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The Concrete Convention and Exposition

Mechanical Properties of Concrete Made with Fluff

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Outline

- Motivation
  - The use of fluff in the concrete industry
- Experimental procedure
  - Granulation of fluff and expanded clay
  - 3 Lightweight concretes
- Experimental results
  - A unique parameter for the concretes
- Discussion of results
- Conclusions

What is fluff?

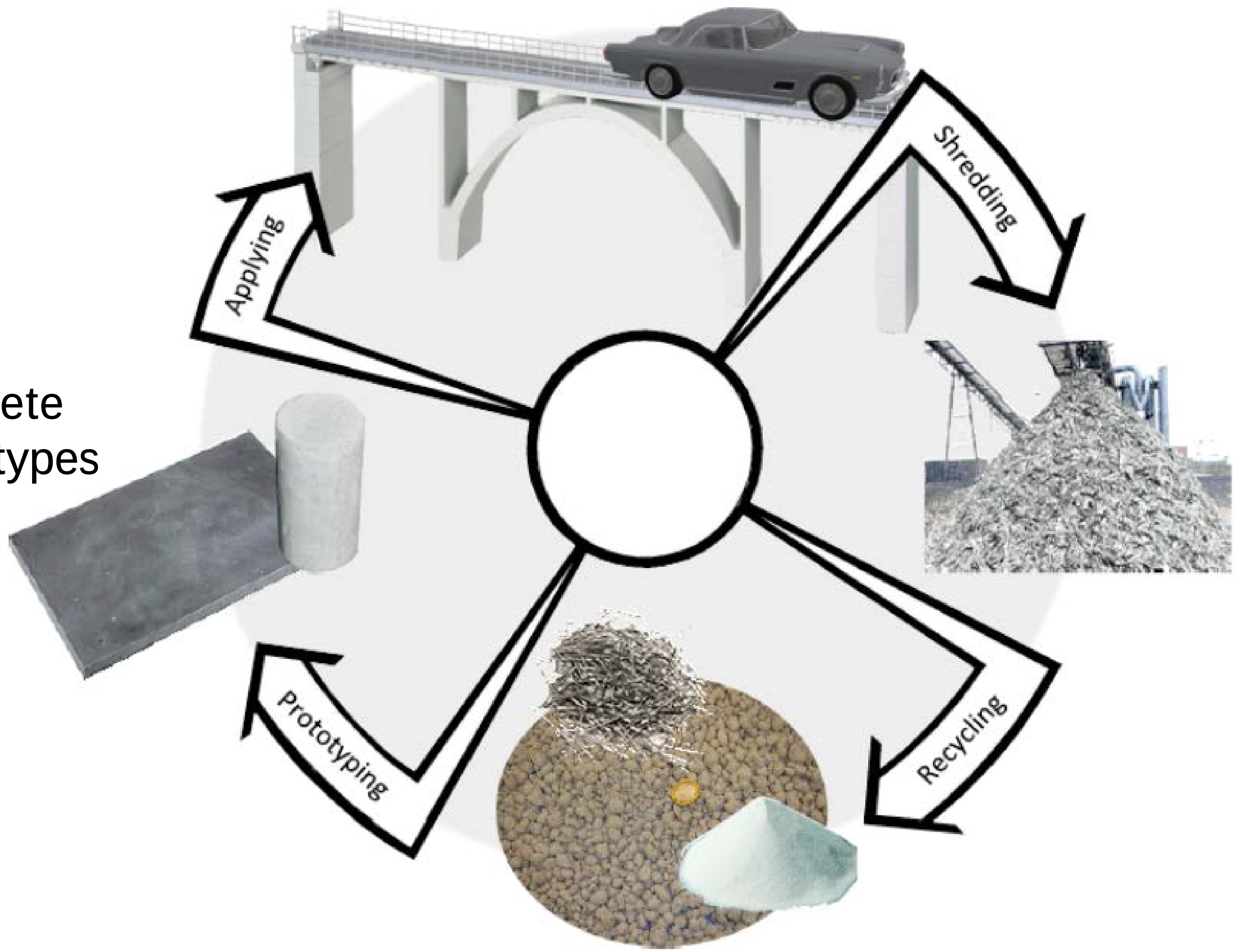
- The shredding of automobiles is a process where a car is reduced into small pieces.
- The shredding of automobiles results in a mixture of ferrous metal, non-ferrous metal and shredder waste, called automotive shredder residue or automobile shredder residue (ASR).
- ASR consists of glass, fiber, rubber, automobile liquids, plastics and dirt. ASR is sometimes differentiated into shredder light fraction and dust. Sometimes these residual materials are called "Car-fluff".

