COST Action TU1208

Civil Engineering Applications of Ground Penetrating Radar

Training School on Electromagnetic Modelling Techniques for Ground Penetrating Radar

9-12 November, 2016, Split (Croatia)

Electromagnetic modelling of historical bridges: an approach for a more exhaustive interpretation of GPR measured data

Mercedes Solla

University of Vigo & Defense University Center

COST is supported by the EU Framework Programme Horizon2020

Contents

1) Introduction
- Complex and heterogeneous structures
- FTDT modelling to assist interpetation

2) Case studies
- *San Antón Bridge*: basic geometry
- *Traba Bridge*: real geometry
- *Lubiáns Bridge*: integration of other NDT

COST is supported by the
EU Framework Programme Horizon2020

Introduction




- ❑ Ancient masonry arch bridges: special attention and maintenance
- ❑ NDT: historical character
- ❑ GPR: complex patterns of reflections
- ❑ FDTD modelling as an important additional tool in interpreting GPR measured data
- ❑ New approaches to reproduce more realistic geometries

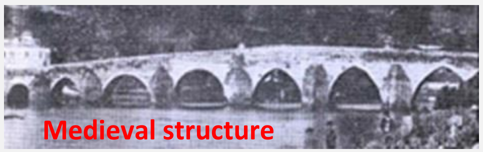
OBJECTIVE:

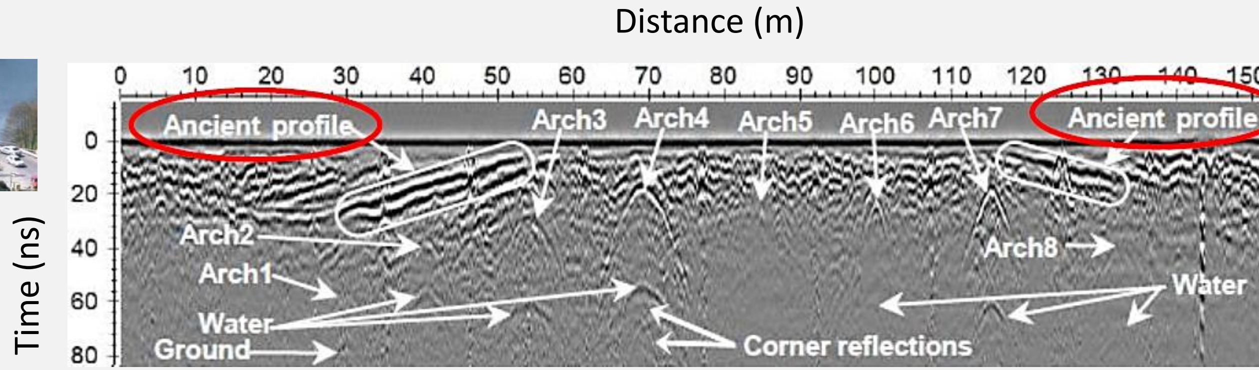
. Internal homogeneity.
. Material identification.
. Holes / cracks.
. Hidden arches.
. Foundations.
. Restorations.
. Ancient shape.
. Structural elements.
. Ring stones thickness.

COST is supported by the
EU Framework Programme Horizon2020

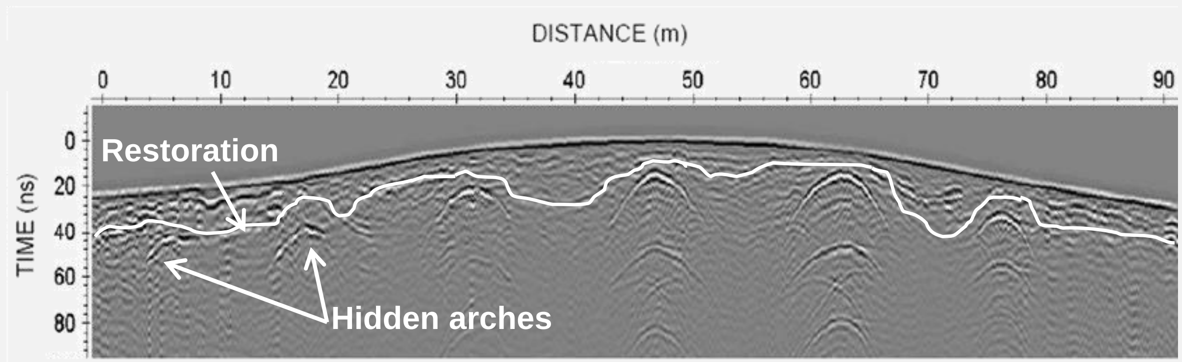
Introduction

Lugo Bridge

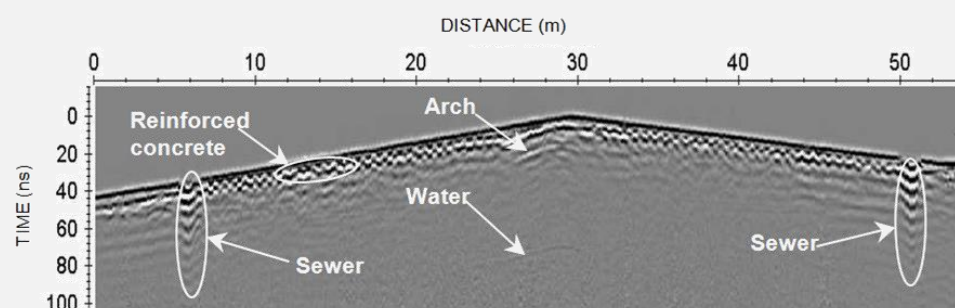




Monforte Bridge



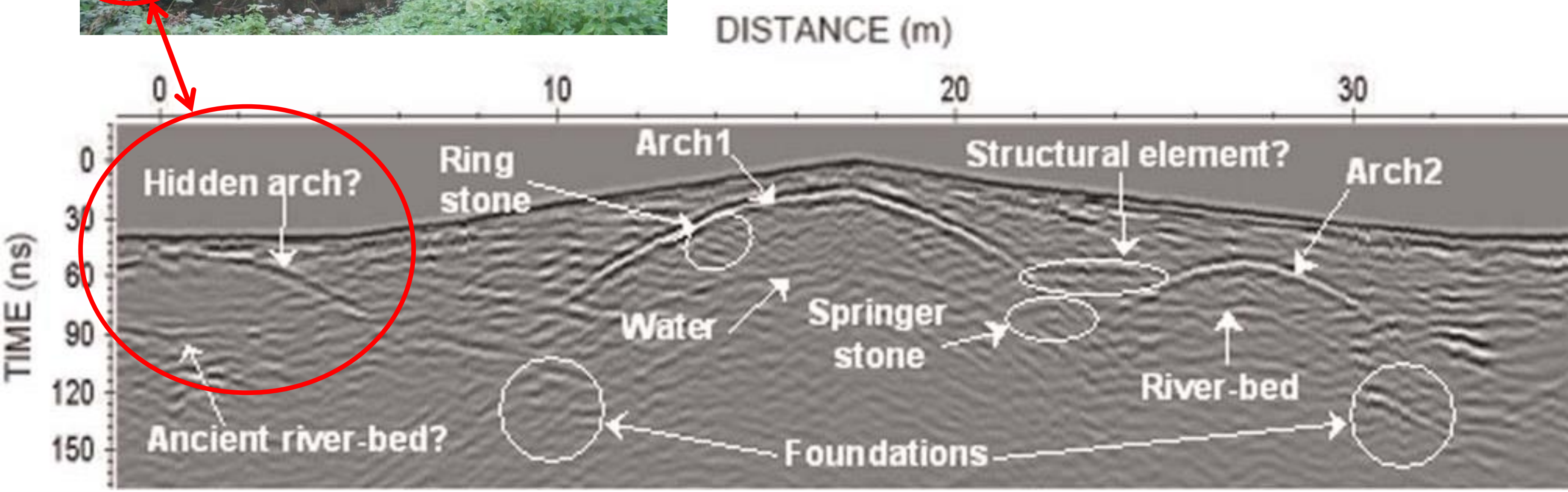
Loña Bridge



Case studies: San Antón Bridge

QUESTIONS:

