ELASTIC AND ELECTROMAGNETIC WAVE MONITORING OF EARLY AGE TRC

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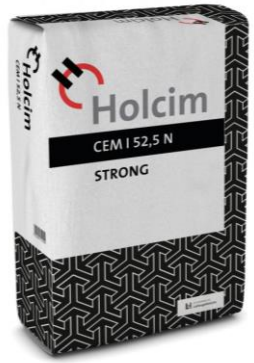
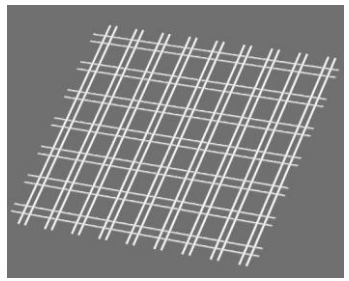
MATERIAL

TEXTILE REINFORCED CEMENTITIOUS COMPOSITE

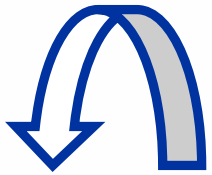




1. "Heydar Aliyev Center / Zaha Hadid Architects" 14 Nov 2013. ArchDaily. Accessed 26 Aug 2020. <https://www.archdaily.com/448774/heydar-aliyev-center-zaha-hadid-architects> ISSN 0719-8884

Durable

Lightweight

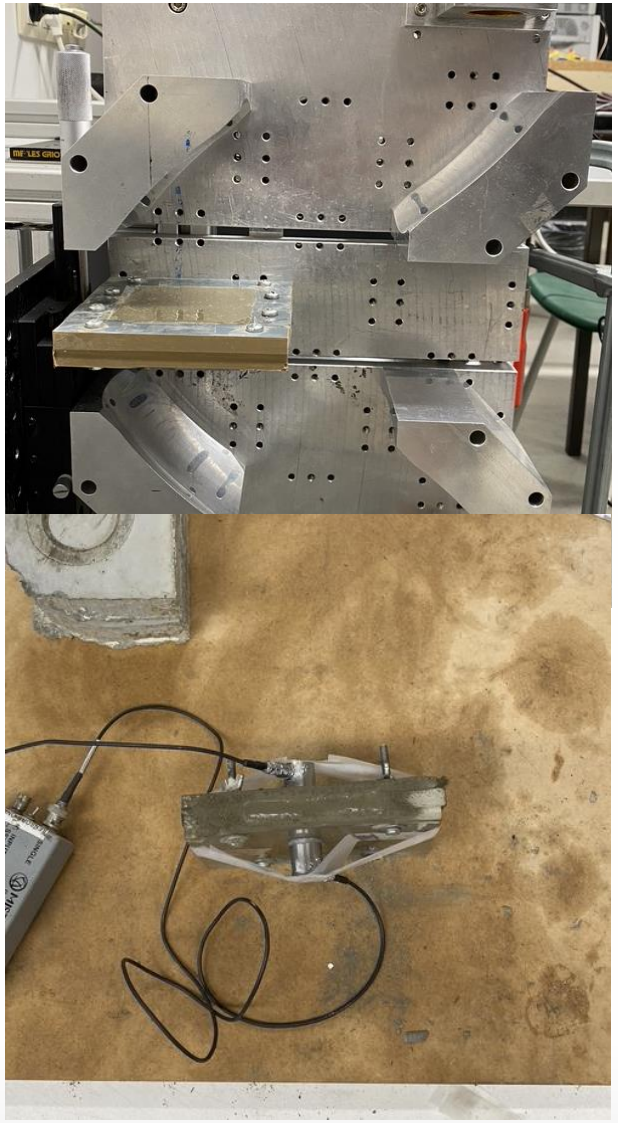


Freeform

OBJECTIVE

CURING MONITORING OF EARLY AGE TRC

Monitor the hydration and curing of early age TRC with Ultrasound Pulse Velocity (UPV), Ultrasound Wave Reflection (UWR) and MMW Spectrometry to provide an assessment on the mechanical and physical changes during this period.



Techniques and setup

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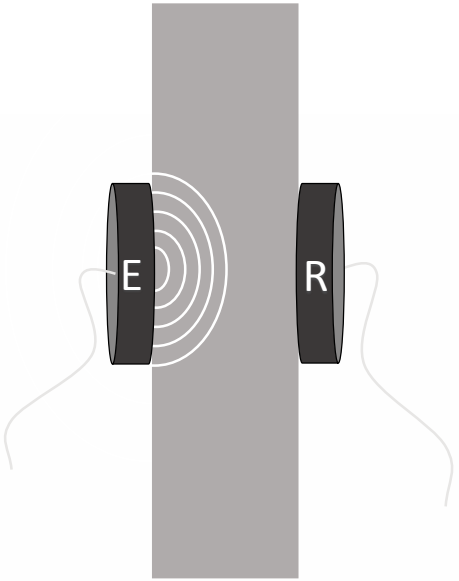
NON-DESTRUCTIVE TECHNIQUES

