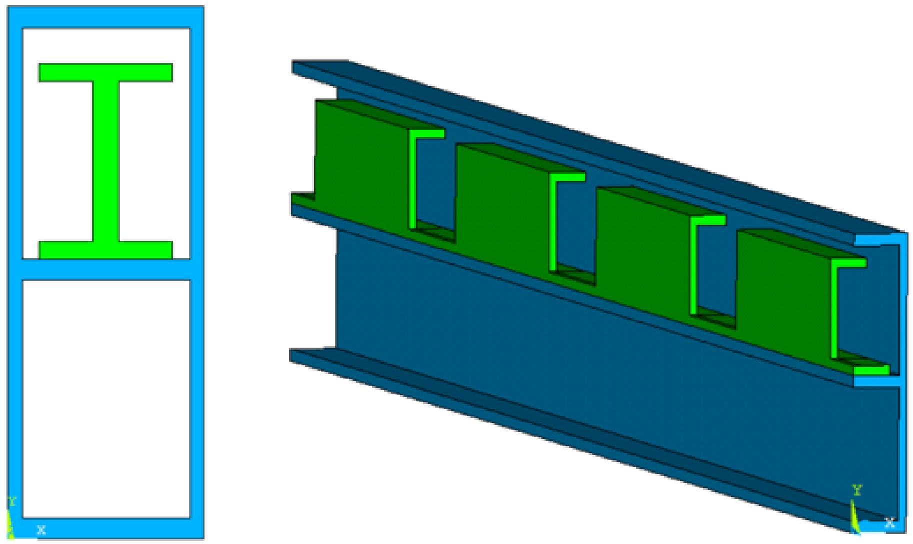
_B

THE MODELS

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



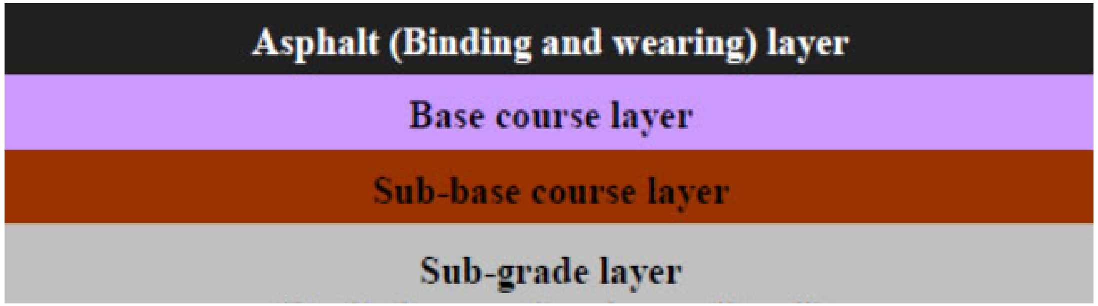
Road stratigraphy



Recharging Unit

MODELING & MONITORING

THE MODELS



Pavement layers

Type	Material	Thickness [m]
Wearing + Binding layer	Bituminous Conglomerate	0.12
Base course layer	Granular mixture stabilized	0.15
Sub-base course layer	Compacted granular material	0.35
Sub-grade layer	Semi-infinite elastic soil	Springs