- **Hidden arch?**
  - □ **Filled or emptied?**
- **Structural element?**



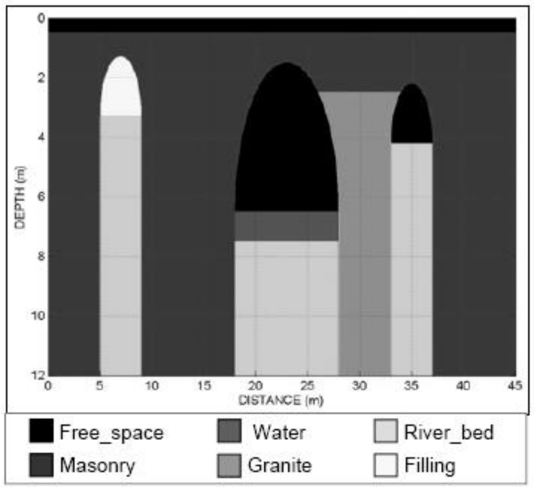
Interpretation of the 250 MHz measured data

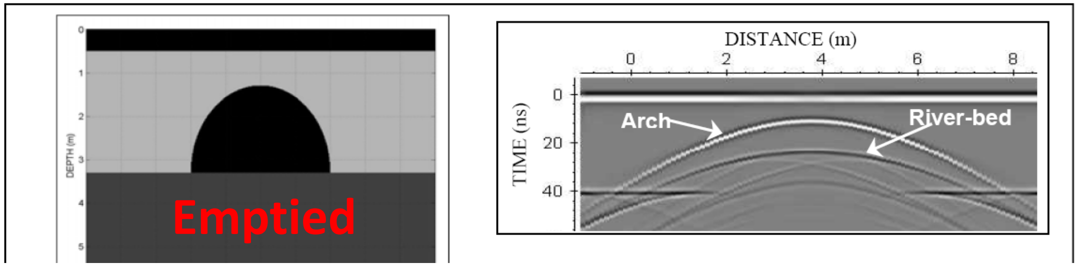
COST is supported by the
EU Framework Programme Horizon2020

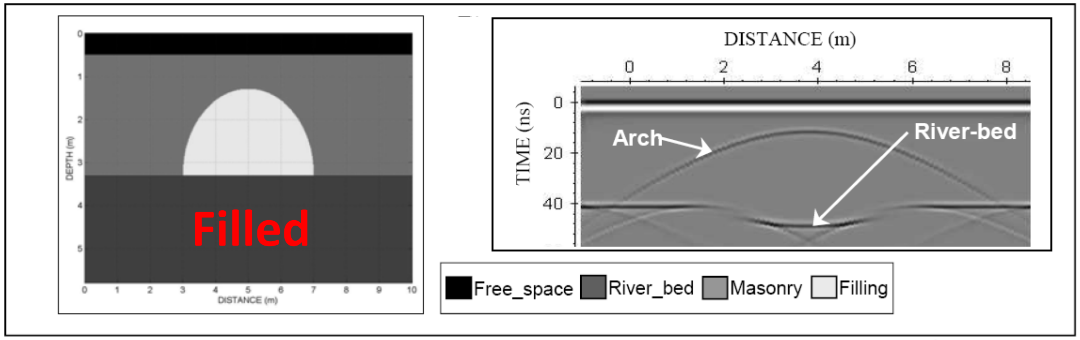
Case studies: San Antón Bridge

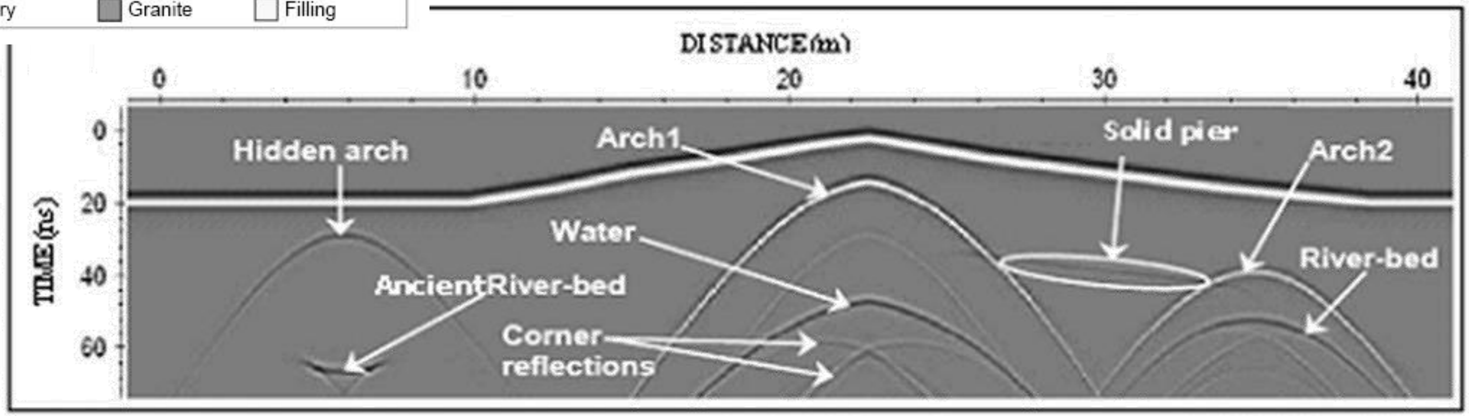
FDTD models

"basic geometry"







