Solutions for concrete problems using *polypropylene Fibre Reinforcement*
Micro Fibres & Macro fibres

• BS EN 14889-2:2006 Part 2 : Polymer fibres –definitions, specifications and conformity

• A polymer fibre can be a straight or deformed piece of extruded orientated and cut material suitable to be homogeneously mixed in concrete or mortar
Classification of Micro fibres

- Class 1a Micro fibres < 0.30 mm in diameter
- Class 1b Micro fibres < 0.30 mm in diameter, Fibrillated
DURUS® S400 - Embossed Fibre

Class 11 > 0.30mm diameter
What do Macro & Micro fibres do in Concrete

- Early age crack reduction
- Long term crack control
- Improved impact, abrasion & shatter resistance
- Improved resistance to cycles of freeze & thaw
- Reduction in explosive spalling in concrete subject to fire
- Provide post crack ductility & ability to replace steel mesh
Where are Macro & Micro fibres used
Slip form concrete

- Without fibres the surface tears leading to surface defects requiring surface repairs.
- With fibres the surface remains intact leading to No repairs
- Saves time, money and no costly lane closures.
Why Concrete barriers
Typical Construction Arrangement – Including Drainage

Construction – How is CSB Built
Explosive spalling
Channel Tunnel rail fire 1996
Aggregates effect

Lightweight - 0 - 0

Lightweight - S - M

Lightweight - S - F
Fire curves

1 = Cellulosic ISO Curve  2 = Hydrocarbon Curve  3 = RABT-ZTV Curve  4 = HCM Curve  5 = RWS Curve
## Types of fire tests

<table>
<thead>
<tr>
<th>HRR (Size of fire in MW)</th>
<th>Examples of road vehicles</th>
<th>Examples of rail vehicles</th>
<th>Examples of metro vehicles</th>
<th>Fire curve</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1 - 2 cars</td>
<td></td>
<td></td>
<td>ISO 834</td>
</tr>
<tr>
<td>10</td>
<td>Small van 2 - 3 cars</td>
<td>Electric locomotive</td>
<td>Low combustible passenger carriage</td>
<td>ISO 834</td>
</tr>
<tr>
<td>20</td>
<td>Big vans, public buses, multiple vehicles</td>
<td></td>
<td>Normal combustible passenger carriage</td>
<td>ISO 834</td>
</tr>
<tr>
<td>30</td>
<td>Bus, empty HGV</td>
<td>Passenger carriage</td>
<td>Two carriage</td>
<td>ISO 834</td>
</tr>
<tr>
<td>50</td>
<td>A combustible load on a truck</td>
<td>Open freight wagons with lorries</td>
<td>Multiple carriages &gt;2</td>
<td>ISO 834</td>
</tr>
<tr>
<td>70</td>
<td>HGV with a combustible load (approx. 4 tonne)</td>
<td></td>
<td></td>
<td>Hydro carbon</td>
</tr>
<tr>
<td>100</td>
<td>HGV average</td>
<td></td>
<td></td>
<td>Hydro carbon</td>
</tr>
<tr>
<td>150</td>
<td>Loaded with an easily combustible load (approx. 10 tonnes)</td>
<td></td>
<td></td>
<td>RWS</td>
</tr>
<tr>
<td>200 or higher</td>
<td>Limited by oxygen, petrol tanker, multiple HGV’s</td>
<td>Limited by oxygen</td>
<td>RWS</td>
<td></td>
</tr>
</tbody>
</table>
Results of B.R.E. Tests.
Where are micro fibres used?

Tunnels using micro fibres:

- Airside Tunnel, Heathrow Airport, Terminal 5, London.
- Malmo city tunnel Sweden
- Brisbane Airport Link Tunnel, Australia
- Weehawken Tunnel, New York, USA
We can also consider Car Park
Maritime Concrete
Marine Concrete

When the oxide film is damaged corrosion of the steel commences. This creates and increase in pressure within the concrete matrix. This pressure then creates spalling. The spalling reduces the cover to the steel and in some cases causes exposure of steel reinforcement. This increases speed of damage to remaining oxide film and further corrosion and spalling.
Fibre Reinforced Concrete in Aggressive Environments
The benefits of Fibre Reinforced Concrete

Macro synthetic fibres can reduce or in some cases eliminate steel reinforcement required.