ULTRASOUND

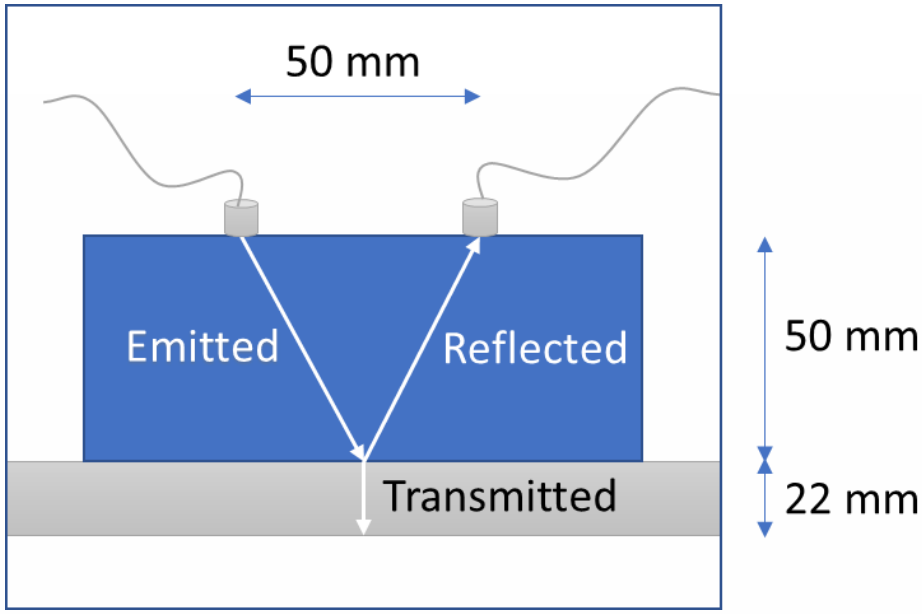
Pulse Velocity



In order to **monitor the development of stiffness** in fresh mortar and TRC, the **WAVE VELOCITY** is measured experimentally and the Young Modulus is estimated.

Wave Reflection

In order to **monitor** the **hydration** of **TRC plates**, the **AMPLITUDE** of the reflection of longitudinal waves was continuously monitored.

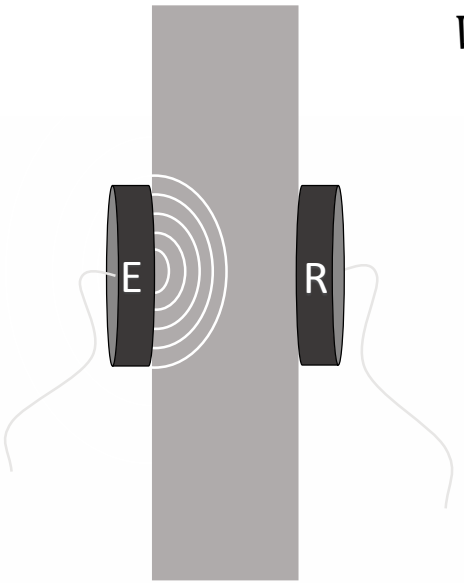


NON-DESTRUCTIVE TECHNIQUES

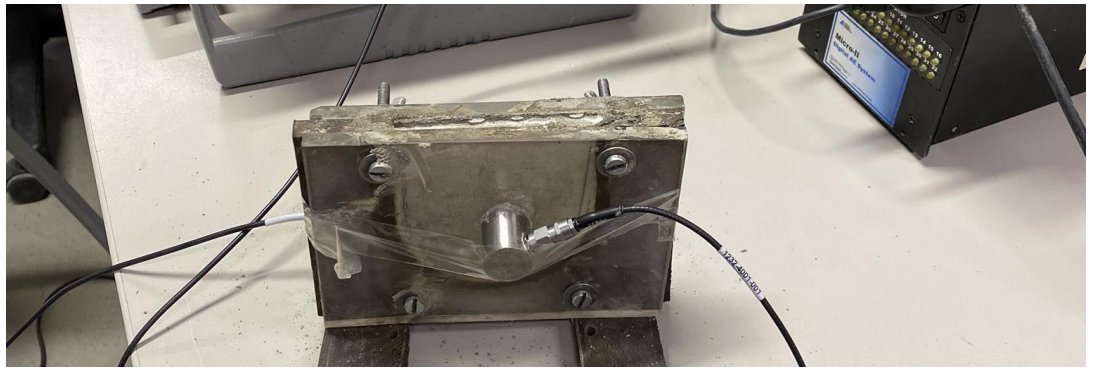
ULTRASOUND PULSE VELOCITY

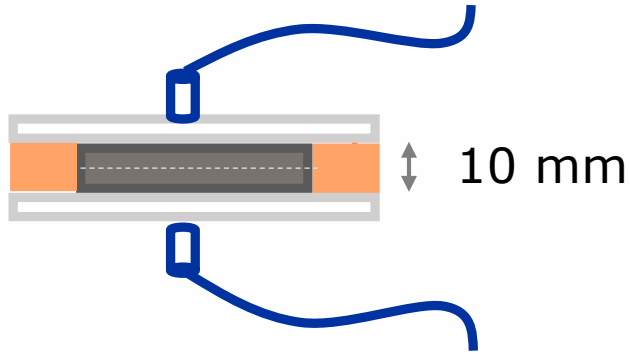
Pulse Velocity

$$V_l = \sqrt{\frac{E * (1 - \nu)}{\rho(1 + \nu)(1 - 2\nu)}}$$



- Micro-II Digital AE System
- R15 sensors
- Agilent 20 MHz Waveform Generator





Top view

NON-DESTRUCTIVE TECHNIQUES

ULTRASOUND WAVE REFLECTION

$$r = \frac{A_r}{A_i} = \frac{\left(\rho_{trc} V_{trc} - \rho_{pvc} V_{pvc}\right)}{\rho_{trc} V_{trc} + \rho_{pvc} V_{pvc}}$$