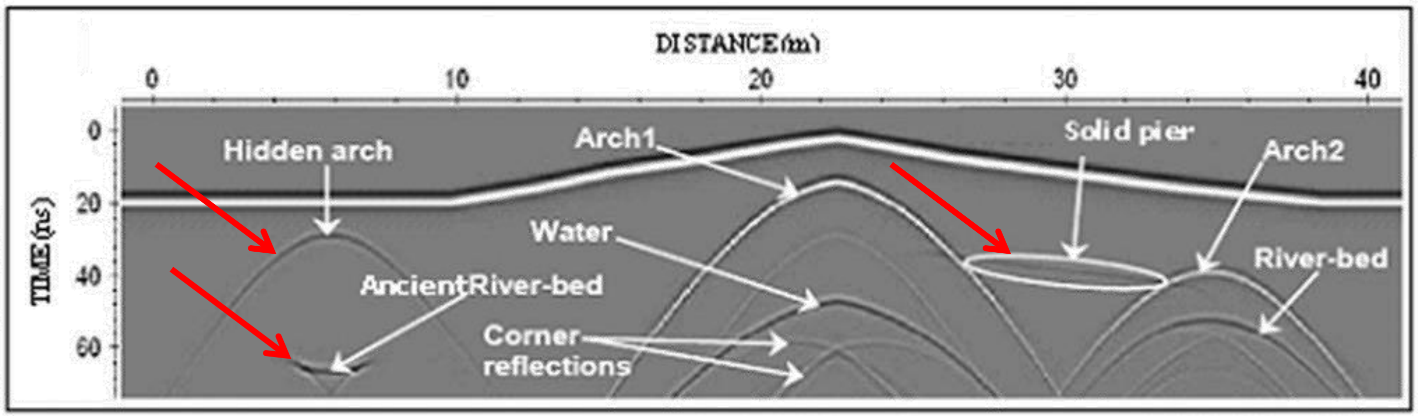


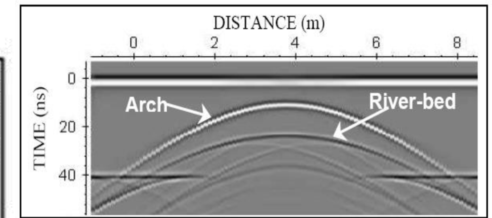
Interpretation of the 250 MHz synthetic data produced

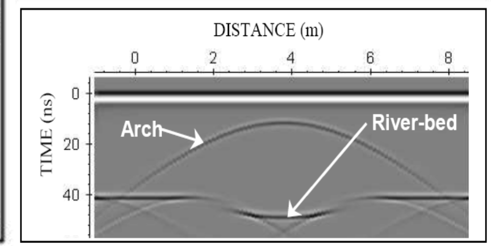
COST is supported by the
EU Framework Programme Horizon2020

Case studies: San Antón Bridge

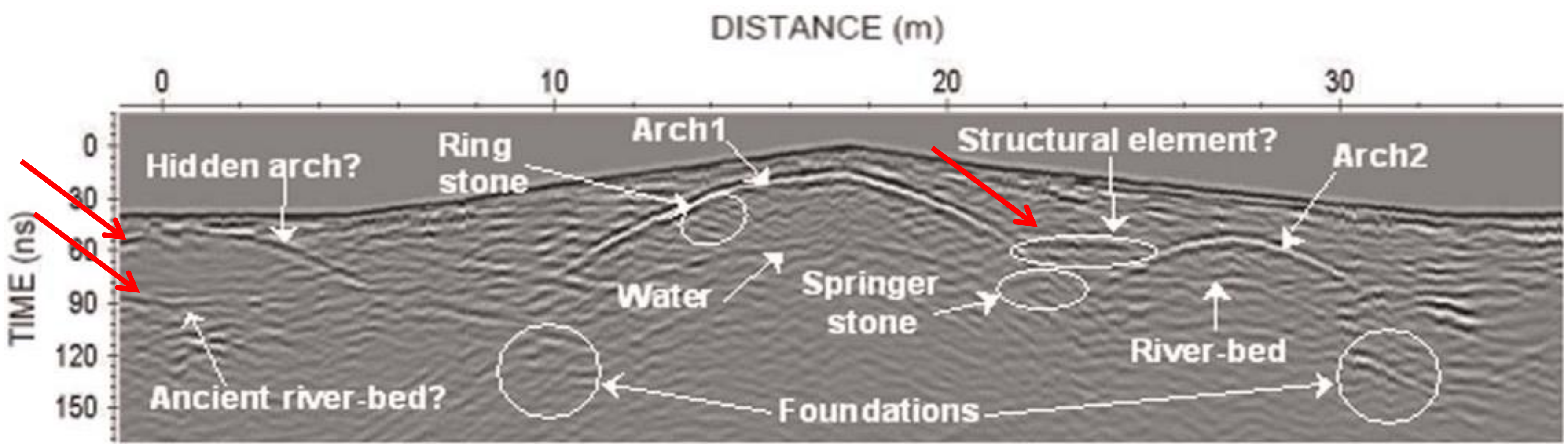
COMPARISON: Synthetic Data vs. Measured Data







Synthetic data



250 MHz measured data

COST is supported by the
EU Framework Programme Horizon2020

Case studies: San Antón Bridge

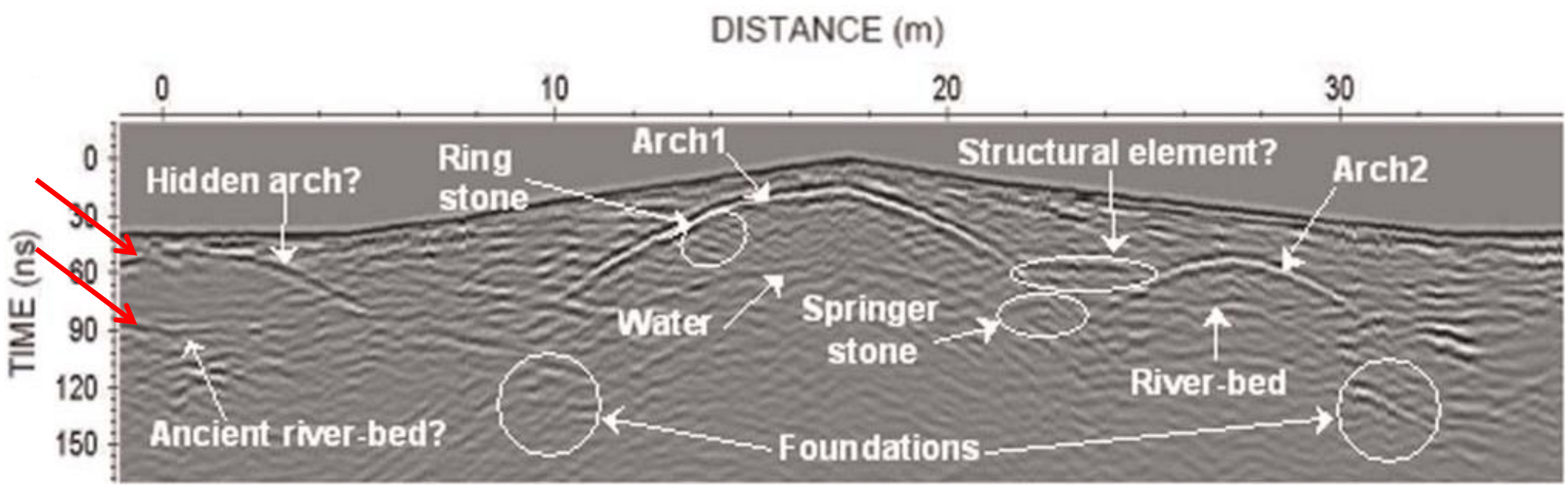
QUESTIONS:

- **Hidden arch?**
  - □ **Filled or emptied?**

There is a third hidden arch
Inversion of the signal polarity: Filled
Flat reflection from the river-bed: Filled