Macro synthetic fibres are made from polypropylene and do not corrode, eliminating the risk of spalling.

No minimum cover required and fibres are present throughout the depth of the concrete matrix.

The use of monofilament fibres can also improve abrasion resistance up to double that of plain concrete.
Peterhead Sea Wall

Original design was for steel bar and B785 welded mesh fabric reinforcement.

The mesh was replaced with 5kg / m³ of Durus S300 macro synthetic fibres.

These fibres were sufficient to accommodate the punch loads calculated for the project along with preventing Shrinkage as well as the proposed mesh.

Additional benefits in abrasion resistance were also accepted.
• Problem concrete wear exposing mesh which punctures lorry tyres.
• Original Design: C40/50 Concrete, 350mm deep with top layer of A393 mesh
• Adfil Specification Used: C40/50 Concrete, 350mm depth slab. 5kg Durus S300, 0.91kg of Fibrin XT
Macro & Micro in external slabs
120 m³ concrete containing either four Kg of S200 fibre was delivered to a site in Denmark

The results have led to the issuing of a certificate allowing the fibre to be used in this application.
Waste Transfer stations

Waste transfer facility floors – Damage from abrasion

Daryll Simpson BSc CEng MICE

The trend for recycling of municipal refuse in the UK has led to the construction of a significant number of new domestic waste transfer facilities. In many of these facilities, the domestic waste is tipped directly onto concrete floors from refuse collection vehicles and then handled by loading shovels. It has been observed that some of these concrete floors have experienced extremely high levels of abrasion, resulting in a rapid surface loss. Wear rates in excess of 25mm in one year have been reported. Floors experience lower levels of abrasion where waste is tipped directly into a waste bunker and is then handled by grab cranes. This advice sheet highlights issues with the former situation.

Also see Concrete Advice 48, Comparing concrete dosing and exposed surfacing.

1. Process

Two transfer types exist: waste transfer and energy from waste. The former is basically a tipping hall where refuse is tipped directly onto the floor and moved by wheelbarrow or tracked loading shovels. The latter has the refuse tipped directly into massive waste bunkers where it is moved by grab cranes to the incinerators.

Typical examples of a waste transfer facility plant are shown in figures 1 and 2.

2. Floor design working life

Clients, designers and users should appreciate that waste transfer floors will need probably not last for the usual design working life of 30 years or more expected for industrial concrete floors. They should be aware that there is a probability that such floors may require major repair or replacement several times within the design working life of the facility.

Figure 1: Volvo EC460 excavator, bucket capacity 0.5-0.83m³, operating weight 15.3-16.5 tonnes

Figure 2: Volvo L110 wheel loader, bucket capacity 2.7-3.0 m³, operating weight 18.0-20.7 tonnes
Resistance to shatter.
Energy Absorption
Innovating through a solution sales approach with Bourne Engineering

- Bourne design and sell a precast concrete car parking system, which is manufactured by two precast partners.
- They had four objectives
  - One improve the long term durability of the product.
  - Two reduce the production cost of these units.
  - Three to produce test data showing improved durability using fibres and a waterproof admixtures alleviating the need to spray waterproof membrane on the concrete after installation.
  - Four to sell more Units
Innovating through a solution sales approach with Bourne Engineering

• Objective one was achieved by showing through design and then full scale testing that the fibres could replace the layer of steel mesh in top of the concrete.