(from Wikipedia)

The idea

From car to concrete infrastructure

Concrete prototypes



Car fluff

Aggregate and fibers

Granulation of fluff

The same procedure for returned concrete

1. Fluff, cement, water, and superplasticizer are mixed into the drum of a mixer.
2. Superabsorbent polymer (SAP) is added.
3. After few minutes of mixing (about 2~3 minutes), the composite is transformed into a granular material
4. An Ettringite Forming Compound (EFC) is put into the mixer and mixed for additional 2-3 minutes.
5. The granular material is discharged to the ground and cured as a traditional cement-based composite

A new aggregate

- A lightweight aggregate
- The same diameter of structural expanded clay
- The strength is similar to that of ordinary expanded clay

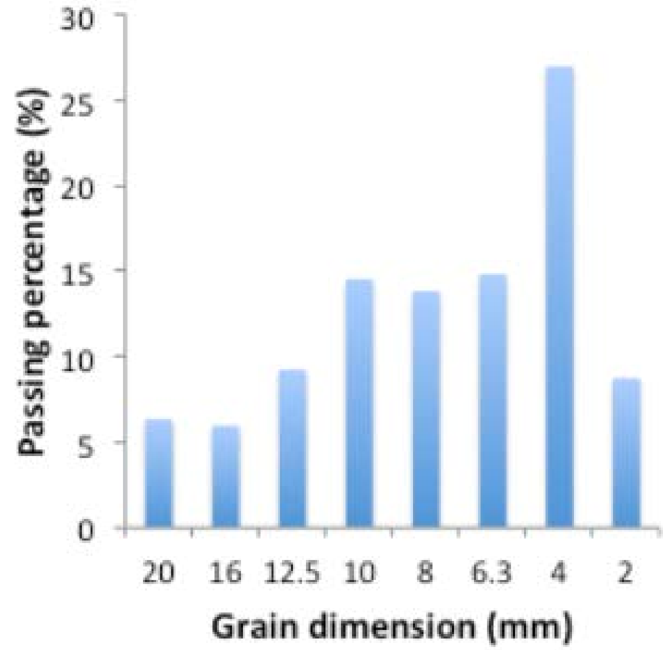


Table 2– Properties of the granulated fluff compared with the expanded clay.

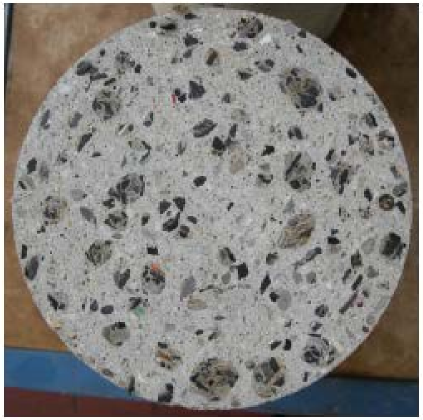
	Structural Exp. clay 0-15 mm	Fluff Grains 0-15 mm	Expanded clay 0-2 mm	Expanded clay 2-3 mm	Expanded clay 3-8 mm	Expanded clay 8-20 mm
Density (kg/m^3)	700	780	600	450	350	300
Compressive strength (MPa)	120	35	45	25	15	7

