# Steel Fibre Reinforced Rubberised Concrete Mixtures

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# Outline

- Introduction
- Forgiving Infrastructure
  - SAFER Project
  - Anagennisi Project
    - Road Pole Demonstration Project
- Steel Fibre Reinforced Rubberised Concrete
  - Mixture development
  - Strength and workability issues
- EXCELSIOR project Introduction
- Closing remarks

# Circular Economy

"closing the loop"


http://www.housingeurope.eu

# The NEED for Forgiving Infrastructure

- There is critical need to adopt improved barrier designs to protect vulnerable road users

  *(EuroRAP (2008). Barriers to change: Designing safe roads for motorcyclists)*

- Our goal for road barriers
  - Absorb impact energy
  - Reduce injury and damage severity

# Most Vulnerable Road Users

- Motorcyclists
  - Comprise a significant 15% of all road fatalities in Europe
- An additional 3% of all road fatalities are
  - moped and
  - other light-powered 2-wheeler riders

# The NEED for Forgiving Infrastructure

# Current Road Barriers..

- Hitting a barrier is a factor in 8-16% of deaths
- Injuries are up to 5 times more severe

# Current Road Barriers..

- Hard metal, Plain concrete
- Limited deformability
- Limited energy absorption

⟹ Upon collision, rider bodies absorb impact

# The NEED for Forgiving Infrastructure

- Plain concrete
  - Limited deformability, Limited energy absorption

+ Rubber $\Longrightarrow$ energy absorption, impact resistance

+ Steel fibres $\Longrightarrow$ flexural strength, energy absorption and toughness

+ Textile/polymer fibres $\Longrightarrow$ improved fresh concrete properties

# Recycled Rubber in Concrete for Forgiving Infrastructure

- Reduction of fatalities in road transport
  - 1 of top ten goals set by the European Union's "White paper on transport"
  - The goal of reducing to half by 2020 will **NOT** be reached

☆ Unless the decrease at much higher rates starting **now!**

*(European Commission (EC) (2011). White Paper on Transport – Roadmap to a single European transport area – Towards a competitive and resource efficient transport system)*

# Anagennisi Project Road Pole Design

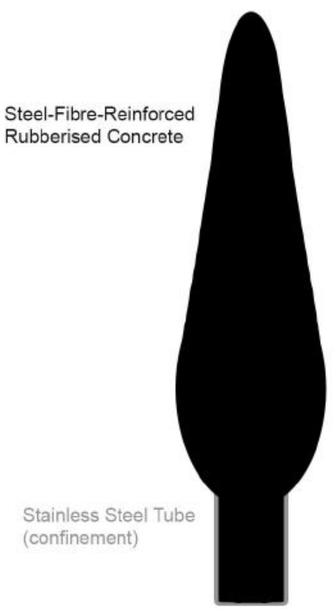
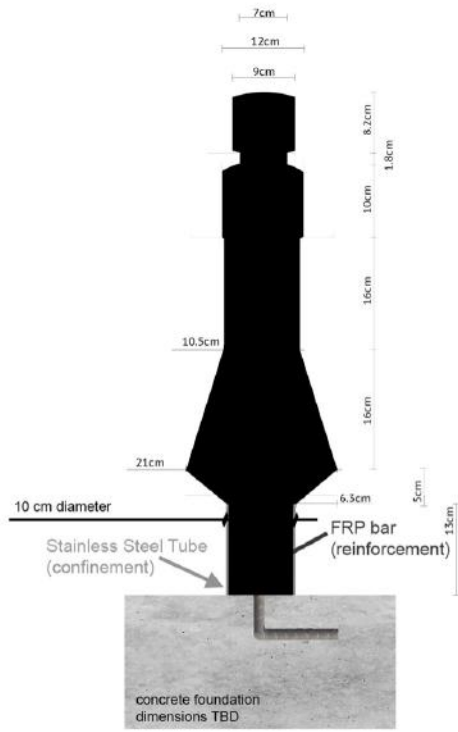
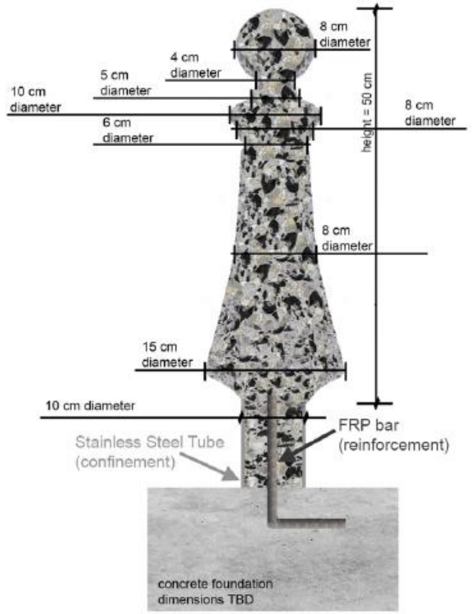