Thickness of the layers

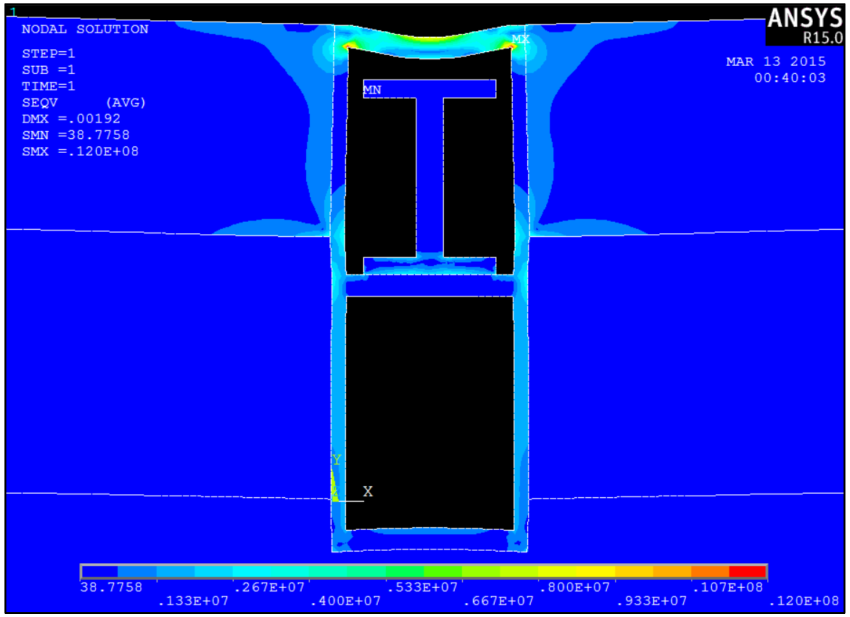
THE MODELS

Applied loads

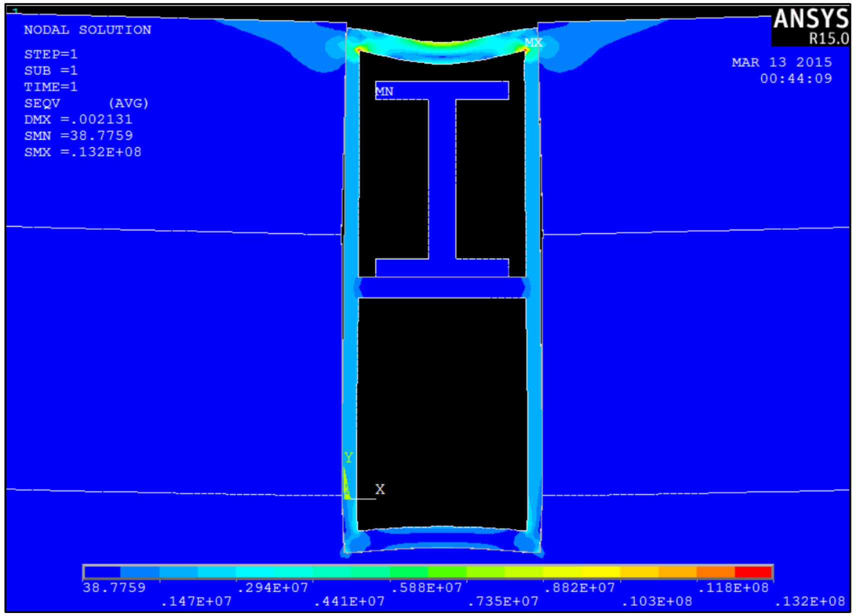
Type of analysis	Value [MPa]	Area [m^2]	Position
Static	1	0.3x0.3	Centre of the model, over coil-box
Harmonic	3 (0 -100 Hz)	0.3x0.3	Centre of the model, over coil-box
Transient	3 (δt=0.015 s)	0.3x0.3	Centre of the model, over coil-box

INFLUENCE OF CONTACT

(Static analysis - von Mises Stress [Pa])



