Demonstrating Steel Fibres from Waste Tyres as Reinforcement in Concrete: Material Characterisation

Houssam Tlemat
Research scholar

Kypros Pilakoutas
Professor of Construction Innovation

Kyriacos Neocleous
Marie-Curie Post-doctoral Research Fellow

Centre for Cement and Concrete, Department of Civil and Structural Engineering, The University of Sheffield, UK
http://www.shef.ac.uk/tyre-recycling
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Outline
Waste Tyre Recycling
Recycled Steel Fibres
Pull-out Tests
Flexural Tests
Conclusions
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Waste Tyre Recycling

- **International Problem:**
  - 1 billion annual arisings worldwide

- Quarter of this amount arises in EU

- EU directives driving force for waste management

- Landfill directive prohibits disposal of tyre by-products by 2006

- Develop new markets to avoid disposal

**EU Average Tyre Statistics 2002**

- **Export, reuse**: 11%
- **Retreading**: 12%
- **Material recovery**: 21%
- **Energy recovery**: 22%
- **Landfill, stockpile**: 34%
- **Material recovery**: 21%
Material Recovery:

- Mechanical processes (e.g. tyre shredding) reduces tyres to steel fibres & granulated rubber.

- Thermal degradation processes (e.g. microwave induced pyrolysis) breaks down tyres into steel, char, liquids and gases.
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The University of Sheffield has filed a patent application for the Use of Tyre Fibres in Concrete.
Pyrolysed Recycled Steel Fibre (PRSF)

- Clean from rubber
- Tensile properties not affected (1250 MPa)
- Fibres contain carbon black on surface
- Fibre not so easy to cut

12 wires (\(\phi 0.23\)mm) twisted to a core strand (\(\phi 0.85\)mm), surrounded with another 15 twisted wires. On the surface there is a twisted single wire.

Overall external diameter: 1.55 mm
Effective diameter: 1.16 mm
Shredded Recycled Steel Fibre (SRSF)

- Fibres contain small amounts rubber and fluff
- Long bid wires need to be removed (sieving)
- Fibres are magnetised

- Fibres tend to ball-up
- Inconsistent size and shape
- Diameter ~ 0.23mm
Industrially Available Steel Fibre (ISF)

- Fibre industrially produced from wire with flattened ends
- Fibre is rigid
- Diameter: 1mm
- Tensile Strength: 1150 MPa
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Pull-out Tests

Why?
• Useful to understand fibre bond characteristics
• Determination of the critical fibre length

Problems:
• Not always easy to perform on fibres (high accuracy required for very small displacement and load)
• No standard method
• A suitable test must be developed for each fibre
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**Double-sided Pull-out Tests**

**Specimen Preparation:**

- **Perspex plate with ISF**
- **10mm plastic tubes filled with silicon were used**
- **Nominal size 100x100x80 mm**
- **Casting done in two stages**
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• Specimen Preparation:

Steel clamps are fixed at the end of each specimen. Deformation is measured over a gauge length of 50mm using two transducers.
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1. 5 kN strain gauged spring beam
2. Chuck attached the clamp with a pin
3. Fixed metal clamp pinned on the chuck
4. Perspex plate with the fibre through its central holes placed in middle of specimen
5. 230 volt Single Phase Motor fitted with 3-step pulley drives the cross-head at a speed of 1.5 mm/min
6. Pulled part of the specimen
7. Cross-head attached to motor
8. Manual handles

Double-sided Pull-out Tests

Test set-up
Test Results for PRSF and ISF fibres
(10 mm embedment length)

- PRSF fibre has better bond at the initial stages
- Bond resistance of ISF provided by end anchorage
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Double-sided Pull-out Tests

Effect of aspect ratio - PRSF and ISF fibres

- Peak tensile stress increases linearly with the aspect ratio
- Better behaviour for PRSF with end anchoring
- Critical length: more than 60mm PRSF, but for practical reasons, 50 mm recommended
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Test results for shredded fibres

- The tested 0.23mm diameter shredded fibres are very fragile
- Only fibres with 10mm embedment length pulled out during loading
- All fibres with 20mm and 30mm embedded length fractured during loading
Why?

- Examine the toughness and energy absorption capacity of steel fibre reinforced concrete
- Determination of design parameters

Problems:

- Results prone to experimental errors
- Variety of testing methods
Specimen preparation:

- Accurate deflection measurement – using a yoke
- 150 x 150 x 550 mm specimens
- Crack inducer: 25 x 4mm notch at mid-span
- Four point loading – 100 kN servo-hydraulic machine – crack mouth opening displacement

Flexural Toughness Tests
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Flexural Toughness Tests

- Effect of fibre volume (average of 3 tests)

Peak load and residual strength after cracking increase with fibre volume.
Effect of fibre type:
(average of 3 tests)

- Response just after peak load is stable for PRSF and ISF fibres
- PRSF is comparable to ISF

Flexural Toughness Tests

![Graph showing load vs. deflection for different fibre types.](image)
Conclusions

- Tensile strength of tested fibres is influenced by the pull-out test method used
- Double-sided pull out tests eliminate measurement errors
- If possible, PRSF should be provided with end anchorage
- PRSF has stiffer initial bond-slip characteristics than the ISF fibre
- An increase in fibre volume increases the flexural toughness significantly
- PRSF and ISF exhibit good energy absorption capacity
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For further information:
http://www.cordis.lu/improving

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