Illustration by
Thomaida Polydorou
(CUT)



# Anagennisi Project Road Pole Design



# Anagennisi Project Road Pole Mix Design

| MATERIAL | Amount (kg/m$^3$) (SSD Condition) | Actual Amount per pole (kg) |
|---|---|---|
| Aggregate (4-10mm) | 330 | 3.3 |
| Sand 1 (0-5mm) | 320 | 3.2 |
| Sand 3 (0-5mm) | 330 | 3.3 |
| Rubber (10-20mm) | 100 | 1.0 |
| Rubber (4-10mm) | 100 | 1.0 |
| Cement II 52.5 | 400 | 4.0 |
| PFA | 50 | 0.5 |
| Microsilica | 50 | 0.5 |
| Water | 180 | 1.8 |
| Visocrete 4000 | 7 | 0.07 |
| Twincon Fibres | 30 | 0.3 |

# Anagennisi Project Road Pole Form



# Anagennisi Project Road Pole Materials

# Anagennisi Project Road Pole

# Anagennisi Project Road Pole

# SAFER Project

Safer Road Barriers made of concrete with rubber particles from recycled tyres

**From waste to RESOURCES**

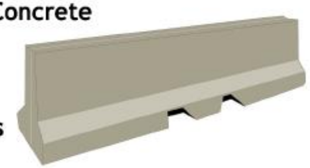
This research proposes to develop optimised steel fibre-reinforced rubberised concrete mixtures as well as road barrier designs, which will lead to the development of SAFER road barriers with outstanding deformability and structural integrity

Innovative eco-material for Forgiving Road Infrastructure

Steel-fibre reinforced Rubberised Concrete

Energy absorbing road barriers



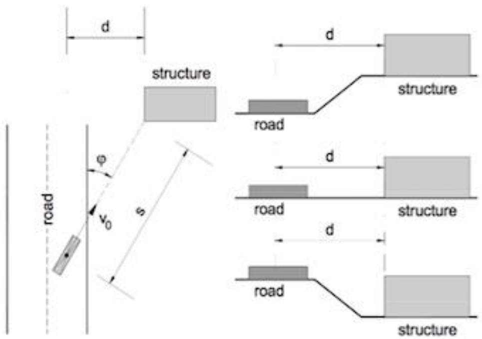
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 748600

Τεχνολογικό Πανεπιστήμιο Κύπρου eratosthenes research center

# SAFER Project

- Steel Fibre Reinforced Rubberised Concrete Barriers
  - 60% aggregate volume
    replaced by Rubber Particles
- Impact Performance Assessment






| | | mean value | standard deviation |
|---|---|---|---|
| *m* | mass | 20 ton | 12 ton |
| *v* | velocity | 80 km/hr | 10 km/hr |
| *k* | equivalent stiffness | 300 kN/m | |

**Statistical parameters for input values**

$$F = v_r \sqrt{km}$$

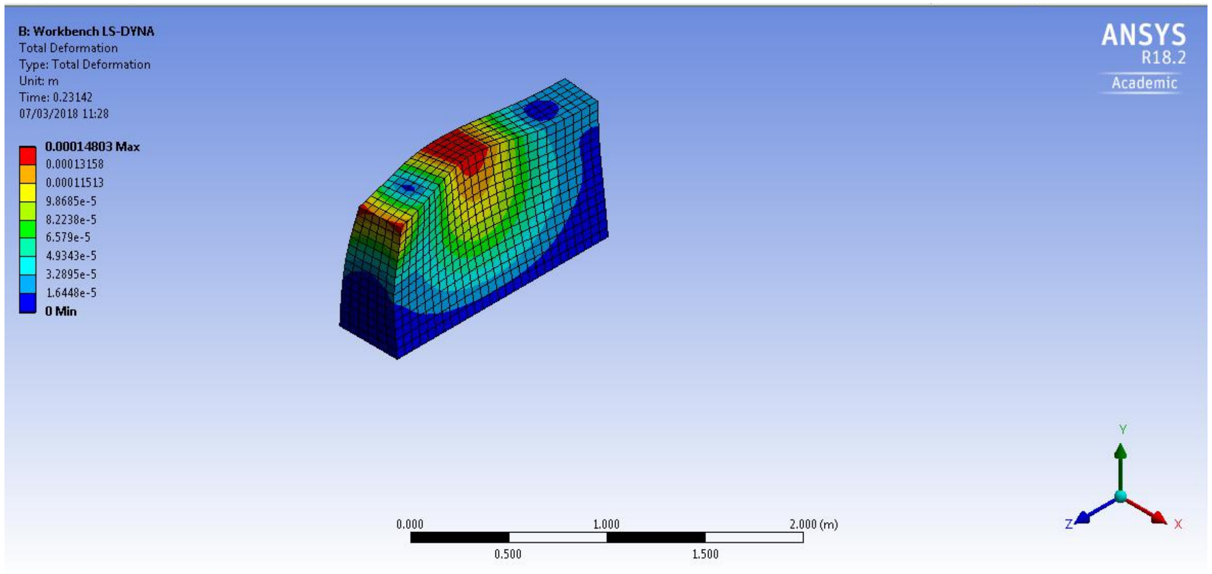
**$m$=32 ton, $v$= 90 km/hr=25 m/s**
**$F$ = 25 (300 ×32)$^{0.5}$ = 2400 kN**