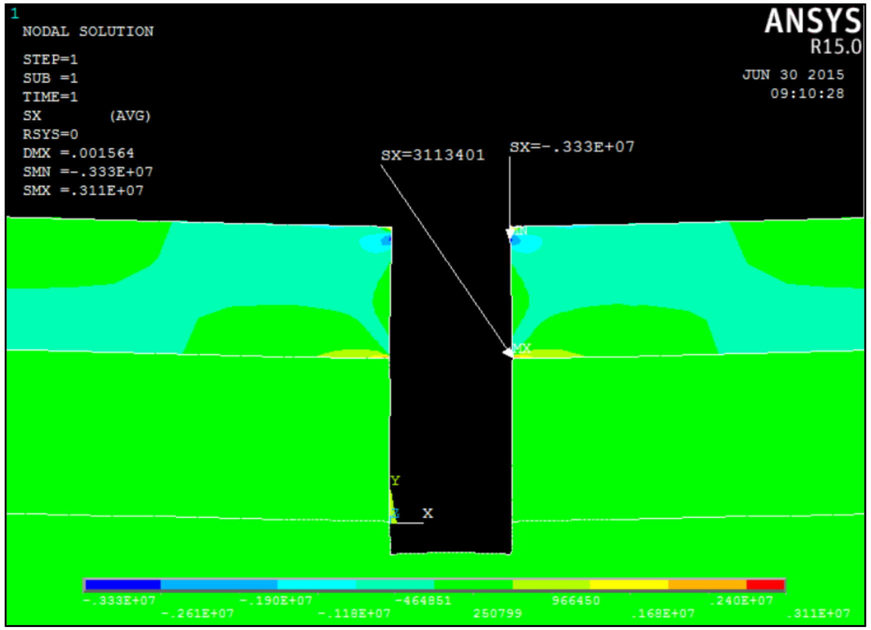
Without contact behavior



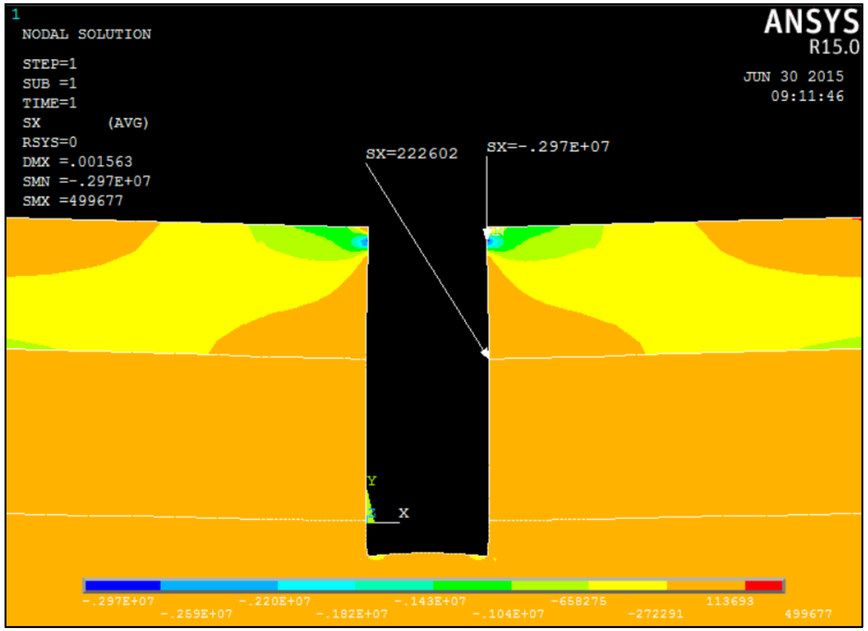
With contact behavior

INFLUENCE OF CONTACT

(Static analysis - Horizontal σ_x [Pa])



Without contact behavior



With contact behavior

MODELING & MONITORING

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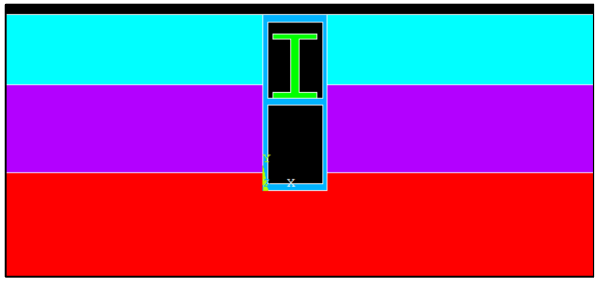
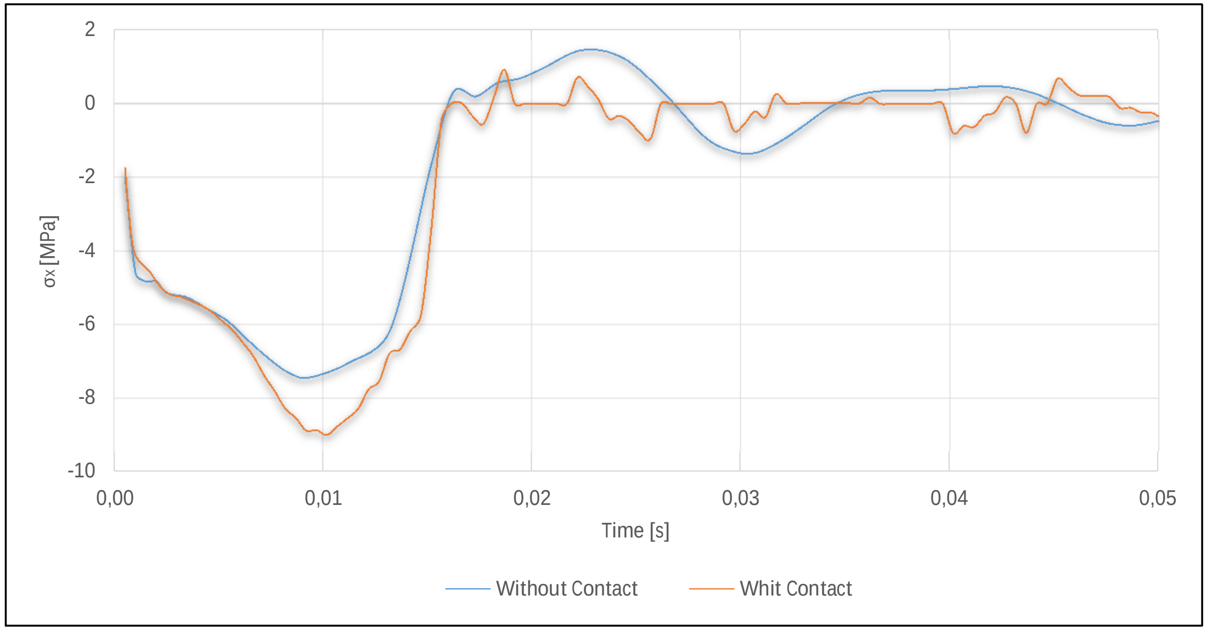
INFLUENCE OF CONTACT

(Dynamic analysis – Horizontal σx [MPa] in the wear layer)