• By replacing the top layer of mesh there is no cover issues and hence corrosion issues leading to improved durability.
Innovating through a solution sales approach with Bourne Engineering

- Objective two reduce production costs.
- Benefits reduce set up time no spacers required.
- Reduced manual handling
- No cutting of the mesh and less waste.
- Reduced cost per M²
- Production started 30,000 M² already secured.
Innovating through a solution sales approach with Bourne Engineering

Fist contract production started August insitu in October
Innovating through a solution sales approach with Bourne Engineering

• Objective three to produce test data showing improved durability compared to competitors.
• Test programme to start in January 2015 which will be as follows.
• Cast concrete slabs with new Durus S500 + a Sika waterproofing admixtures.
• Flexural test, punching shear, deflection long and short term, chloride penetration test and water tightness in a cracked and un-cracked specimen.
PP Nordica – Give precast
PP Nordica – Give precast
Sprayed Concrete for tunnels & Mining using
Shotcrete testing

EFNARC plate test

ASTM C1550 RDP TEST
Shotcrete

In order to enter this market we need to have a fibre which can achieve energy absorption of 500, 700 & 1000 Joules. The methods used for this test are the EFNARC panel test and the Round determinate panel test (RDP).
For comparison purposes we have also conducted cast panels and a summary of the results is as follows:

**25 Kg/m³ of 65/35 glued Steel fibres**

6535 glued steel fibres @ 25 Kg dosage

<table>
<thead>
<tr>
<th>Load in KNs</th>
<th>deflection in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

**4 Kg/m³ Durus S300**

DURUS S300 55 mm @ 4 Kg dosage

<table>
<thead>
<tr>
<th>Load in KNs</th>
<th>deflection in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>70</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>40</td>
</tr>
</tbody>
</table>

**6535 glued steel fibre@25 Kg dosage**

Energy Absorption

<table>
<thead>
<tr>
<th>Energy Absorption</th>
<th>Deflection in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>0</td>
</tr>
<tr>
<td>800</td>
<td>5</td>
</tr>
<tr>
<td>700</td>
<td>10</td>
</tr>
<tr>
<td>600</td>
<td>15</td>
</tr>
<tr>
<td>500</td>
<td>20</td>
</tr>
<tr>
<td>400</td>
<td>25</td>
</tr>
<tr>
<td>300</td>
<td>30</td>
</tr>
</tbody>
</table>

**DURUS S300 @ 4 Kg dosage**

Energy Absorption

<table>
<thead>
<tr>
<th>Energy Absorption</th>
<th>Deflection in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td>0</td>
</tr>
<tr>
<td>800</td>
<td>5</td>
</tr>
<tr>
<td>700</td>
<td>10</td>
</tr>
<tr>
<td>600</td>
<td>15</td>
</tr>
<tr>
<td>500</td>
<td>20</td>
</tr>
<tr>
<td>400</td>
<td>25</td>
</tr>
<tr>
<td>300</td>
<td>30</td>
</tr>
</tbody>
</table>

Energy absorption at 25 mm deflection was 805 Joules

Energy absorption at 25 mm deflection was 819 Joules
Reduced Health & Safety Issues.

- Reduced manual handling 1 Kg of Durus S300 synthetic fibre is equivalent to approximately 6 Kg of steel fibres.
- Safer and lighter to handle than steel.
- The exposed fibres will not cut skin or rip work clothes.
- More user friendly packaging.

Reduced storage issues on site.

E.g.) 10,000M³ of shotcrete will need:

- 45 tonnes (45 pallets) of Durus S300
- OR
- 250 tonnes (250 Pallets) of Steel Fibre
Cost effective.

- Reduced rebound compared to steel fibres.
- Increased $M^2$ covered per $M^3$ of Concrete.
- Reduced fibre cost per $M^2$.
- Reduced truck movements.
- Reduced overall transport / freight costs.
- Construction time is decreased.

Additional Benefits When Using Durus $S300$.

- No Rusting or Corrosion.
- No Surface Staining.
- Reduced Wear on Concrete Pumps, Spraying Nozzles and Equipment.
- Durus fibre cannot be misplaced
- No need for cutting, fixing and placing of steel mesh
- 3-Dimensional reinforcement system
Benefits of Macro fibres over Steel Mesh

- No site H&S problems
- Less manual handling problems
- No corrosion issues
- Steel mesh can and often is badly placed
- Speed of construction
Improved speed of construction
Reduced Carbon Footprint

Many papers are now suggesting that the reduction is between 30 – 60% when using Macro Synthetic Fibres instead of welded steel mesh fabric reinforcement.