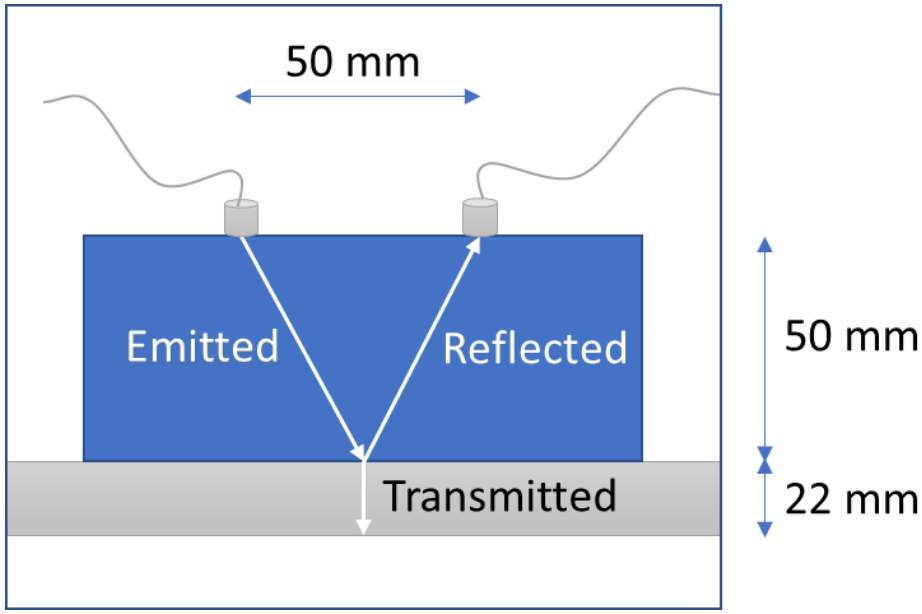
$A = Amplitude\ of\ reflected\ and\ transmitted\ waves.$

$\rho = Density\ of\ materials$

$V = Wave\ velocity$

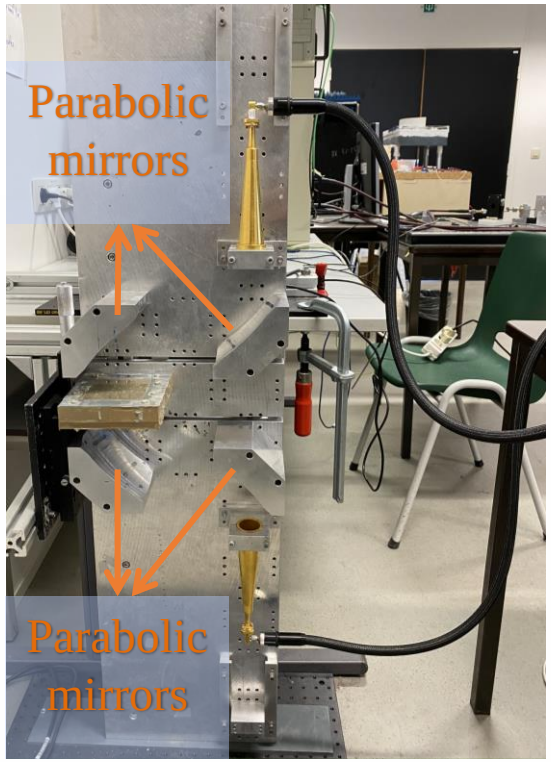
In order to **monitor** the **hydration** of **TRC plates**, the **AMPLITUDE** of the reflection of longitudinal waves was continuously monitored.

Wave Reflection



NON-DESTRUCTIVE TECHNIQUES

MMW SPECTROMETRY



Electromagnetic technique based on **sweeping frequencies** in a determined **bandwidth** (**between 30 and 300 GHz**) through a sample. With the **amplitude** of the **transmitted** and **reflected waves** and known **geometry**, the **EM properties can be determined.**

Water (High permittivity)

+

Cement (Low permittivity)

+

Sand (Low permittivity)

+

Textiles (Low permittivity)

=

TRC (Low permittivity)