- **Structural element?**

Macize or solid ashlar



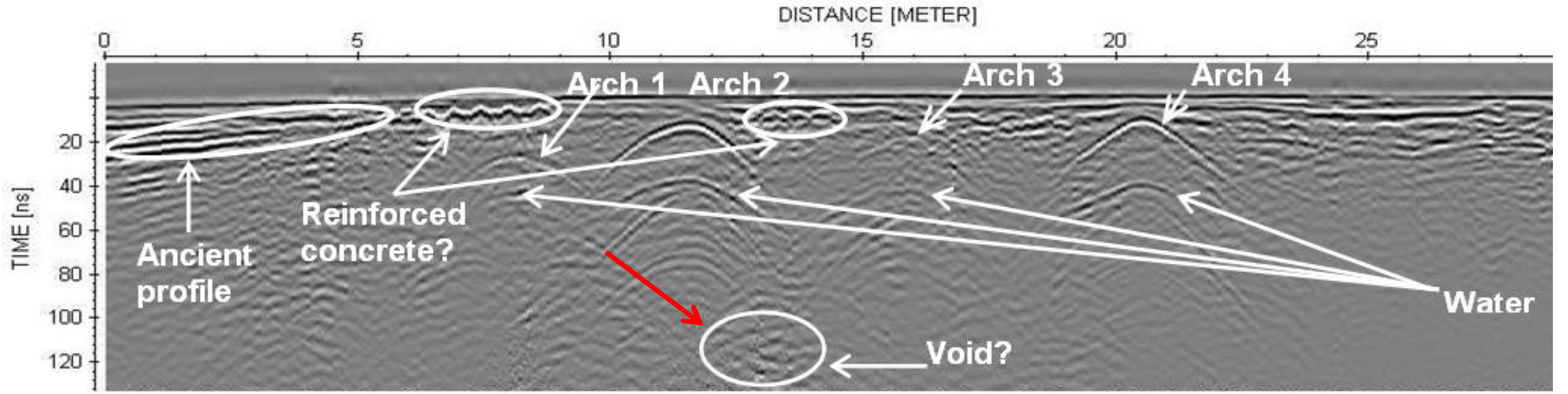
Interpretation of the 250 MHz measured data

COST is supported by the
EU Framework Programme Horizon2020

Case studies: Traba Bridge

QUESTIONS:

- Void in a pier?



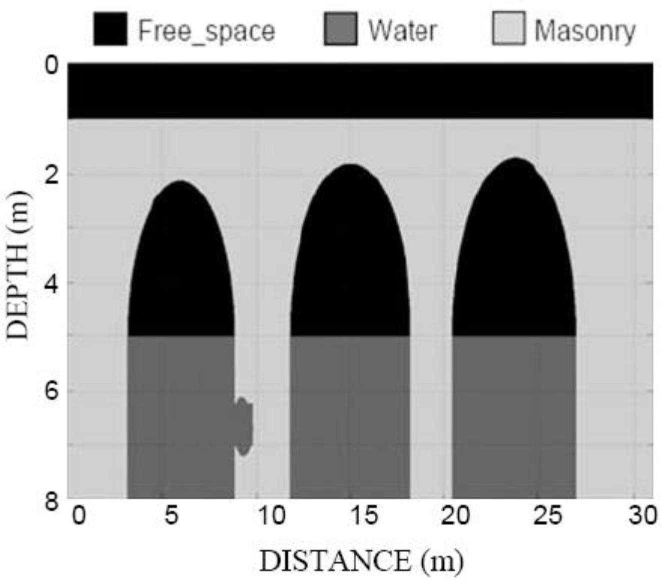
Interpretation of the 250 MHz measured data

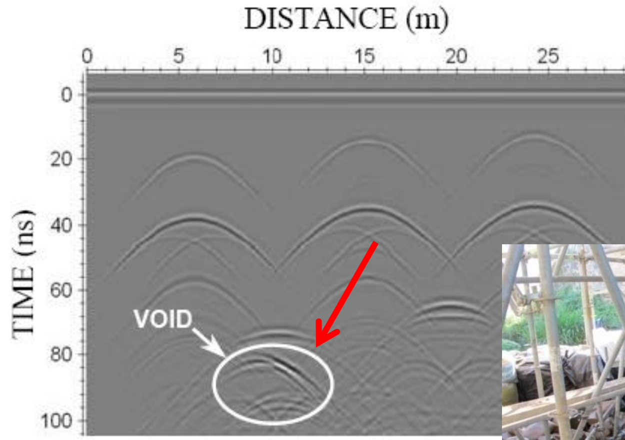
COST is supported by the
EU Framework Programme Horizon2020

Case studies: Traba Bridge

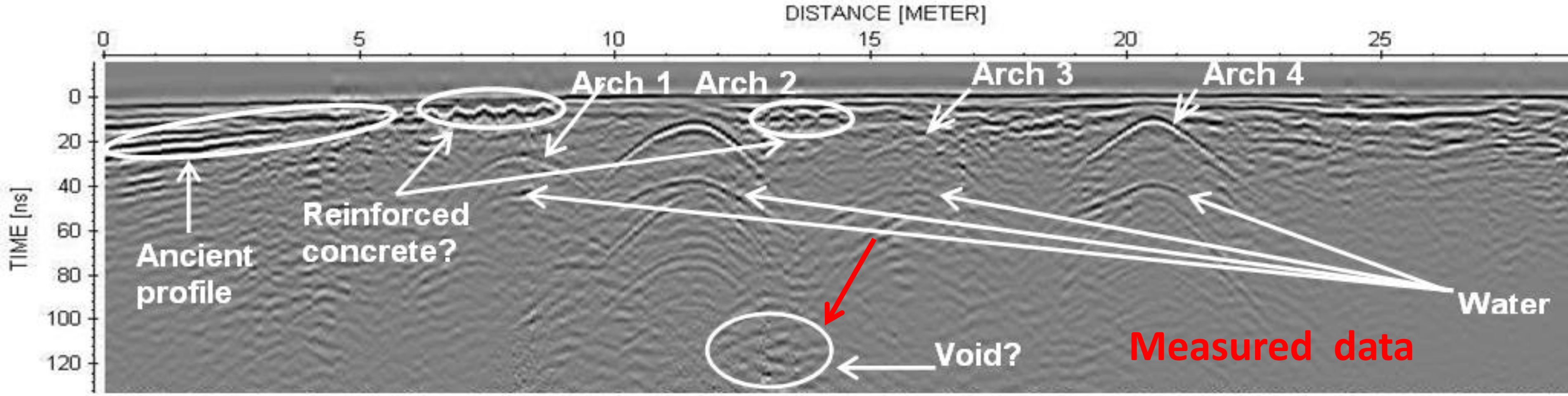
FDTD model

"basic geometry"