Three lightweight concretes

M1

M2

M3

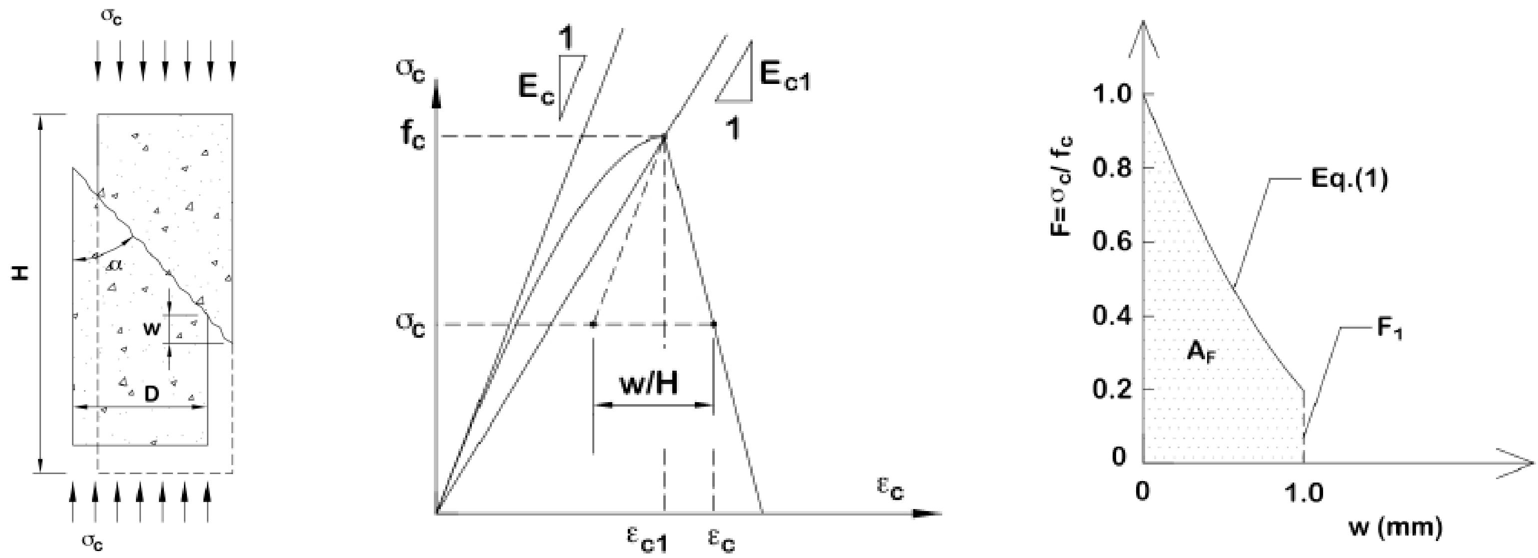


- M1 - w/c= 0.5, expanded clay as coarse aggregate
- M2 - w/c= 0.5, fluff grains as coarse aggregate
- M3 - w/c= 0.56, fluff grains as coarse aggregate

Materials	M1	M2	M3
CEM II/ALL 42.5R (kg/m^3)	370	399	362
Fine limestone (kg/m^3)	122	131	176
Sand 0-2 mm (kg/m^3)	434	434	434
Sand 0-4 mm (kg/m^3)	434	434	434
Structural expanded clay 0-15 mm (kg/m^3)	380		
Granulated fluff (kg/m^3)		380	380
Superplasticizer (kg/m^3)	2.9	3.2	2.9
Water (kg/m^3)	184	198	201
Density (kg/m^3)	1870	2010	2000
Slump 0' (mm)	180	210	240
Slump 15' (mm)	155	180	220
Cubic compressive strength at 7 days (MPa)	35.3	22.8	25.5

Mechanical tests

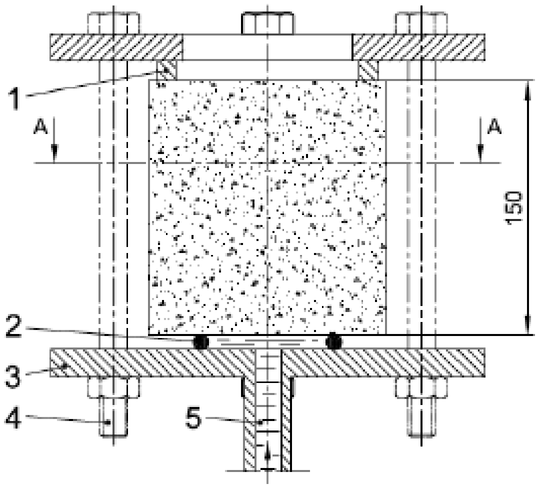
- Uniaxial compression tests on cylinders