Horizontal σx in the wear layer with and without contact behaviour



MODELING & MONITORING

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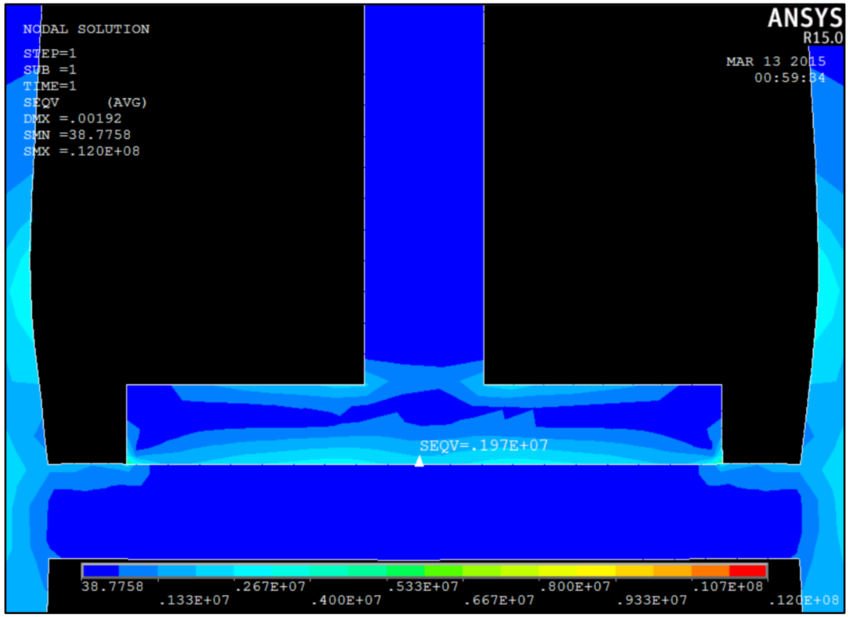
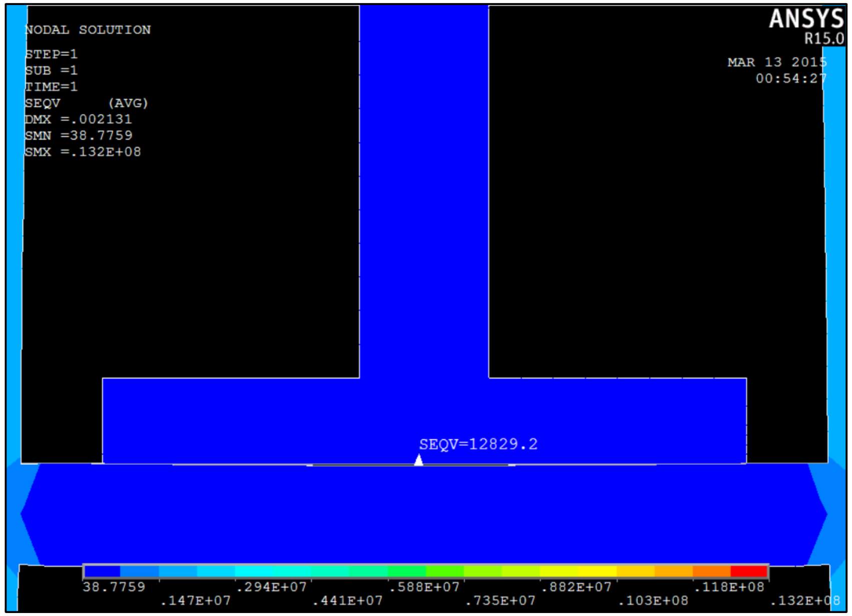
INFLUENCE OF CONTACT

(Static analysis - von Mises Stress [Pa] on ferrite core)



Without contact behavior



With contact behavior

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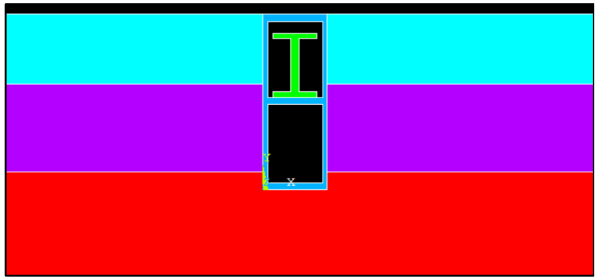
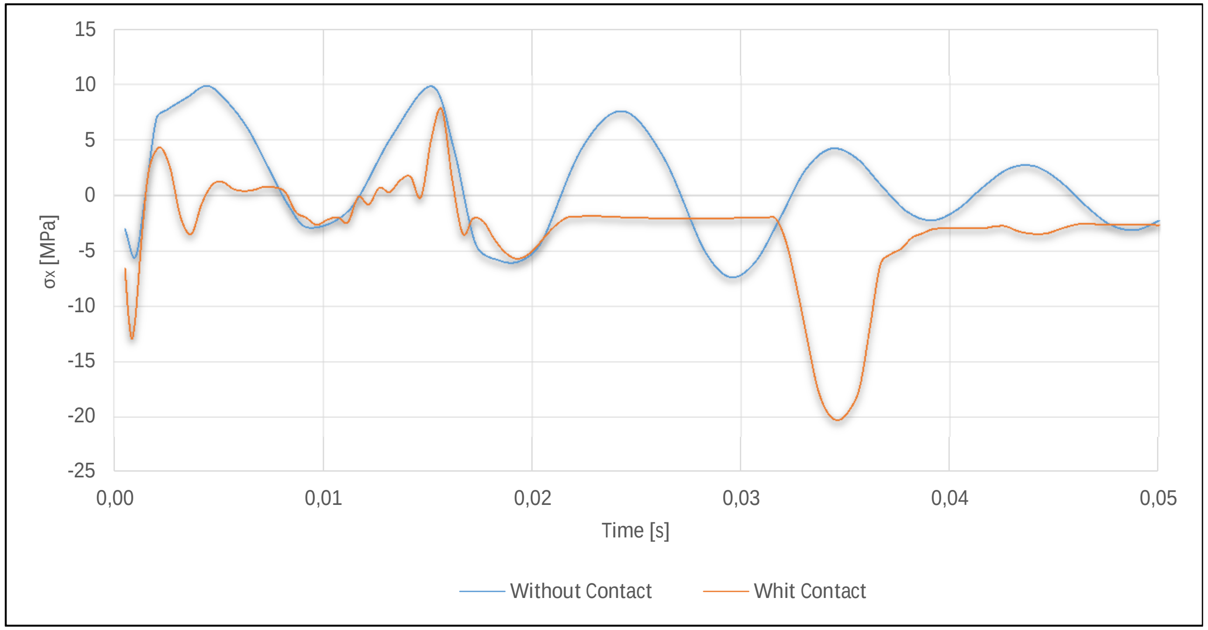
INFLUENCE OF CONTACT