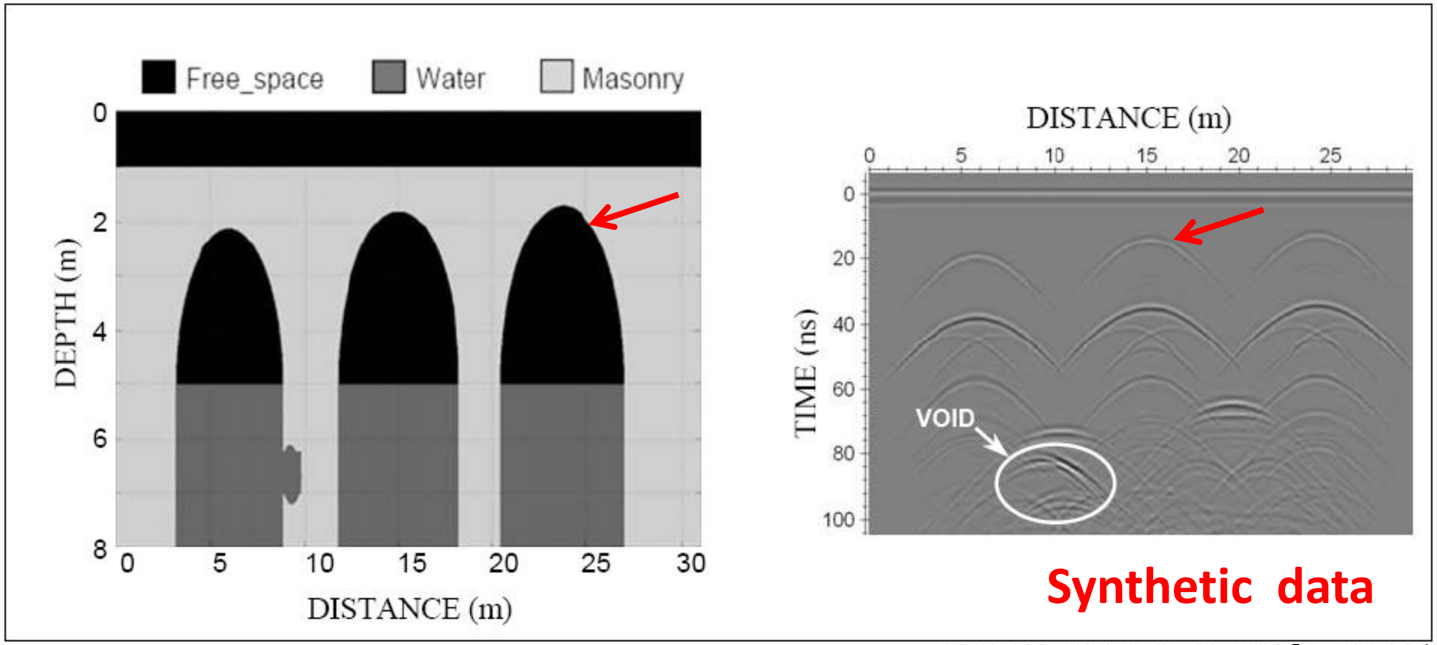
Synthetic data



COST is supported by the
EU Framework Programme Horizon2020

Case studies: Traba Bridge

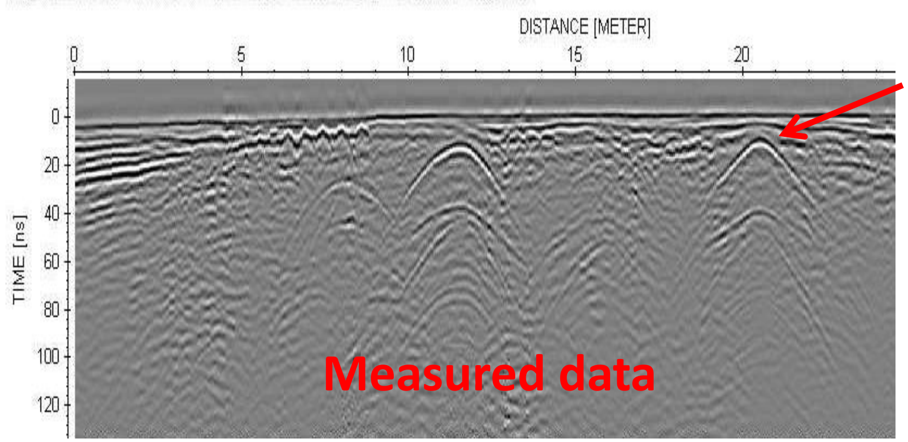
Complex geometries (e.g. gothic arches)



FDTD model

"basic geometry"

Real geometry



COST is supported by the
EU Framework Programme Horizon2020

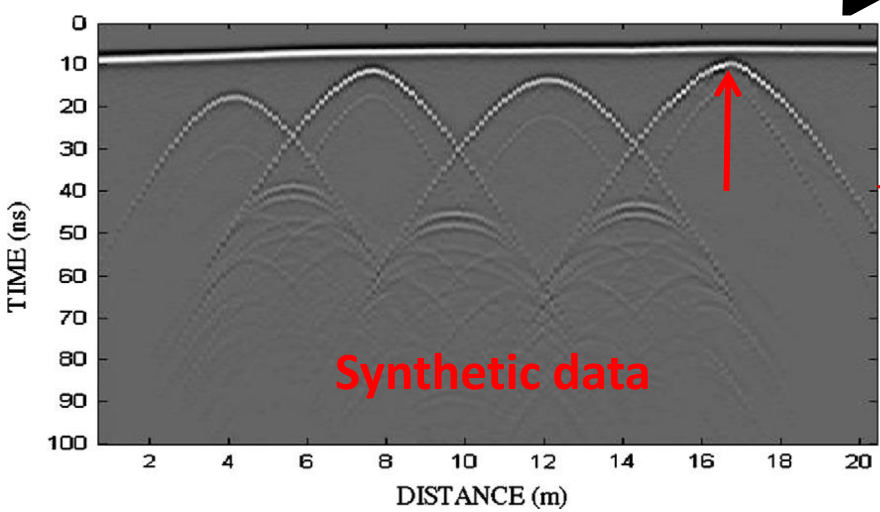
Case studies: Traba Bridge

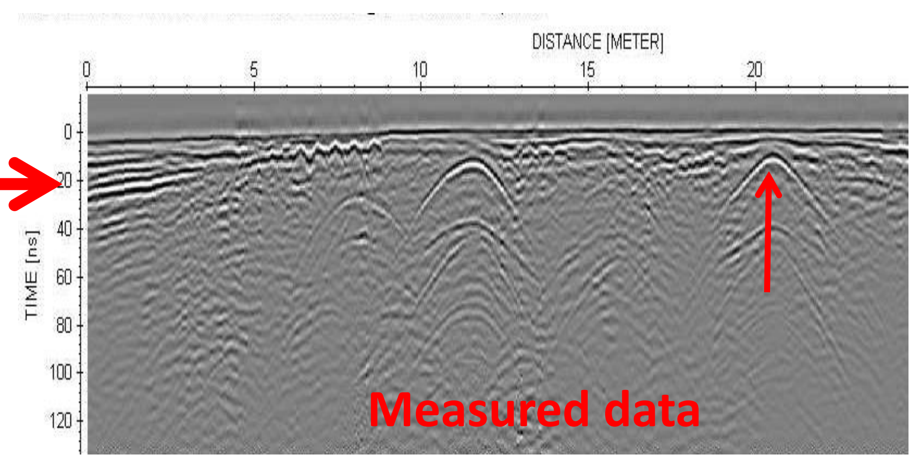
Complex geometries (e.g. gothic arches)

