Mix design of fiber reinforced concretes

Exercise 9
• The poor tensile strength of concrete can be improved by the use of fibers.

• The fibres act as reinforcing in reinforced concrete - only in a different scale. The effect is “denser” but “shorter”.

• Their main purpose is to increase the energy absorption capacity and toughness of the material, but also increase tensile and flexural strength of concrete.
• There is considerable improvement in the post-cracking behavior of concretes containing fibers. Although in the fiber-reinforced concrete the ultimate tensile strengths do not increase appreciably, the tensile strains at rupture do.

• Compared to plain concrete, fiber reinforced concrete is much tougher and more resistant to impact.

• Plain concrete fails suddenly once the deflection corresponding to the ultimate flexural strength is exceeded; on the other hand, fiber-reinforced concrete continue to sustain considerable loads even at deflections considerably in excess of the fracture deflection of the plain concrete.
Areas of Application

- thin sheets
- roof tiles
- pipes
- panels
- shotcrete (ruiskubeton)
- curtain walls (ei-kantavat (ulko)seinät)
- ground slabs
- precast elements
- composite decks
- Impact resisting structures
- floors
Fibre materials:

- **Steel**
  - substantial strengths 500-2000 N/mm$^2$ and modulus of elasticity 200 N/mm$^2$
  - Adhesion improved by the shaping of the fibres

- **Glass fibres**
  - substantial strengths 700 – 4000 N/mm$^2$ and modulus of elasticity 70 Gpa
  - Adhesion is not as good as with steel fibres
  - Long term durability/resistance is a problem -> coating

- **Polypropylene, polyethylene and other plastics**
  - Low strengths 100 N/m$^2$ and even lower modulus of elasticity 5 N/mm$^2$

- **Carbon fibres**
Sileä pintainen (pyöreä, litteä tai mikä tahansa muoto)

Hammastettu, syövytetty, karhennettu pinta

Pyöreä laajennetuilla päillä

Pyöreä nappipäillä

Pyöreä koukkupäillä

Poimutettu (pyöreä, litteä tai mikä tahansa muoto)

Polygonaaliseksi kierretty (uusi)
Koukkupäisiä irtonaisina

Litteä aaltomainen irtonaisina

Koukkupäisiä liimakammassa

Tuplakoukkupäisiä liimakammassa
CE marking per directive 93/68/EC)

Identification number

Name and address of the manufacturer

The last two numbers of the year when the marking was made

Certificate number
Reference to the European standard

Description of the product: common name, purpose of use, group, measurements, shape tensile strength and effect on consistence

The manufacturer of the fibre must specify the minimum amount of fibres for achieving residual flexural tensile strength of 1.5 MPa in crack mouth opening displacement of 0.5 mm and residual tensile strength of 1 MPa in crack mouth opening displacement of 3.5 mm.
Strength:

- Amount of fibres
- Distribution of the fibres
- Orientation of the fibres
- Material properties:
  - Tensile strength
  - Modulus of elasticity
- Shape of the fibre
- Slenderness ratio (hoikkuusluku)
- Properties of the concrete
  - Maximum size of aggregate
  - Strength of the concrete
  - Amount of cement
Slenderness ratio (hoikkuusluku)

- The slenderness ratio can serve as a measure of stiffness:

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\text{Slenderness ratio} = \frac{\text{Fibre length}}{\text{Fibre diameter}}
\]
Examination of fractured specimens of fiber-reinforced concrete shows that failure takes place primarily due to fiber pull-out or debonding.

- Thus unlike plain concrete, a fiber-reinforced concrete specimen does not break immediately after initiation of the first crack.

This has the effect of increasing the toughness

The failure mechanism is by pull-out.

- you never exceed the tensile strength of the fiber. Bond is much weaker.
• The addition of any type of fibers to plain concrete reduces the workability.

• Concrete mixtures containing fibers posses very low consistencies. However, the placeability and compactability of concrete is much better than reflected by the low consistency.
Fibre reinforced concretes can, in general, be produced using conventional concrete practice, though there are some important differences. The basic problem is to introduce a sufficient volume of uniformly dispersed fibres in order to achieve the desired improvements in mechanical behaviour, while retaining sufficient workability in the fresh mix.
The performance of the hardened concrete is enhanced more by fibres with a higher aspect ratio, since this improves the fibre-matrix bond. On the other hand, a high aspect ratio adversely affects the workability of the fresh mix. In general, the problems of both workability and uniform distribution increase with increasing fibre length and volume

- Aspect Ratio = Length / Diameter
- Typical aspect ratios range from about 30 to 150.
- Maximum usage of fibres: 2% by volume.
Figure 2 Effect of fibre aspect ratio on the workability of concrete, as measured by the compacting factor [8]

One of the chief difficulties in obtaining a uniform fibre distribution is the tendency for the fibres to ball or clump together. Clumping may be caused by a number of factors:

I. The fibres may already be clumped together before they are added to the mix; normal mixing action will not break down these clumps.

II. Fibres may be added too quickly to allow them to disperse in the mixer.

III. Too high a volume of fibres may be added.

IV. The mixer itself may be too worn or inefficient to disperse the fibres.

V. Introducing the fibres to the mixer before the other concrete ingredients will cause them to clump together.
• Most commonly the fibres should be added last to the wet concrete.
• The concrete typically should have a slump of 50-75 mm greater than the desired slump of the fibre reinforced concrete
• The use of collated fibres held together by a water-soluble sizing which dissolves during mixing largely eliminates the problem of clumping
Mix Proportions:

- High cement content
- Water reducing admixtures (superplasticizers)
- Small maximum size of aggregate
- Fibers (1-2% by volume)
Fiber-reinforced concrete is generally made with a high cement content and low water/cement ratio.