(Dynamic analysis – Horizontal σ_x [MPa] on ferrite core)



Horizontal σ_x on ferrite core with and without contact behaviour



MODELING & MONITORING

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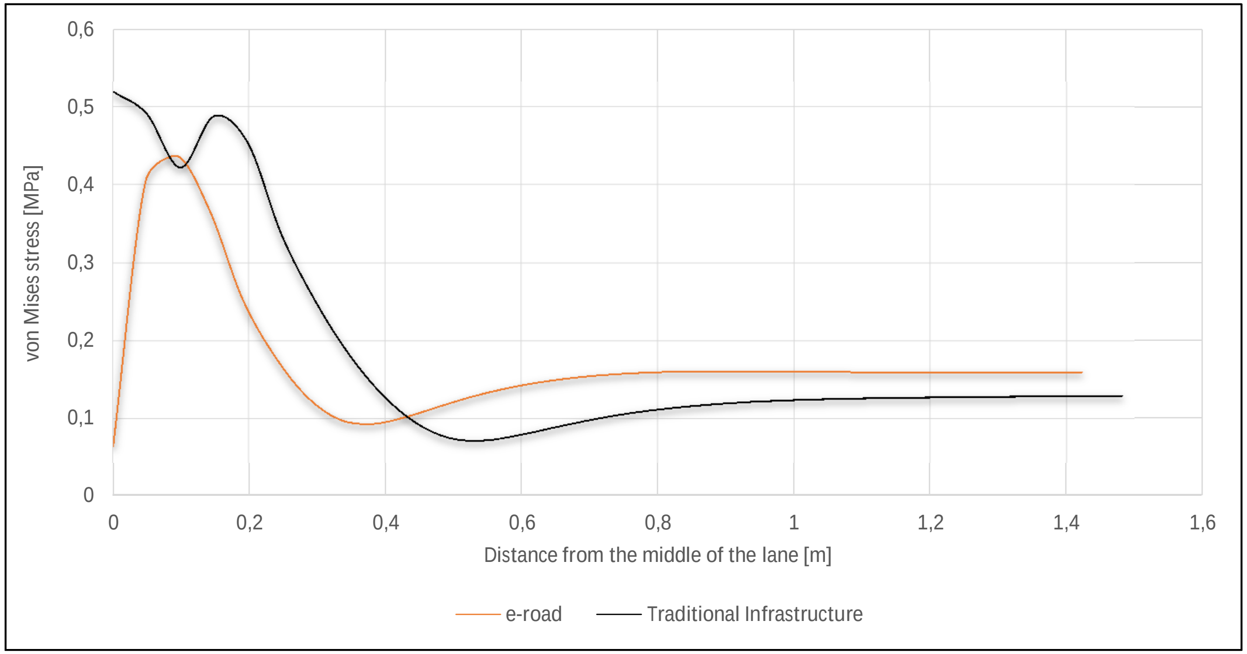
COMPARING E-ROAD AND TRADITIONAL INFRASTRUCTURE