$v_r = (v_0^2 - 2\,a\,s)^{0.5}$ if $a$=4 m/s$^2$ $s$=80 m
$\varphi$=15° $d$=20 m

$$F = F_o\sqrt{1 - d/d_b} \quad \text{(for } d < d_b\text{)}.$$

# SAFER Project

- Impact Performance Assessment

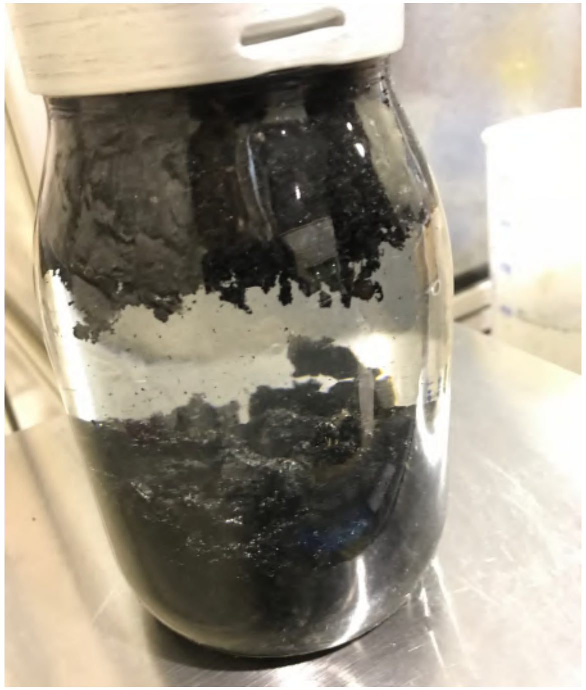



*This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. [748600]*

# Steel Fibre Reinforced Rubberised Concrete Mixture Development

- Mineral aggregate in Concrete are replaced with Rubber by Volume
  - Specific Gravity is critical in calculating the correct amount of rubber to use

# Steel Fibre Reinforced Rubberised Concrete Mixture Development



# Steel Fibre Reinforced Rubberised Concrete Mixture Development

- Need to provide adequate water for cement hydration
    - Water entrapped limits concrete strength
    - Rubber Contaminants absorb water

# Steel Fibre Reinforced Rubberised Concrete Mixture Development

# Steel Fibre Reinforced Rubberised Concrete Workability

- High rubber content → Low workability
- Using a variety of rubber particle sizes is best
  - Generally replace sand with rubber powder and coarse aggregate with similar size rubber particles

# Steel Fibre Reinforced Rubberised
# Workability

- High rubber content
  - → Low workability
- Concrete Slump Test values near 0

# Steel Fibre Reinforced Rubberised Concrete Workability

- Sufficient consolidation of concrete mixture is key
  - Remove entrapped air
  - Achieve better packing of granular particles
- At CUT
  - Vibrating Table

# Steel Fibre Reinforced Rubberised Concrete

- Water-to-cement ratio suggested 0.35 - 0.45
- Add plasticiser, super-plasticiser
- Pulverised Fly Ash (replace about 10% of the cement)
- Silica Fume (replace about 10% of the cement)
- Steel Fibres further reduce Workability !!!