Carbon Footprint Assessment of Polypropylene Fibre Reinforced Concrete Floors
Cutright, Patnaik, Mahoney.

Steel fibre reinforced concrete in free suspended slabs - case study of the Swedbank arena in Stockholm
Xavier Destrée
Performance

- **3 Dimensional Reinforcement**
  - Always placed correctly

- **Crack Control**
  - Early age cracking (Micro synthetic)
  - Long term cracking (Macro synthetic)

- **Impact, Abrasion & Shatter Resistance**

- **Joint Stability**
  - Option to go “Jointless” (Steel)

- **Post Crack Ductility**
  - (Macro synthetic)

- **Corrosion Resistant**
  - (Micro & macro synthetic)
Productivity

Reinforcement delivered with concrete
- no storage, no lifting, no cutting
- no spacers, no fixing of reinforcement

Easier positioning of Joints
- larger bay sizes
- reduction in formwork setting & stripping

Speeds up concrete placement
- no access problems to bays
The End

Any Questions please
Ground supported floor Slabs
Macro Fibres

Plain Concrete

• Brittle Catastrophic Mode of Failure
• Bond Between Paste and Aggregate and Aggregate Shape Controls Quality and Strength

ASTM C 78, JSCE-SF4
Macro Fibres

Fibre Reinforced Concrete

• Ductile Mode of Failure
• Fibres distribute stresses & transfer stresses to un-cracked section

ASTM C 78, JSCE-SF4
Flexural Strength is NOT Increased
Flexural Strain Capacity IS Enhanced
# Increased flexural toughness

<table>
<thead>
<tr>
<th>Test set-up</th>
<th>Plain concrete</th>
<th>Durus concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>beam-test</strong></td>
<td><img src="image" alt="No ductility" /></td>
<td><img src="image" alt="High ductility" /></td>
</tr>
</tbody>
</table>

- **No ductility**
- **High ductility**
Design

TEST Results

Area below the curve indicates the post-crack behaviour and produces $f_{eq}$

Ratio of the load from first crack to 3mm deflection produces Re3 ratio
Attention to Detail

Load Transfer with Macro Fibres

Provide continuous crack restraint
Designs

1. Full design
2. Take basic info
3. EQI calculation
4. Customer likes it
5. Customer

Flow:
- Full design → Take basic info → EQI calculation → Customer likes it → Customer
### EQi Calculation

<table>
<thead>
<tr>
<th>Project</th>
<th>External Whiskey Warehouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness</td>
<td>175 mm</td>
</tr>
<tr>
<td>Concrete Grade</td>
<td>C28/35</td>
</tr>
<tr>
<td>Mesh Type</td>
<td>A252 mm/m</td>
</tr>
<tr>
<td>Location</td>
<td>Center</td>
</tr>
</tbody>
</table>

**Calculation Details**

- **Depth of Compression Zone**: \( a = \frac{A_F y}{0.85 f_c} \) (1m width slab)
- **Tensile Strength** \( f_y \) steel = 500 Mpa
- **\( M_{mesh} \)**: 10.78 kNm/m
  - Calculated with reference to EC2
- **Dosing Rate**: 3 kg/m³
  - Bonar Durus S400
- **Res**: 23 %
- **\( M_{fiber} \)**: Calculated with reference to DBV Merkblatt 2001 edition