(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

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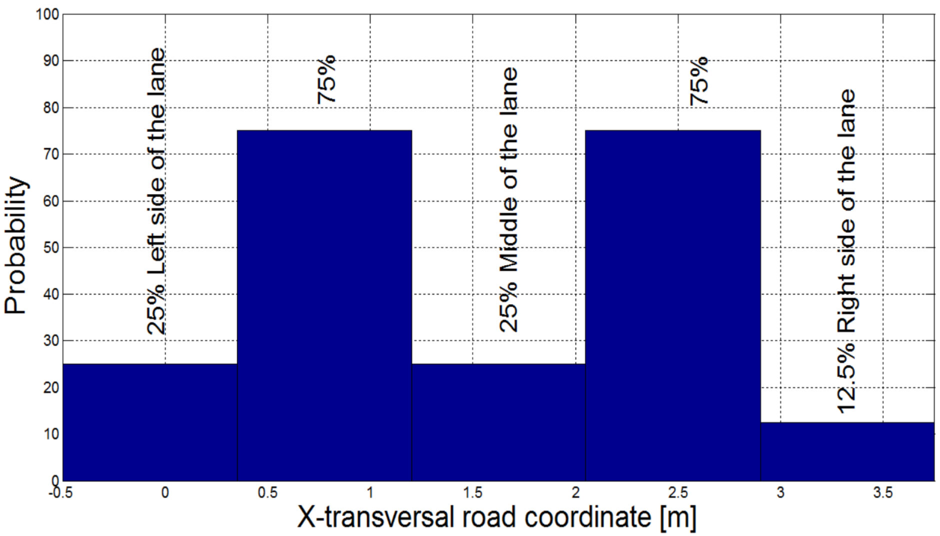
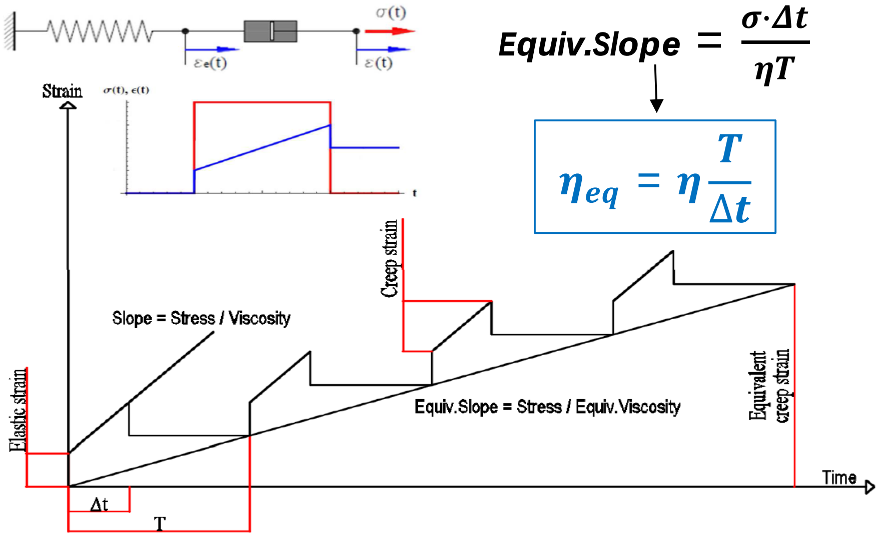
MAINTENANCE

Probability to hit each path of lane



Creep averaged model



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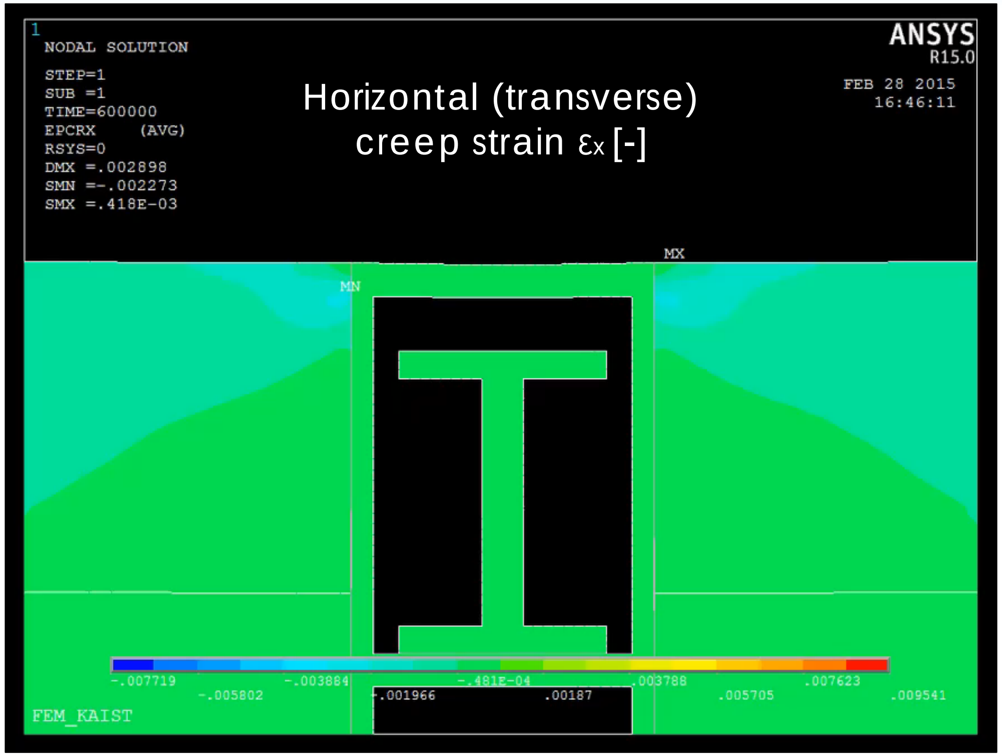
MAINTENANCE



Creep analysis highlights the critical areas; in these areas the cycles to failure are evaluated