Approach for more realistic and large scale FDTD models

Photogrammetry: Real geometry

Binarized image: FDTD model



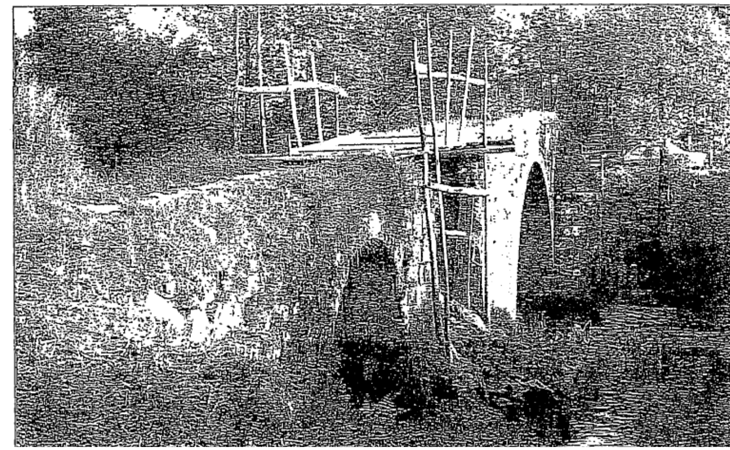


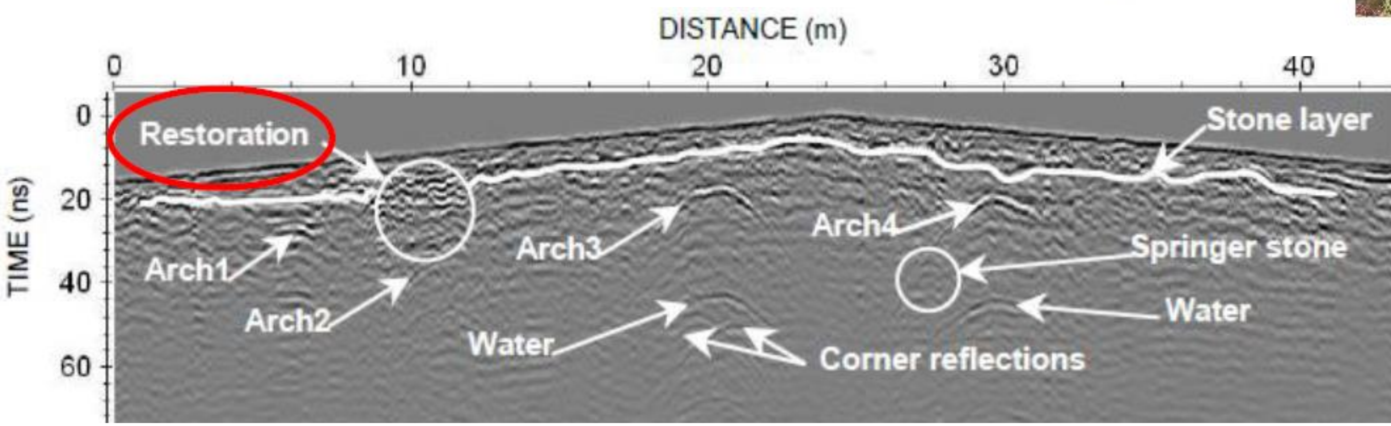
COST is supported by the
EU Framework Programme Horizon2020

Case studies: Lubiáns Bridge

QUESTIONS:

- **Restorations?**





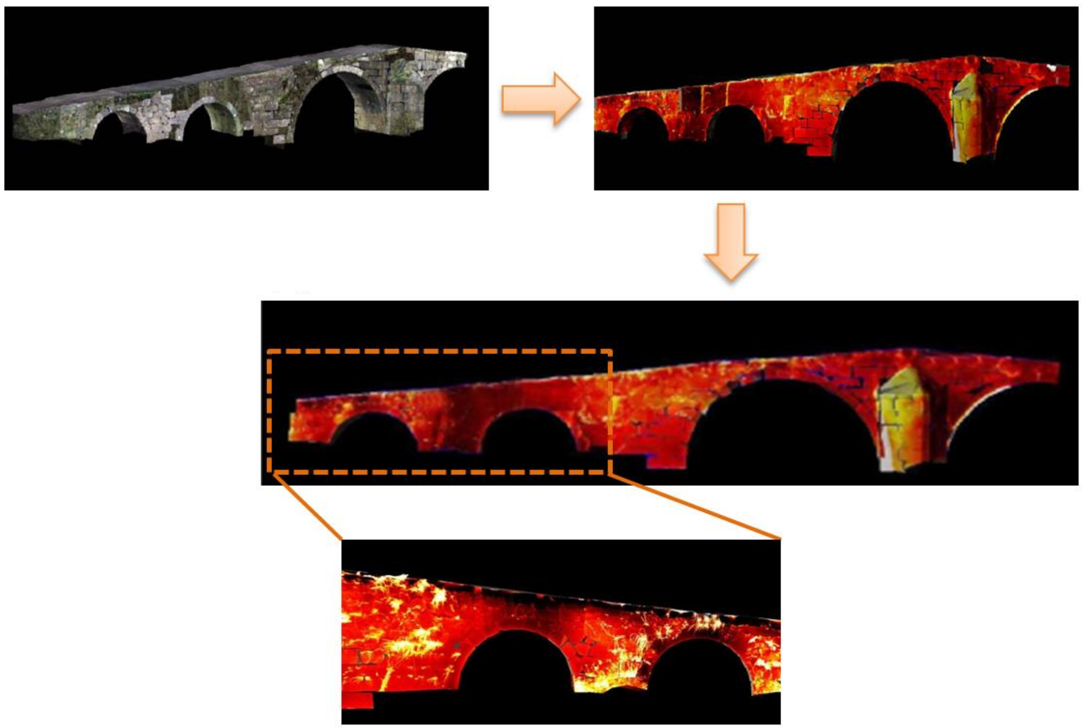
Interpretation of the 500 MHz measured data

COST is supported by the
EU Framework Programme Horizon2020

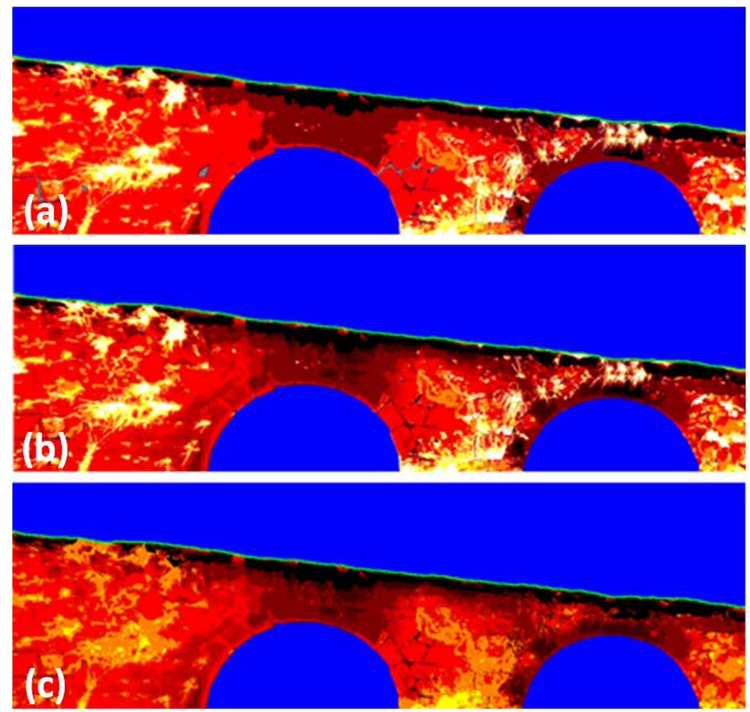
Case studies: Lubiáns Bridge

INTEGRATION OF OTHER NDT IN MODELLING

Photogrammetry: its precise geometric data defines the structure in fine detail.
Thermography: enables zoning from differences in heat-emissivity values.