Results

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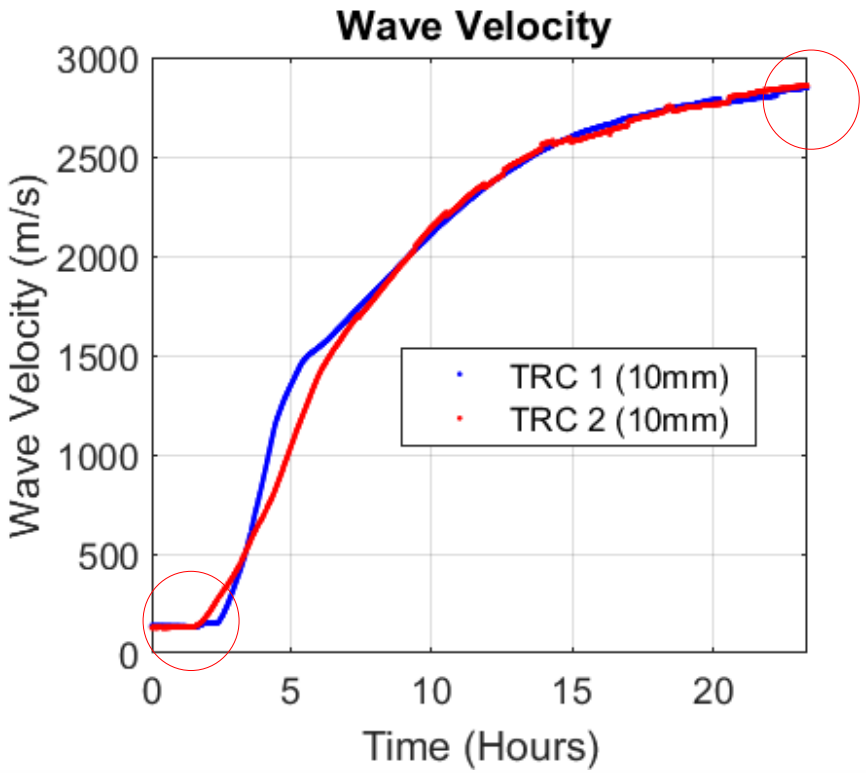
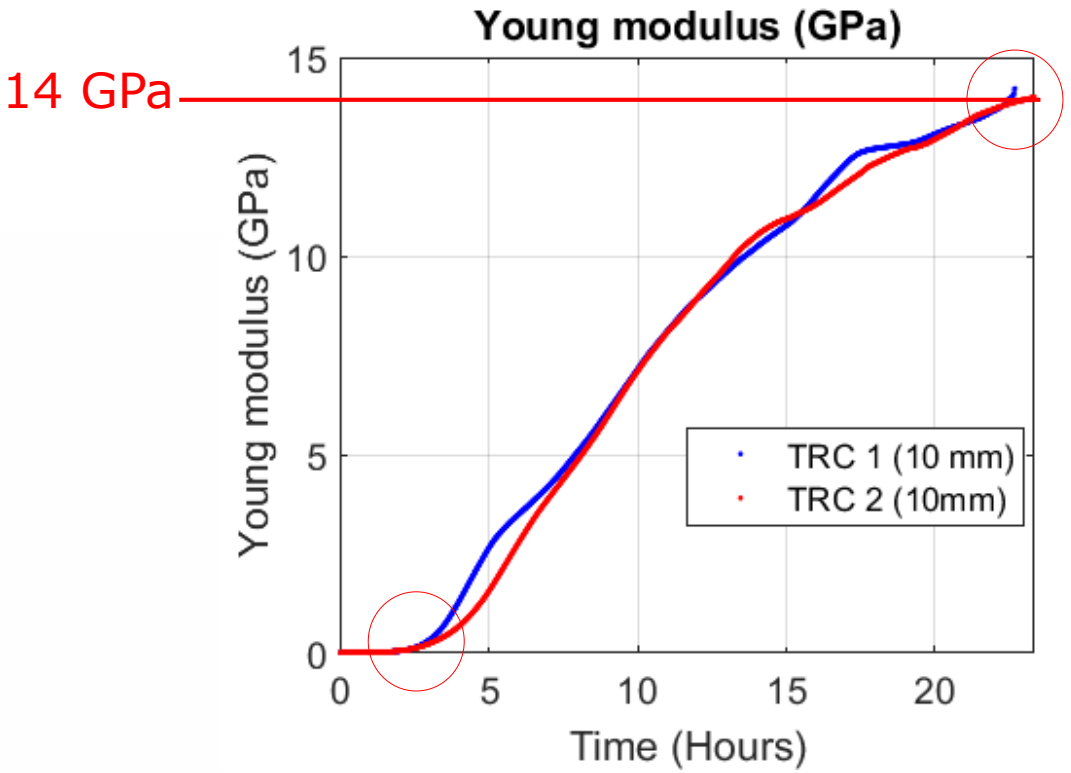
RESULTS

UPV

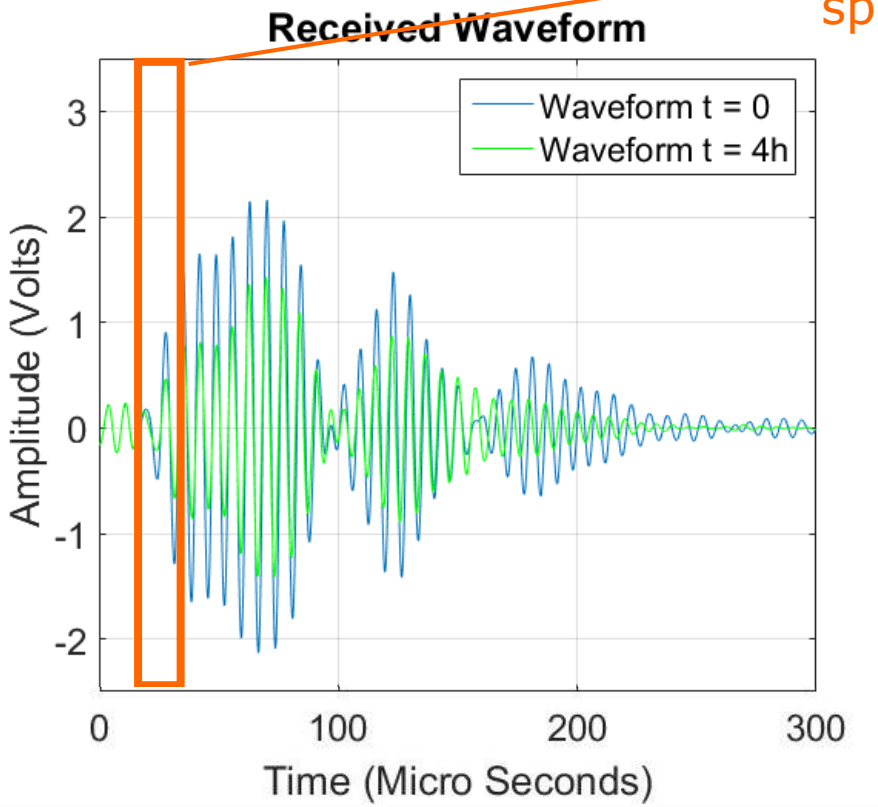

Wave Velocity
Wave Velocity (m/s)
Time (Hours)
TRC 1 (10mm)
TRC 2 (10mm)
0
500
1000
1500
2000
2500
3000
0
5
10
15
20