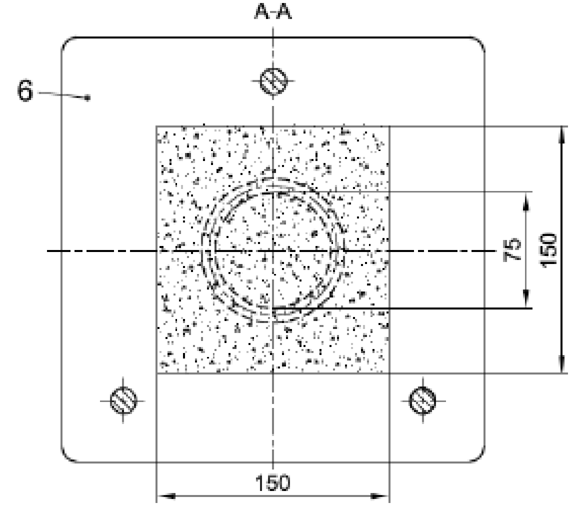


- The following parameter are defined:
  - Compressive strength f_c from the stress-strain relationship
  - Ductility A_F = area defined by the normalized stress *vs.* inelastic displacement of the post-peak behavior

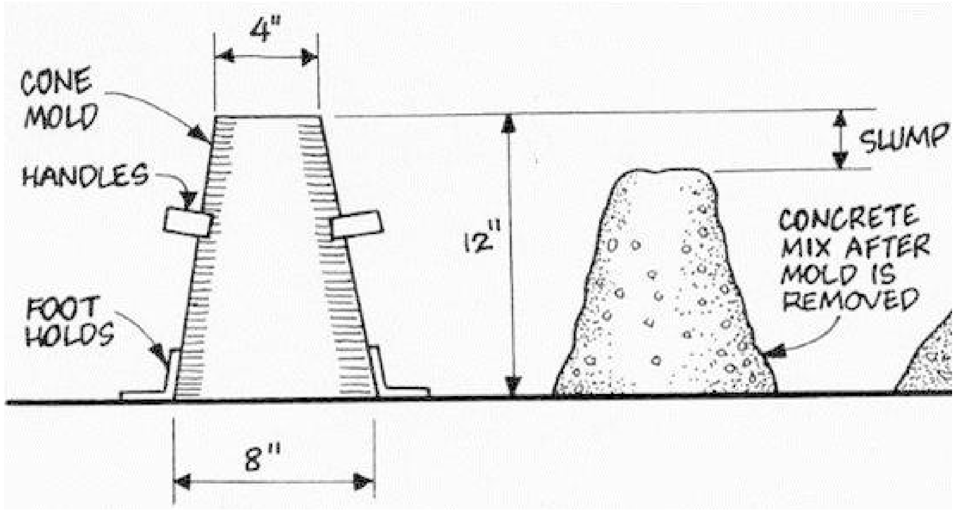
Other tests

- Depth of water penetration – UNI 12390-8





- Spread at 0' and 15' with the cone slump test



Test results

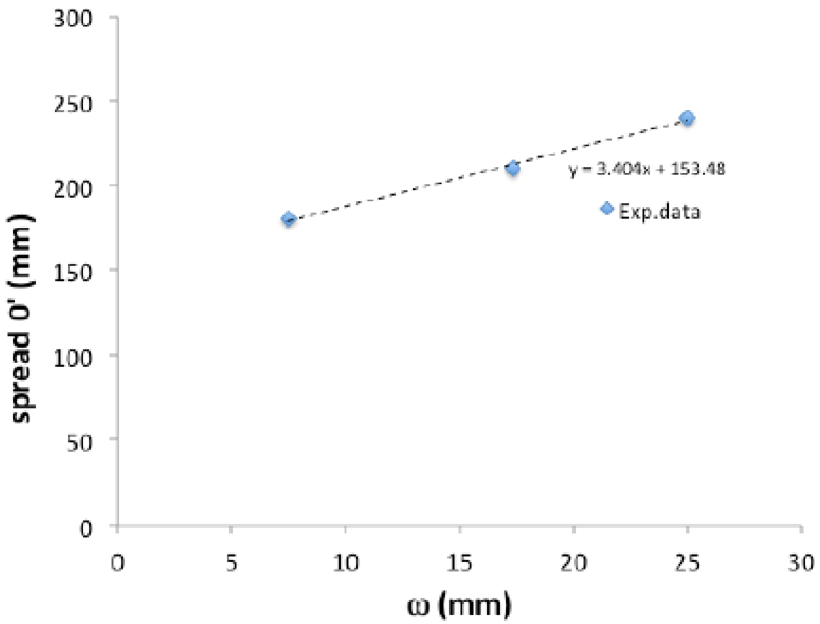
Type of concrete	Specimens	f_c (MPa)	A_F (mm)	d (mm)
M1	A	39.0	0.53	14-16
	B	36.1	0.53	
	C	36.8	0.51	
M2	A	23.4	0.78	35-35
	B	23.8	0.76	
	C	22.0	0.81	
M3	A	21.9	0.79	42-48
	B	20.8	0.79	
	C	21.5	0.80	

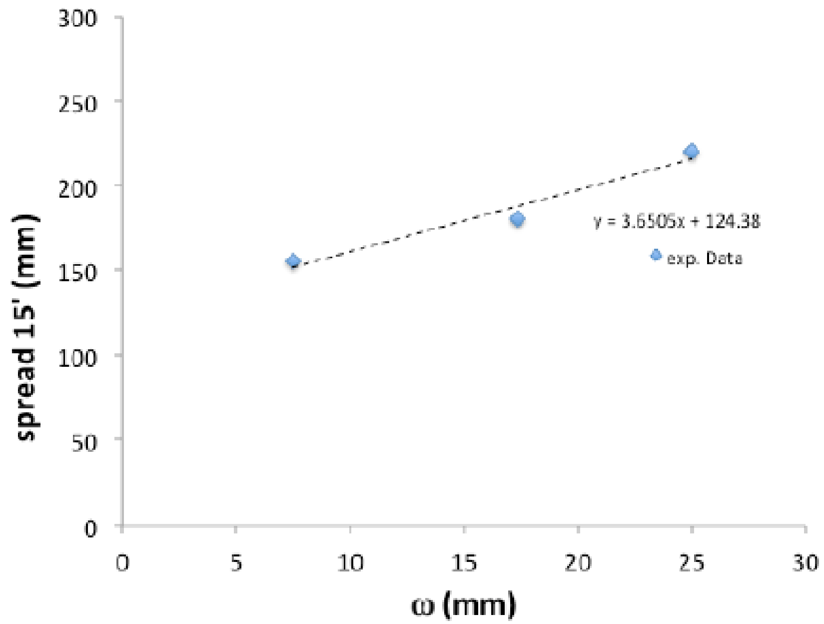
- If strength decreases, the ductility of the post-peak behavior increases.
- Workability (or d) increases when the water/binder ratio increases.
- The higher W/B, the lower the strength.

A common behavior

- Is there a single parameter to which the performances of the three lightweight concretes can be referred to?
- According to Wille et al.(2011), the water/cement ratio and the content of air are the main parameters affecting the strength of UHPC.
- Thus, in this case, we can refer to $\omega = d \cdot W/B$
  - d = depth of water penetration under pressure (mm)
  - W/B = water/binder ratio (in weight) used to cast the concrete (and not to granulate the fluff).