**Conclusion**: Valid Alternative

**Version**: 2014 1.0
## Full design Q & A sheet

<table>
<thead>
<tr>
<th>Question &amp; Explanation:</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADFIL Project Reference No:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Area/dimensions:</strong></td>
<td>Determine the length and width of the building or hardstanding.</td>
</tr>
<tr>
<td><strong>Internal or external concrete</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Current proposed design:</strong></td>
<td>May be useful as a cross reference for design validity</td>
</tr>
<tr>
<td><strong>Ground conditions:</strong></td>
<td>Well drained or not? Clay or granular material? Cut and fill? Imported fill?</td>
</tr>
<tr>
<td><strong>Formation CBR or ‘k’ values:</strong></td>
<td>If CBR at formation &lt;3%, it will probably require piling or ground improvement. If ‘k’ value (modulus of sub grade reaction) &lt;0.027N/mm3, it will probably require piling or ground improvement.</td>
</tr>
<tr>
<td><strong>Granular sub base:</strong></td>
<td>Classification (type 1, 2, 6F3, etc). Depth (sub base will enhance ‘k’ value and therefore impact on design)</td>
</tr>
<tr>
<td><strong>Stabilised sub base, anticipated CBR values:</strong></td>
<td>Lime stabilisation implies clay material therefore confirm long term settlement or heave situation. Cement stabilisation may be used to render existing materials non frost susceptible. Note: for any stabilisation it is important to request confirmation of anticipated settlement.</td>
</tr>
<tr>
<td><strong>Vibro compaction/stone piles, anticipated bearing capacity:</strong></td>
<td>As per stabilisation it is important to note there will be medium to long term settlement which can be predicted. The issue with settlement is that providing it is known in advance, we can accommodate a limited amount of deflection stress within the design calculations.</td>
</tr>
<tr>
<td><strong>Pile Type:</strong></td>
<td>Are the piles precast concrete, augered, continuous flight augered, bored etc? Do the piles have an enlarged head for slab support or not? What is the diameter and depth of the enlarged head? Do the piles have any variation in length across the site as it will affect elastic compression etc?</td>
</tr>
<tr>
<td><strong>Pile Grid:</strong></td>
<td>What is the distance between piles in both directions? Do the piles have a relatively shorter span from the penultimate row to the edge of the building?</td>
</tr>
<tr>
<td><strong>Edge Support:</strong></td>
<td>Is the slab to be simply supported on a perimeter or edge beam? If yes, what is the distance from the support to the nearest row of piles? Is the slab to be deemed cantilevered or to be built with a virtual beam?</td>
</tr>
<tr>
<td><strong>Restraint condition:</strong></td>
<td>Is the slab tied into the frame/foundations to accommodate horizontal thrust? Are there any inserts through the slab that may inhibit shrinkage behaviour?</td>
</tr>
<tr>
<td><strong>Dock levellers, number and type:</strong></td>
<td>Dock levellers may be precast or cast in situ. Dock levellers will need to be isolated from the main slab.</td>
</tr>
<tr>
<td><strong>Load, Uniformly Distributed Load (tonnes or Kn/m²):</strong></td>
<td>It is not usually the limiting factor in the design. UDLs in excess of 50Kn/m² are unusual and need to be interrogated.</td>
</tr>
</tbody>
</table>
Fibre Reinforced Concrete in Aggressive Environments
Design for Loading and Post Crack Behaviour

The design and use of macro synthetic fibres in this application can be applied using literature such as Concrete Society Technical Reports:

**CSTR 34** A guide to design and construction of Concrete Industrial Ground Floors

**CSTR 65** Guidance on the use of Macro Synthetic Fibre Reinforced Concrete

**CSTR 66** External In-situ Concrete paving
Unique selling points

• Good Brand name Adfil means quality.
• We offer micro and macro fibres.
• We offer Designed solutions with PI.
• User Friendly packaging.
• Knowledgeable staff who care.
• Continuous product development.
• Good quality products with few complaints.
<table>
<thead>
<tr>
<th>Model</th>
<th>Manufacturer</th>
<th>Bag Type</th>
<th>Quantity</th>
<th>Weight</th>
<th>Stock Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD400P45bg-P504-S</td>
<td>Durus S400</td>
<td>4kg paper Bags - 45mm long</td>
<td>180 bags</td>
<td>720 Kg</td>
<td>UK stock item</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>15 full layers of 12 bags/layer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SD400P45bg-P505-S</td>
<td>Durus S400</td>
<td>5kg paper Bags - 45mm long</td>
<td>180 bags</td>
<td>900 Kg</td>
<td>UK Stock item</td>
</tr>
<tr>
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<td></td>
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<td>Durus S400</td>
<td>4kg paper Bags - 55mm long</td>
<td>180 bags</td>
<td>720 Kg</td>
<td>Not a stock item</td>
</tr>
<tr>
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