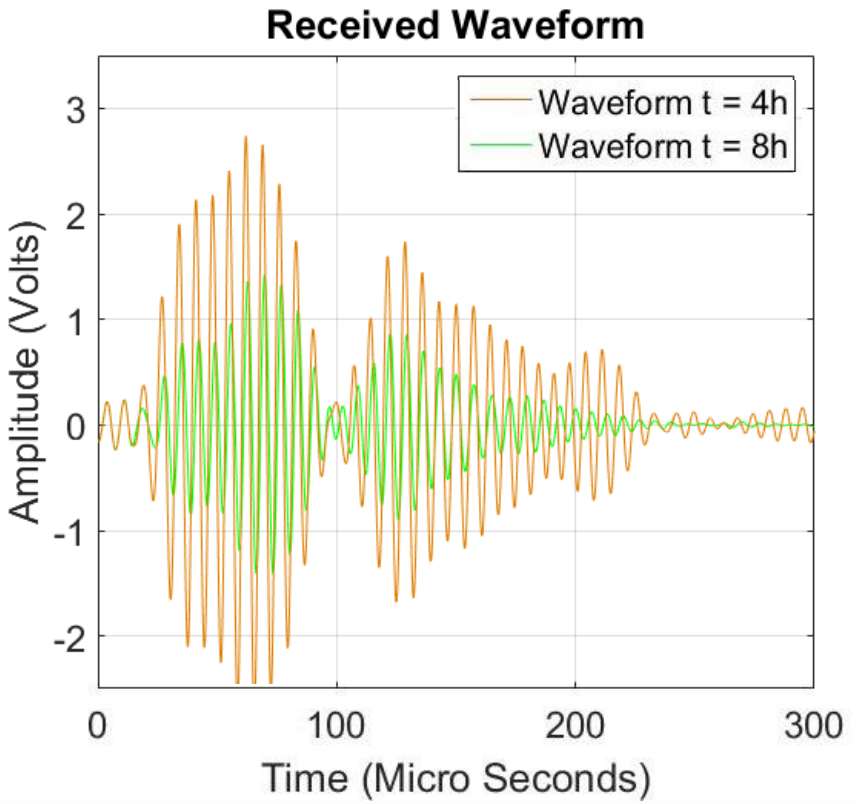

14 GPa
Young modulus (GPa)
Young modulus (GPa)
Time (Hours)
TRC 1 (10 mm)
TRC 2 (10mm)
0
5
10
15
0
5
10
15
20

RESULTS

UWR

Reflection span





RESULTS

UWR

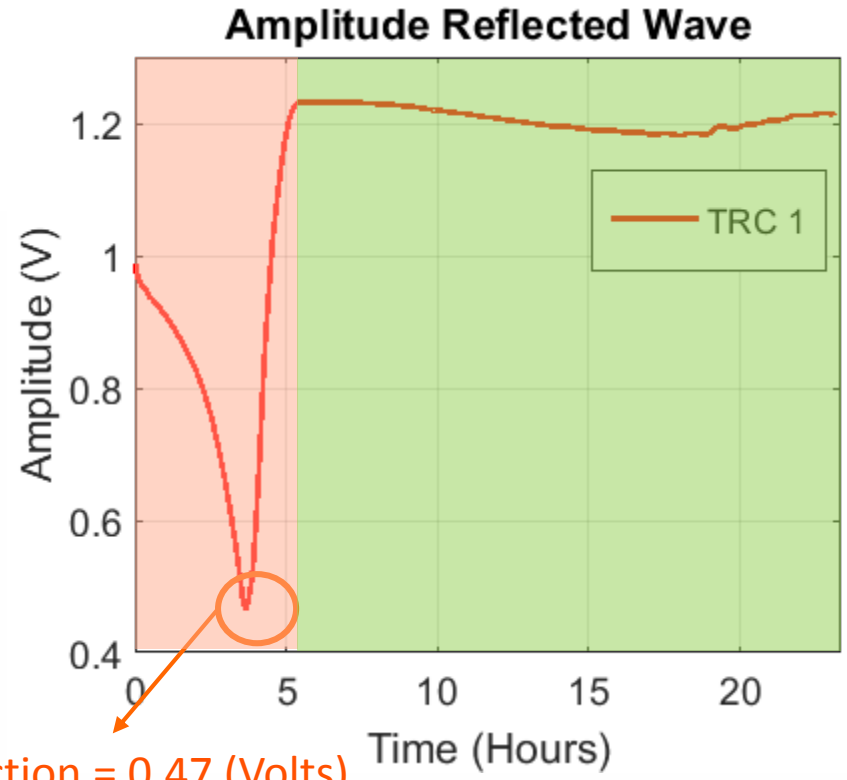
1. Hardening of surface of TRC

Minimum point – Theoretically
Z1 = Z2.

High sensitivity of the test

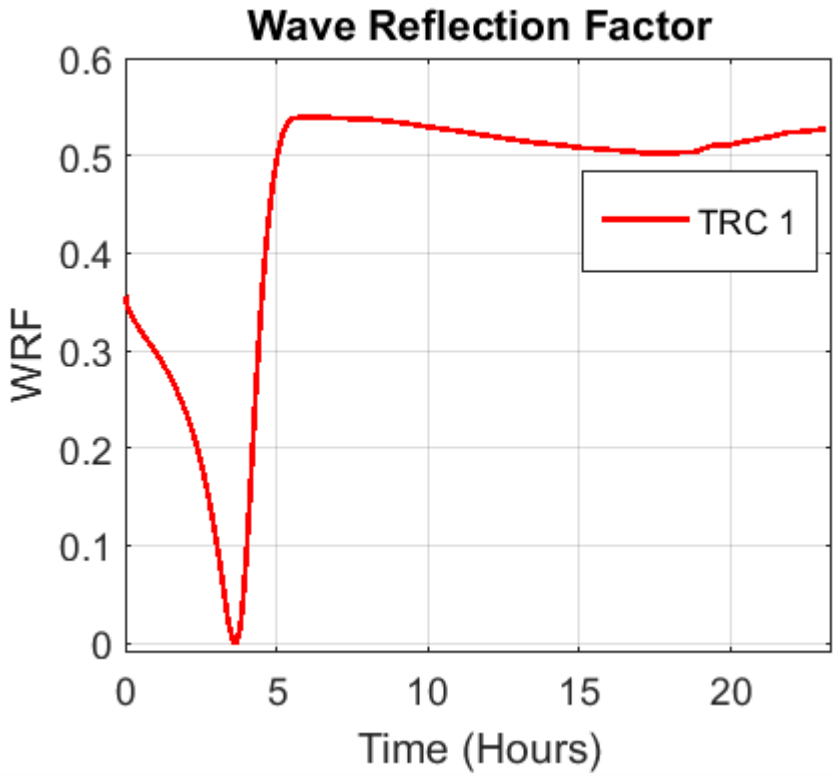
2. Low sensitivity of the test.