From phenomenological laws is obtained *N*=210,000

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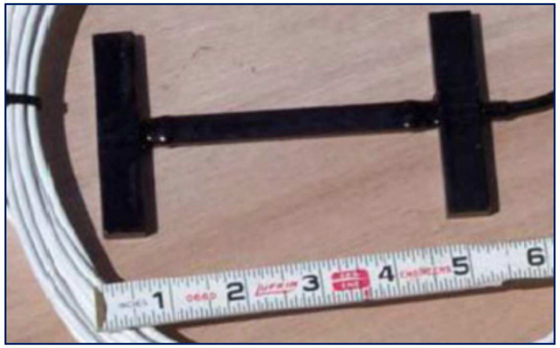
MONITORING

Strain monitoring sensors [*]



Stress monitoring sensor [*]

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**

MODELING & MONITORING

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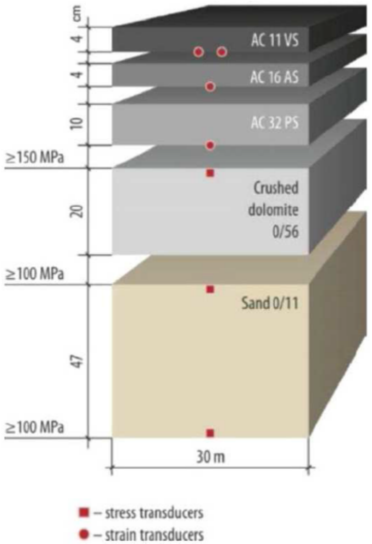
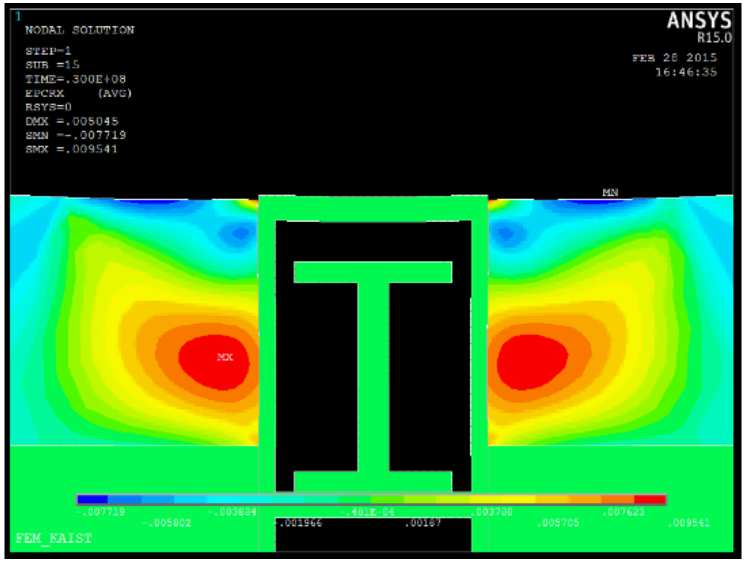
MONITORING

Example of strain and stress sensors positioning in a traditional infrastructure [*]



Most critical areas predicted by Finite Elements Model in ANSYS



MODELING & MONITORING

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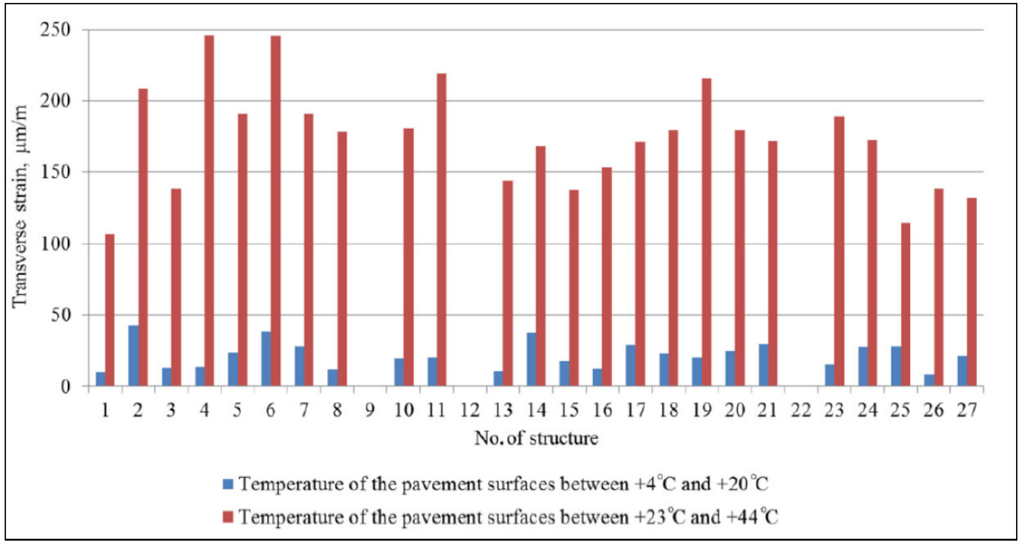
COMPARASION WITH EXPERIMENTAL DATA

From 6 years of experimental data [*]