# Steel Fibre Reinforced Rubberised Concrete Strength

- High rubber content → Lower Compressive Strength
  - Limited cement hydration products around rubber particles
    - Lack of binding
- Ideal Packing of concrete to improve mechanical properties
  - Packing of granular particles influenced by
    - Shape, texture, specific gravity, moisture condition, mixing, placing, consolidation

# Steel Fibre Reinforced Rubberised Concrete Strength

- Add Silica Fume, Fly Ash
  - Enhance compressive strength, flexural strength
    - Improved packing
    - reaction with cement hydration products
- Considering NEW rubber pre treatment methods
  - Enhance bonding between rubber and cement paste

# Steel Fibre Reinforced Rubberised Concrete Strength

- Rubberised Concrete VS Plain Concrete
  - Larger deformations than plain concrete
  - More gradual and uniform failure
  - Steel fibres enhance flexural strength
  - Significantly better impact performance

# Steel Fibre Reinforced Rubberised Concrete Issues

- No appropriate method for rubber particle property characterisation
- Different types of rubber, different levels of contamination
- Water absorption values vary between negligible and 85%
- Lack of standard tests → Insufficient information is limiting development

# Promising Material for Forgiving Infrastructure Applications

- Plain concrete
  - Limited deformability, Limited energy absorption

+ Rubber $\Longrightarrow$ energy absorption, impact resistance

+ Steel fibres $\Longrightarrow$ flexural strength, energy absorption and toughness

+ Textile/polymer fibres $\Longrightarrow$ improved fresh concrete properties


# March 2018

Prof. Diofantos Gl. Hadjimitsis
Project coordinator
Vice-Rector of Academic Affairs, Cyprus University of Technology

The EXCELSIOR has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 763643

CONSORTIUM

Cyprus University of Technology · DLR · TROPOS Leibniz Institute for Tropospheric Research · DEC

EXCELSIOR ERATOSTHENES: Excellence Research Centre for Earth Surveillance & Space-Based Monitoring of the Environment

# Funded under H2020

## EXCELSIOR'S DETAILS

Pillar: **Spreading excellence and widening participation**

Work Programme Year: **H2020-2016-2017**

Work Programme Part: **Spreading Excellence and Widening Participation**

Call: **H2020-WIDESPREAD-2016-2017**

Topic: **H2020-WIDESPREAD-04-2017-TeamingPhase1**

Type of action: **CSA (Coordination and support action)**

Project GA number: **763643**

Proposal acronym: **EXCELSIOR**

Total Budget: **400,000 €**

Duration: **12 months**

End: **31 August 2018**

HORIZON 2020

Cyprus University of Technology DLR TROPOS DEC

EXCELSIOR

ERATOSTHENES: Excellence Research Centre for Earth Surveillance & Space-Based Monitoring of the Environment

# Project Consortium

Cyprus University of Technology

DEC DEPARTMENT OF ELECTRONIC COMMUNICATIONS

NATIONAL OBSERVATORY ATHENS

IAASARS

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

TROPOS Leibniz Institute for Tropospheric Research

Cyprus University of Technology · DLR · TROPOS · DEC

# The idea behind

## Formulation of Business Plan

to **upgrade** the existing ERATOSTHENES Research Centre, into a **sustainable, viable and autonomous Centre of Excellence** for Earth Surveillance and Space-Based Monitoring of the Environment (**EXCELSIOR**), which will provide the highest quality of related services both on the **National, European and International** levels.

The **long term aim** of the upgraded centre is to **create new opportunities for innovative ground-breaking research and promote Cyprus to the European Research Area** in the field of systematic monitoring of environment using earth observation, space and ground based integrated technologies.

**Teaming Phase 2, Deadline 15 November 2018**
**ERATOSTHENES Centre of EXCELLENCE: 15M€ from EU + 15M€ from National funds**

EXCELSIOR ERATOSTHENES: Excellence Research Centre for Earth Surveillance & Space-Based Monitoring of the Environment

The 'EXCELSIOR' TEAMING project is built on the existing ERATOSTHENES Research Centre capacities. The aim of the proposed TEAMING project is to further promote the existing ERATOSTHENES Research Centre (ERC), established within the Cyprus University of Technology (CUT) into a sustainable, viable and autonomous Centre of Excellence (CoE) for Earth Surveillance and Space-Based Monitoring of the Environment, which will provide the highest quality of related services on the National, European and International levels.

A Centre of Excellence for conducting basic and applied research and innovation in the areas of the integrated use of remote sensing and space-based techniques for monitoring the environment. The Centre will create 200 new job positions, placing Cyprus on the international map for the study of the Environment through space technologies..

**The ERATOSTHENES CoE, with its expertise and infrastructure, could be a hub for the Earth Observation activities in the eastern Mediterranean area, due to the key geostrategic position of Cyprus.**

# Acknowledgements


SAFER

Τεχνολογικό Πανεπιστήμιο Κύπρου

MARIE CURIE ACTIONS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for Research & Innovation

# Thank you

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