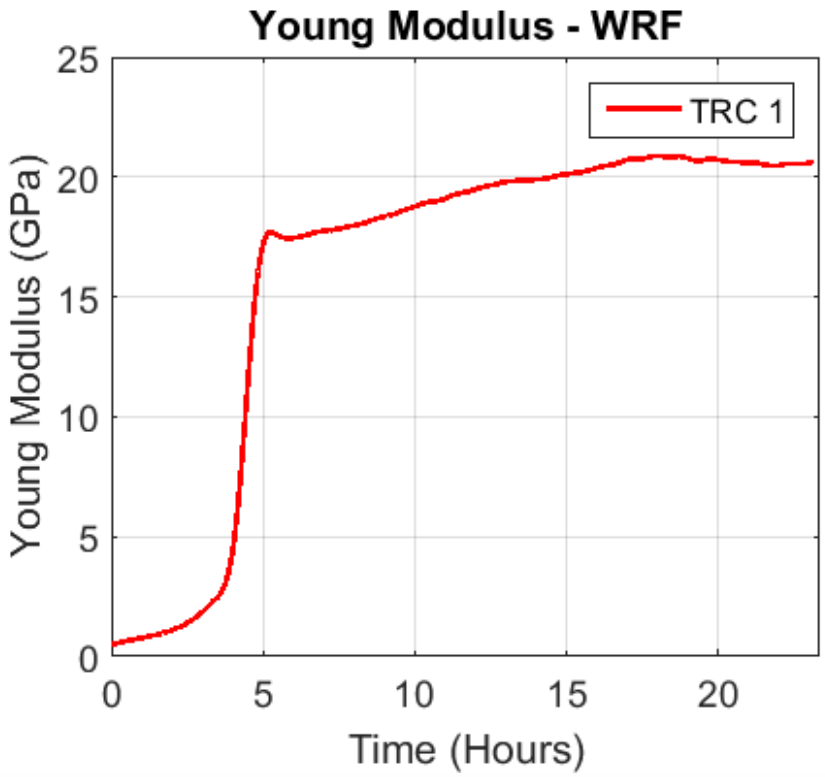
It is relative to the buffer material.