Orthothermogram



FDTD MODEL

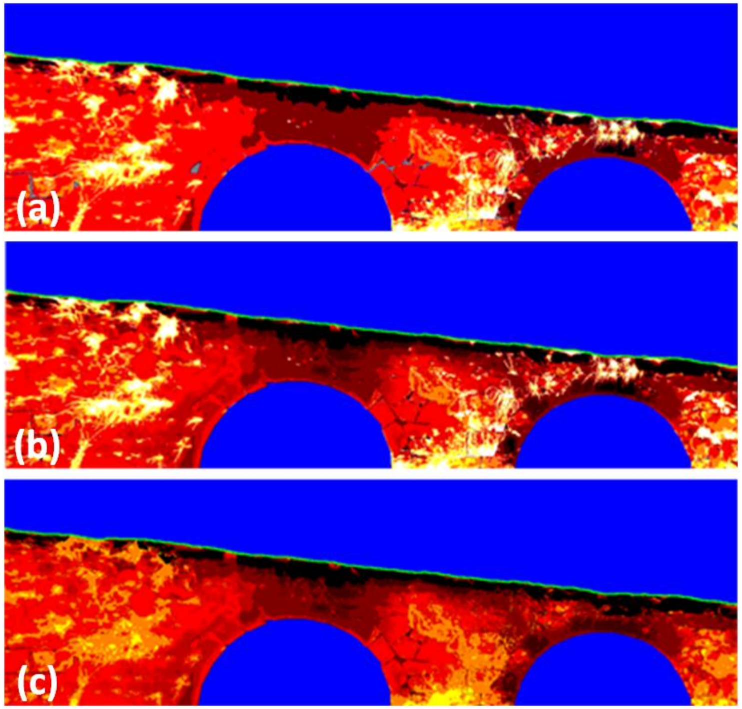
COST is supported by the
EU Framework Programme Horizon2020

Case studies: Lubiáns Bridge

INTEGRATION OF OTHER NDT IN MODELLING

Similar temperatures correspond to regions with similar properties.

- The first step (a) consisted on transforming the original color palette (256 colors) to a reduced version of up to 16 colors.
- Further improvements are performed on the image (b). First one is the elimination of gray areas, which are zones with no assigned temperature. These gray areas are removed via interpolation with surrounding areas. Second one, and more important, is to identify large regions from the previous step and split them in smaller zones according to the temperature in the original image.



FDTD MODEL

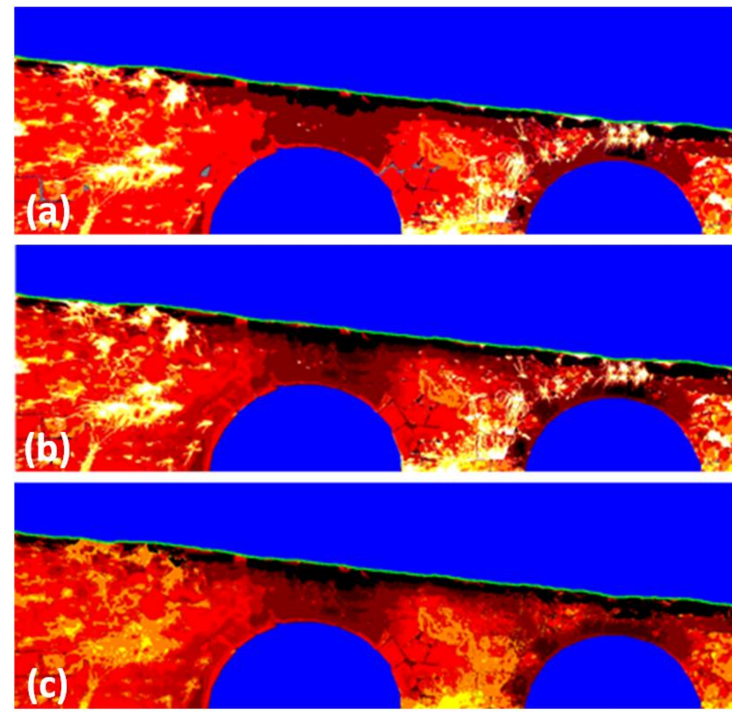
COST is supported by the
EU Framework Programme Horizon2020

Case studies: Lubiáns Bridge

INTEGRATION OF OTHER NDT IN MODELLING

Similar temperatures correspond to regions with similar properties.

- Because the real radargram is obtained from what is behind the vegetation, in order to improve accuracy, it is mandatory to implement a method to remove it. Vegetation corresponds to areas with the highest reflectivity (whiter areas), whereas bridge construction materials have lower ones (red and black zones). As it is impossible to know the real material behind this vegetation, the solution (c) was to employ an interpolation technique with surrounding areas.



FDTD MODEL

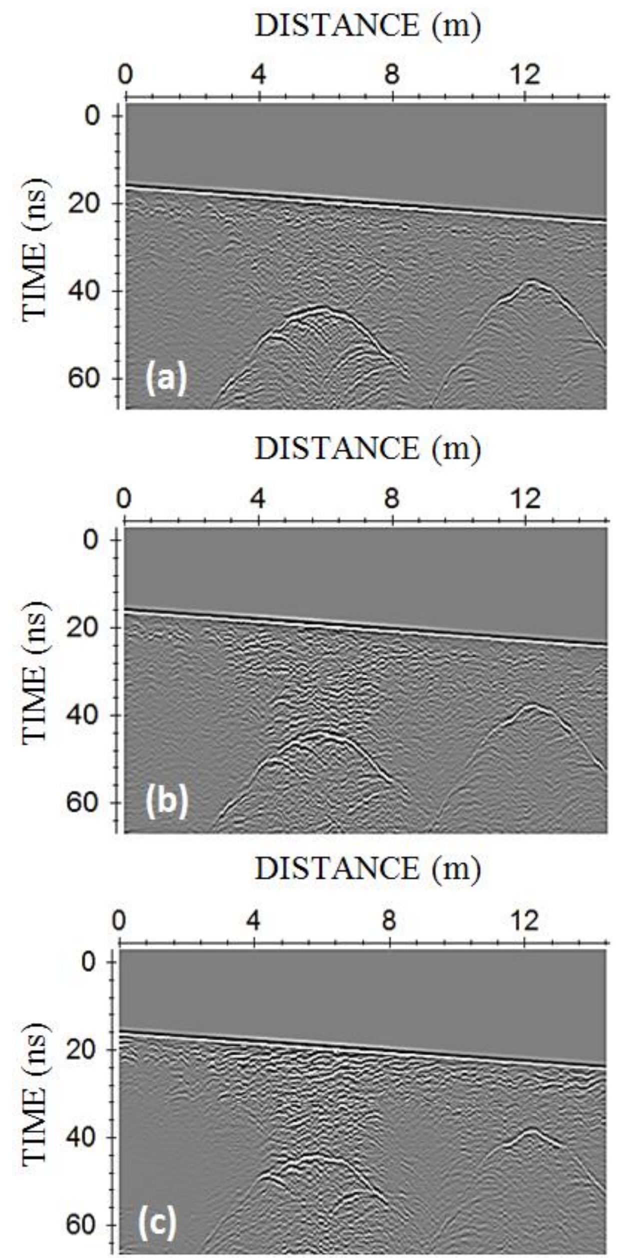
COST is supported by the
EU Framework Programme Horizon2020