[*] "Measurement of strain at the bottom of asphalt layers showed that <u>the strain value is independent of asphalt type</u>, 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

MODELING & MONITORING

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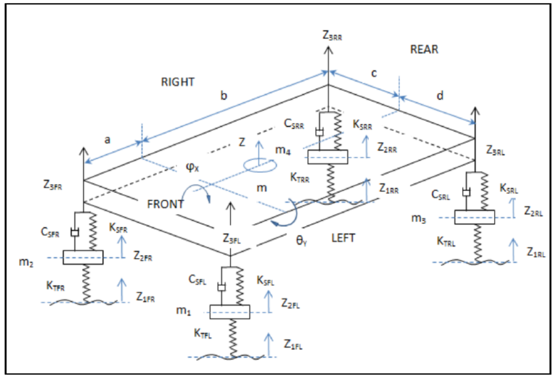
COMPARASION WITH EXPERIMENTAL DATA

From a numerical model

7 DOF vehicle model, loaded with road roughness



Unplugged

CRF CENTRO RICERCHE FIAT

The output forces are the input of F.E.M.

MODELING & MONITORING

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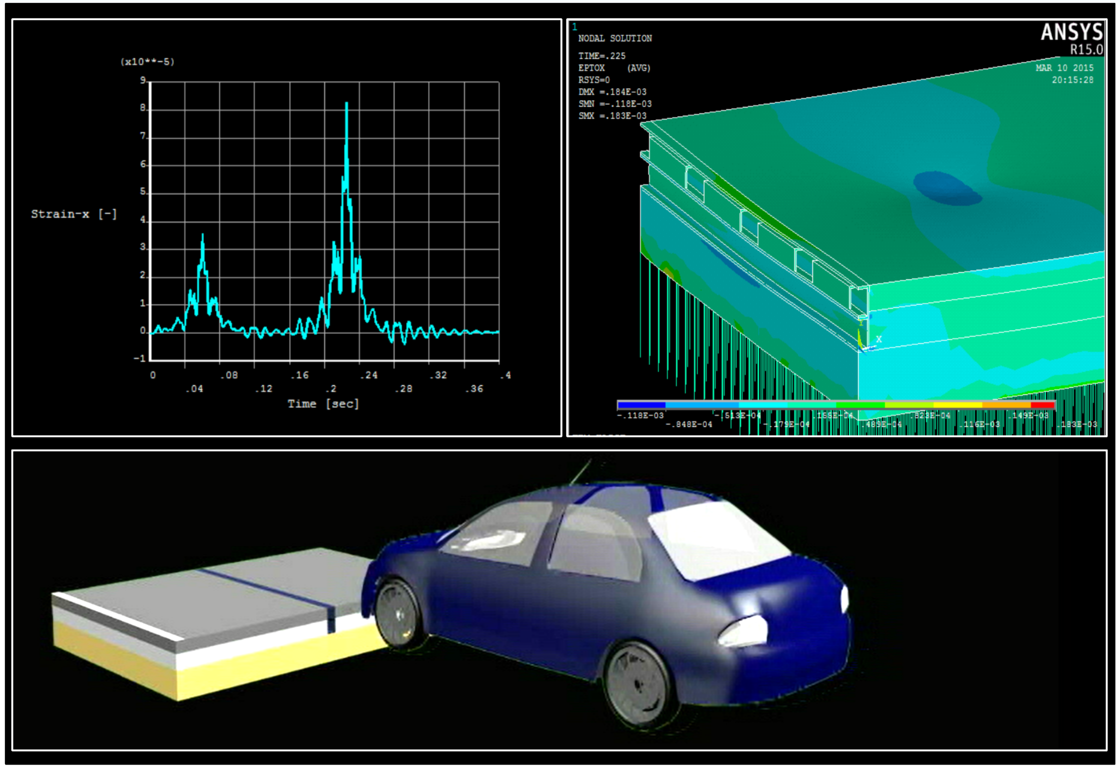
COMPARASION WITH EXPERIMENTAL DATA



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

SHMU 7 Torino 2015

Unplugged

This project is funded by the EC, FP7

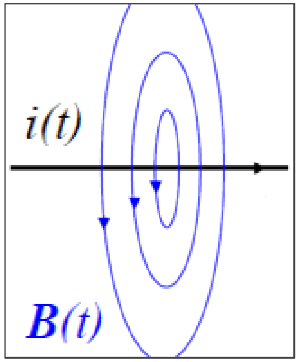
FABRIC

Feasibility analysis and development of on-road charging solutions for future electric vehicles

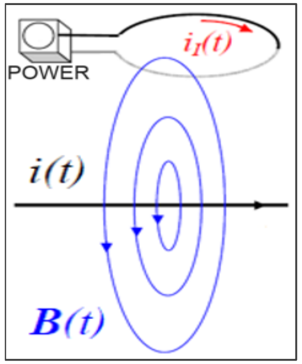
DYNAMIC INDUCTIVE RECHARGING

HOW IT WORKS ?

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 $i_I(t)$ capable to provide the necessary power to recharge the vehicle.