Minimum reflection = 0.47 (Volts)
Time min reflection = 219min = 3h 39 min

E = 4.47 GPa



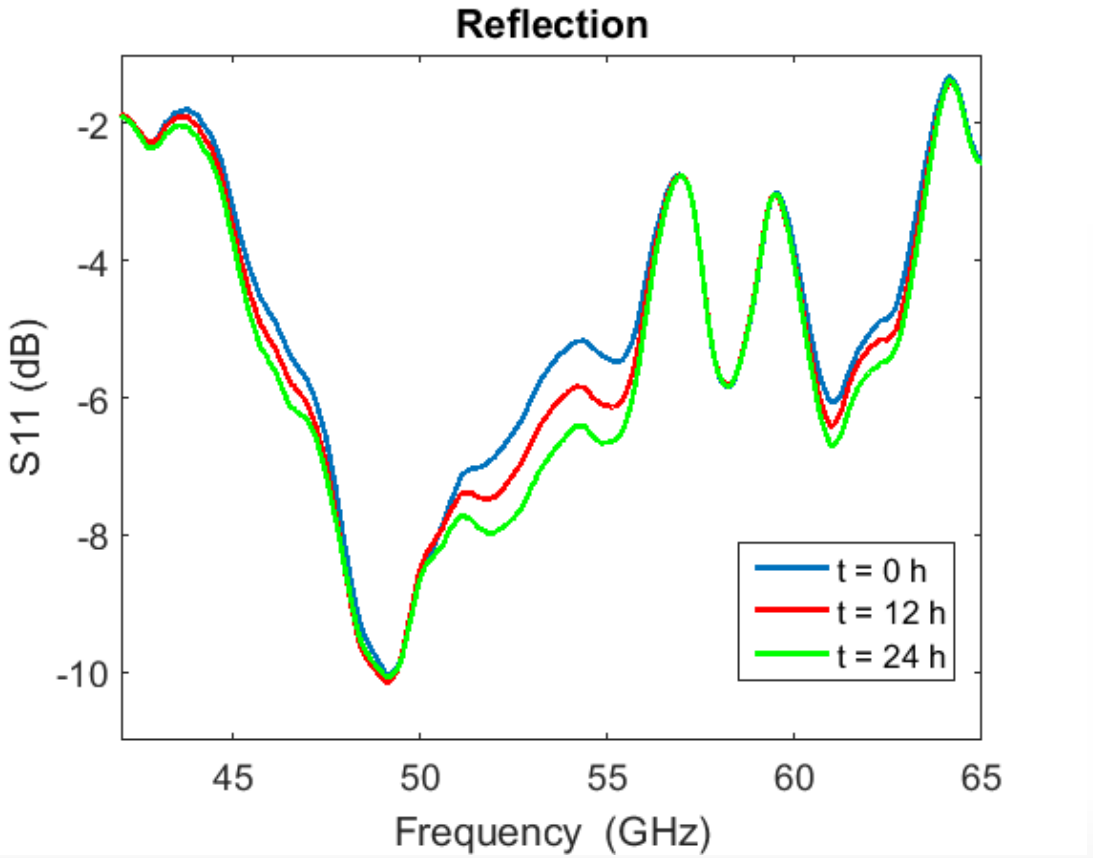


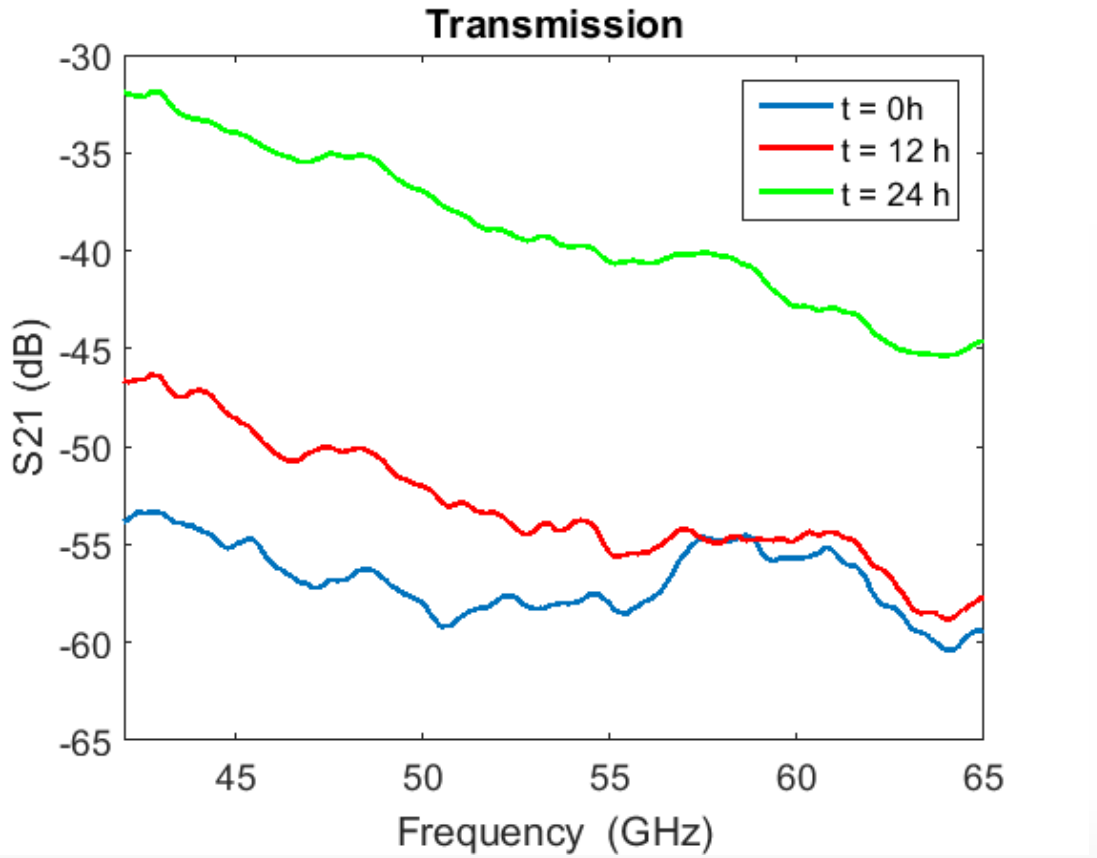
The amplitude monitored was normalized by dividing it vs air and subtracting the minimum reflection to 0.

The Young modulus was calculated.