Case studies: Lubiáns Bridge

INTEGRATION OF OTHER NDT IN MODELLING

To randomly generate layers: Pareto on/off distributions.

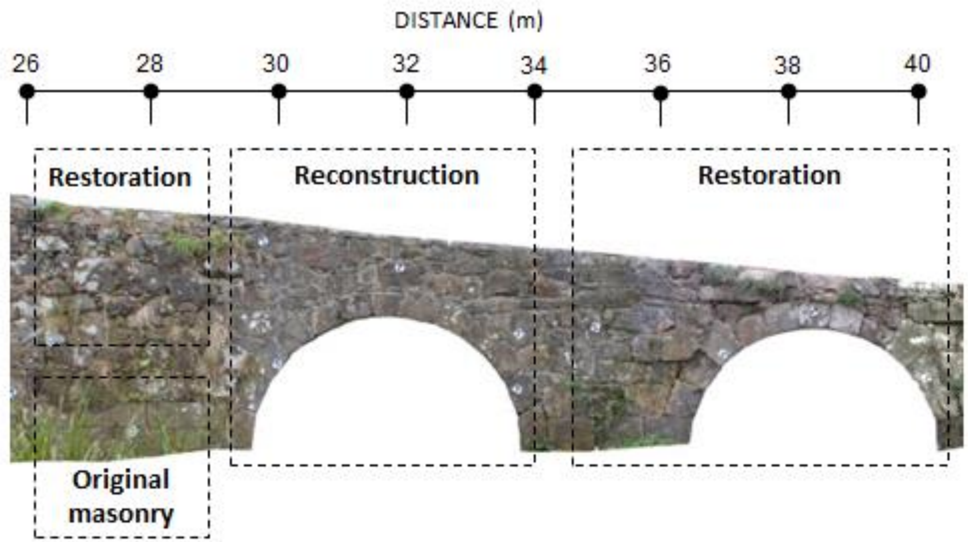
Assumption (a): material layout distributions were all the same for all regions. Regions formed by more than one material were modelled with a uniform distribution (each material with a custom heterogeneity setup).
Assumption (b): A layered layout composed of stone and cement was assumed. However, layer sizes and material proportions still did not match those of the real data.
Assumption (c): The final setup in the restored zone led to an average length of 30 cm, whereas the thickness was adjusted to 6 and 4 cm for stone and cement, respectively. In the case of the pavement structure, this setup resulted in an average length of 60 cm and thickness of 5 and 3 cm for stone and cement, respectively.



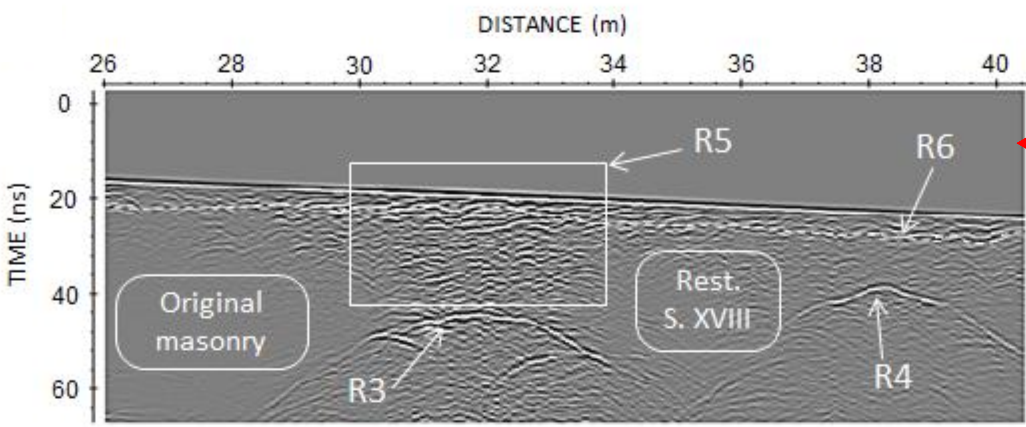
COST is supported by the
EU Framework Programme Horizon2020

Case studies: Lubiáns Bridge

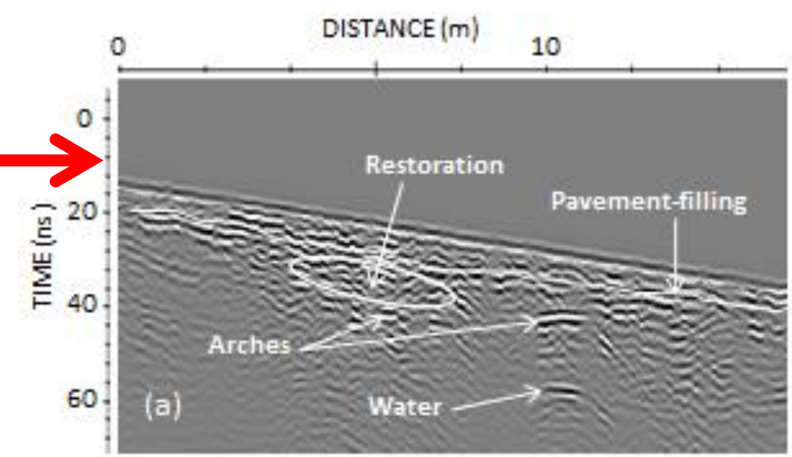
INTEGRATION OF OTHER NDT IN MODELLING



Region	Filling materials	Dielectric constant (k)
Pathway	Granite flagstones	60%: 5-7
	Cement	40%: 12-13
Original masonry	Granitic ashlar	100%: 6-7
Restoration s.XVIII	Granitic masonry	60%: 7-9
	Clay	40%:11-14
Reconstructions.X X	Granitic masonry	60%: 7-9
	Cement	40%:11-14



Synthetic data



Measured data

COST is supported by the
EU Framework Programme Horizon2020

COST Action TU1208

Civil Engineering Applications of Ground Penetrating Radar

Training School on Electromagnetic Modelling Techniques for Ground Penetrating Radar

9-12 November, 2016,
Split (Croatia)

Electromagnetic modelling of historical bridges: an approach for a more exhaustive interpretation of GPR measured data

Mercedes Solla
University of Vigo & Defense University Center

COST is supported by the
EU Framework Programme Horizon2020