Spread *vs.* ω



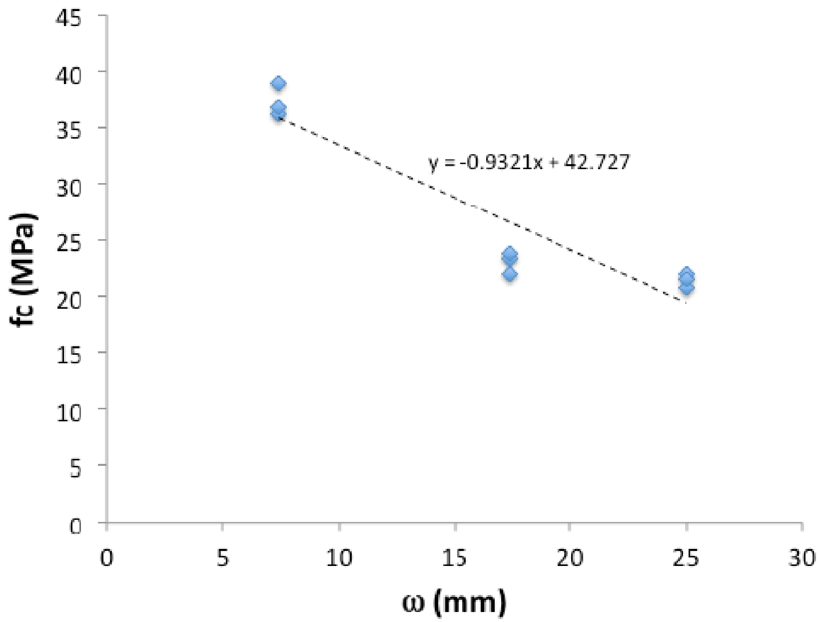


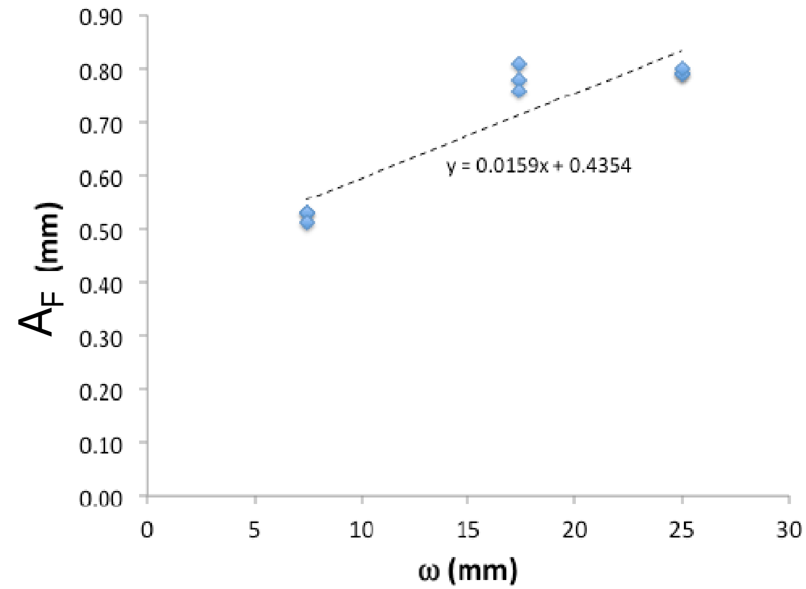
- A single linear equation can be used in all the concretes, regardless of the type of aggregate

$$spread = a + b \cdot \omega$$

  - a = 154 mm and 124 mm, for 0' and 15', respectively
  - b = 3.5 in all the cases

Strength and ductility vs. ω





$$f_c = 43 - 0.94 \cdot \omega$$

$$A_F = 0.44 + 0.0016 \cdot \omega$$

- Linear equations can be used for f_c and A_F of all the concretes, regardless of the type of aggregate

Conclusions

- A single parameter ω can characterize the behavior of lightweight concrete made with both expanded clay and granulated fluff.
- As ω increases, compressive strength decreases.
- On the contrary, both the workability (i.e., the spread measured through the cone slump test) and the post-peak fracture toughness in compression increase with ω.
- Depending on the required structural performances and on the concrete workability, the optimal value of ω, and therefore of the content of the granulated fluff, can be evaluated.

Thank you

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