RESULTS

MMW SPECTROMETRY

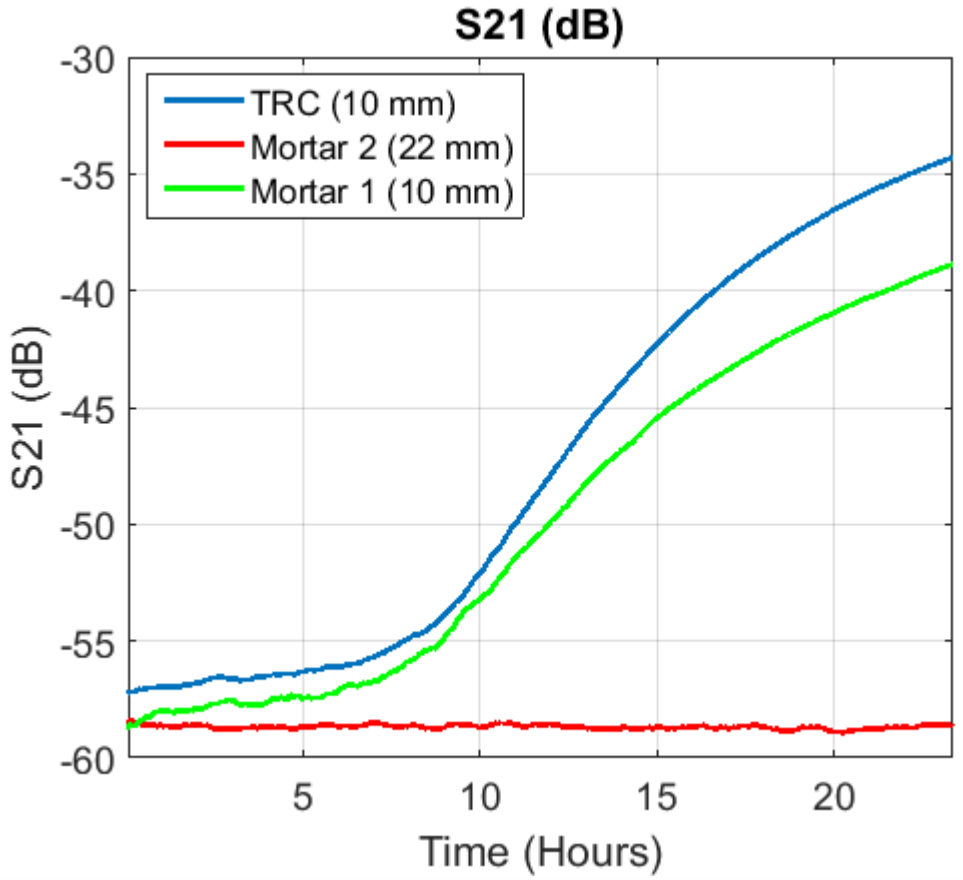




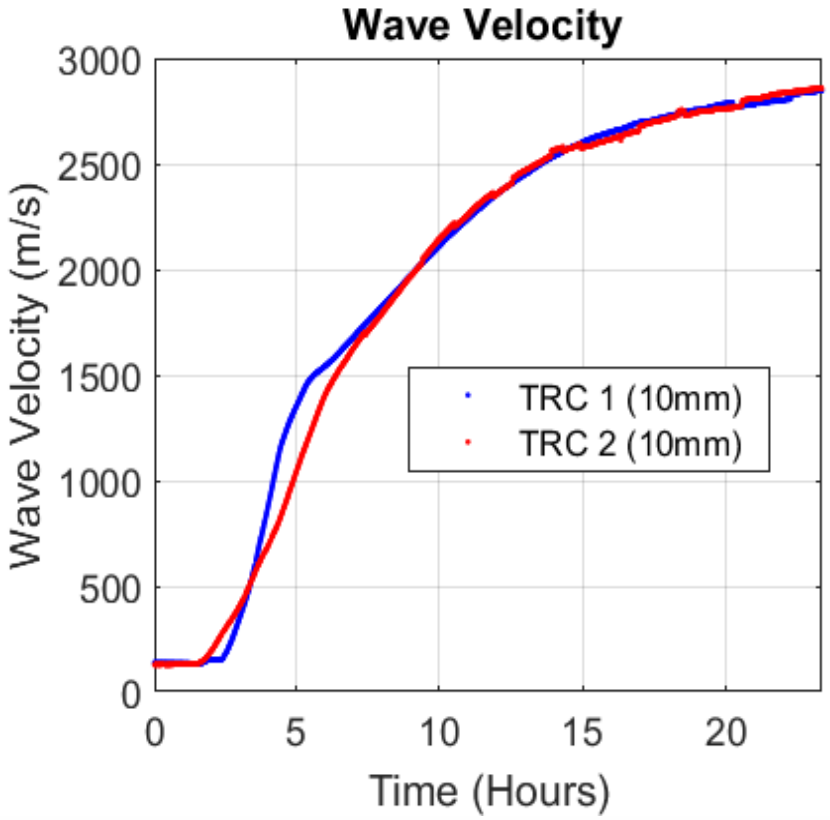
RESULTS

MMW SPECTROMETRY – S21

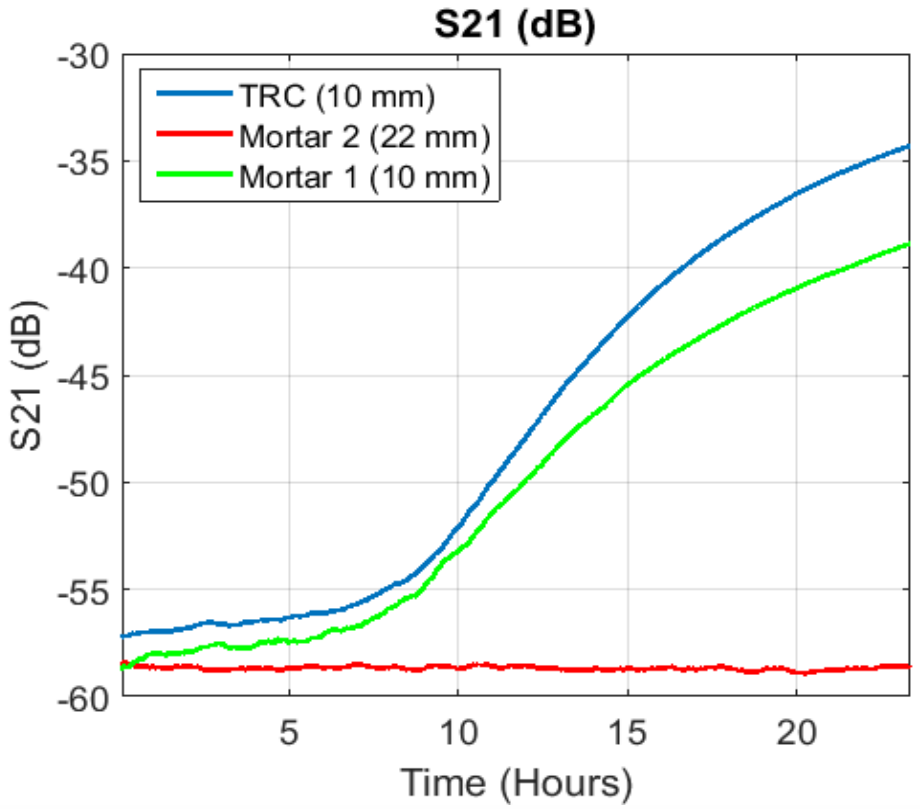
1. The wave passes through the sample of 10 mm.
2. It can not pass through thicker samples (22 mm)
3. 47.5 GHz
4. Dormant period, or period in which the wave cannot pass through the sample
5. Reactions and higher EM wave transmission



COMPARISON MMW AND UPV 24H



Development of strength



Reduction of free water & chemical reactions

Conclusions

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CONCLUSIONS

GENERAL CONCLUSIONS

- UPV can successfully monitor the development in stiffness of early age TRC, allowing for estimation of the Young's Modulus.
- When both sides of the sample are not accessible, UWR can be used as an alternative monitoring technique from where the stiffness of the surface of the material can be estimated. The BM can be chosen to match an indicative impedance.
- MMW in transmission shows sensitivity to chemical reactions involved in the hydration and curing of TRC and mortar specimens, allowing for monitoring during this stage. The sensitivity of MMW allows for differentiation between TRC and mortar.

ACKNOWLEDGMENTS

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Thank you

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