Steel Fibre Reinforced Rubberised Concrete Barriers as Forgiving Infrastructure

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Outline

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- Circular Economy Concept – Recycled Tyre Materials into Concrete
- Road Safety - The Need for Forgiving Infrastructure
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  - SAFER Project
    - Steel Fibre Reinforced Rubberised Concrete
      - Mixture Development
      - Workability, Strength and Rubber variability issues
- Development of Steel Fibre Reinforced Rubberised Concrete Barriers
- Closing Remarks

Circular Economy

"closing the loop"

http://www.housingeurope.eu

Road Safety - PRIORITY

- 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)

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

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

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

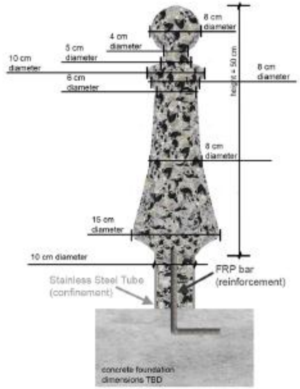
Recycled Rubber in Concrete for Forgiving Infrastructure

- Plain concrete
  - Limited deformability, Limited energy absorption

\+ Rubber ⟹ energy absorption, impact resistance

\+ Steel fibres ⟹ flexural strength, energy absorption and toughness

Anagennisi Project Road Pole Design



Anagennisi Project Road Pole

Anagennisi Project Road Pole

SAFER Project

Steel Fibre Reinforced Rubberised Concrete Road Barriers Mixture Development

- Mineral aggregate in Concrete are replaced with Rubber by Volume
  - For this application, a 60% of the overall mix aggregate is replaced by equivalent volume of similar size rubber particles
  - Specific Gravity is critical in calculating the correct amount of rubber to use
- 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 Mixture Development

Lightweight Aggregate water absorption test on Rubber

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
- Sufficient consolidation of concrete mixture is key
  - Remove entrapped air
  - Achieve better packing of granular particle

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
  - Packing of granular particles influenced by
    - Shape, texture, specific gravity, moisture condition, mixing, placing, consolidation

Steel Fibre Reinforced Rubberised Concrete Strength

- Silica Fume (Microsilica), Recycled Steel fibres
  - Enhance compressive strength, flexural strength
- Larger deformations than plain concrete
- More gradual and uniform failure
- Flexible behaviour of rubber particles decreases internal friction during unloading process → recovers extra strain

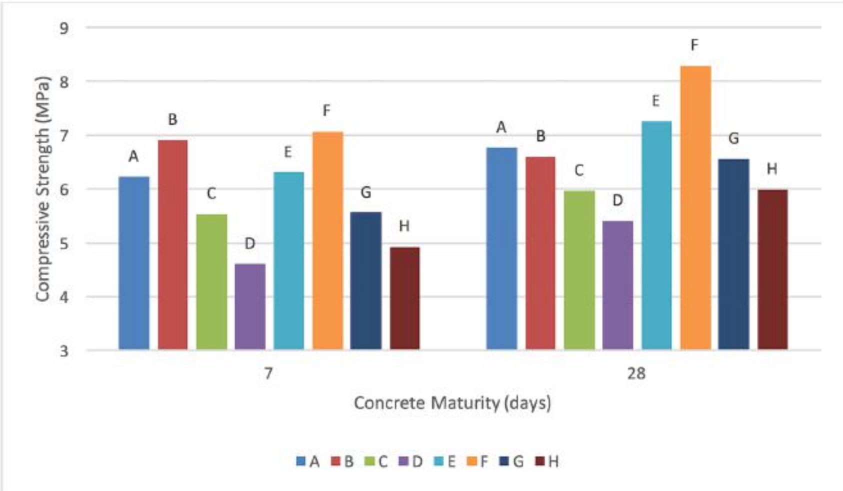
ISSUE - Recycled Tyre Rubber Variability

- No appropriate method for rubber particle property characterisation
- Different types of rubber, different levels of contamination, SG varies
- Water jet instead of mechanical cutting of recycled tyres
  - Devulcanised rubber particles
- Lack of standard tests → Insufficient information is limiting development

SAFER Project Barrier Trial Mixtures

Mix ID	Variable
A	Original Mix (Cement only, No PFA or MS)
B	Original Mix + 25 kg/m^3 SF
C	20% of cement replaced by PFA
D	C + 25 kg/m^3 SF
E	20% of cement replaced by MS
F	E + 25 kg/m^3 SF
G	10% of cement replaced by PFA & 10% of cement replaced by MS
H	G + 25 kg/m^3 SF

SAFER Project Barrier Trial Mixtures

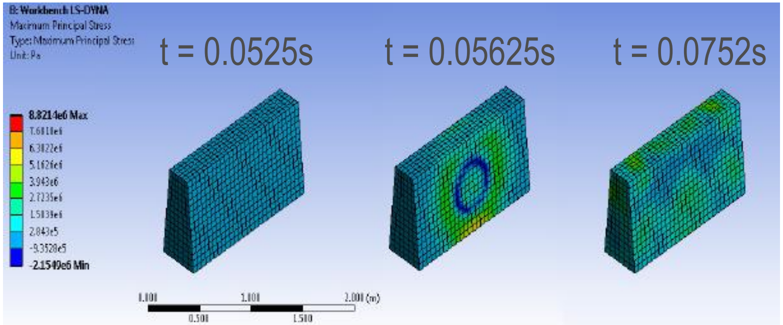


SAFER Barrier Optimum Mix Design

Mix Constituent	Amount (kg/m^3)* *unless otherwise noted
Cement	400.0
Silica Fume (Micro-silica)	100.0
Fine Natural Aggregate	310.5
Coarse Natural Aggregate	378.0
Fine Rubber Particles	169.7
Coarse Rubber Particles	207.0
Recycled Steel Fibres	25.0
Water	225.0
Super-plasticiser	3.375 (L/m^3)

SAFER Project

- Impact Performance Assessment



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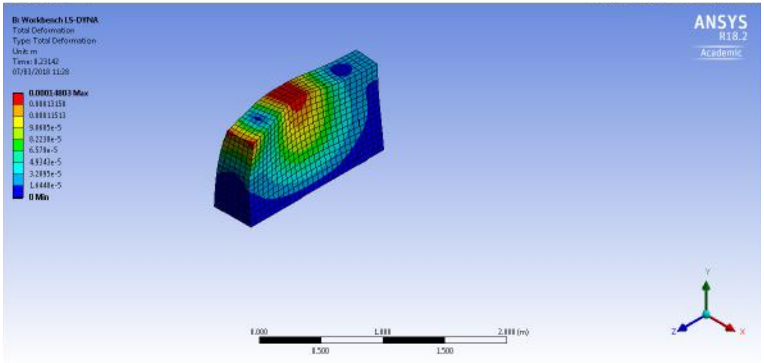
Ansys LS-Dyna Material Input Parameters

Property	SAFER Mix Experimental Value
Density (kg/m3)	1884
Compressive Strength, fc (Mpa)	8.3
Tensile Strength*, ft/fc	0.3
Bulk Modulus, E (Gpa)	4.7
Shear Modulus, G (Gpa)	1.96
Elastic strength/ft	0.9
Elastic strength/fc	0.4
Hardening slope	4.5

*expressed as a function of compressive strength

SAFER Project

- Impact Performance Assessment



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