

RECYCLING AND REUSE OF RAW MATERIALS

2. CEMENT-BASED MATERIALS: MORTARS, LIME, CONCRETE

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WHAT IS A MORTAR?

Mortar is a type of mixture of cement paste, water and fine aggregates.

In fresh concrete, mortar is the material occupying the **interstices** among the particles of coarse aggregates.

In masonry constructions, joint mortar may contain *masonry cement*, or it may contain **hydraulic cement with lime** (and possibly other admixtures) to afford greater plasticity and workability than those that are attainable with standard Portland cement mortar.

Mortars are usually used in masonry constructions to bind building blocks, e.g. stones, bricks and concrete masonry unit, to fill and seal the irregular gaps between them, spread the weight and loads, and sometimes to add decorative colors or patterns to the walls.



MORTARS

Mortars are categorized based on the type of application:

- **BRICKLAYING OR STONE-LAYING MORTAR:** this type of mortar is used to bond together stones and bricks;
- **FINISHING MORTAR:** it is used for pointing and plastering works.



Bricklaying or stone-laying mortar



Finishing mortar

MORTARS

Mortars are categorized also based on the type of binding materials, which affect the quality and the strength of the final product itself:

- **CEMENT MORTAR:** The binder is **cement**, and the fine aggregate is sand, typically in the range 1:2 to 1:6. This ratio provides the strength and water resistance.
- **AERATED CEMENT MORTAR:** Air-entrainer agents are added to the cement mortar to increase its plasticity and workability.
- **LIME MORTAR:** the binder is the **lime**, which is more breathable than cement mortar and more flexible. It means that this mortar is less likely to trap moisture within the construction.



Cement mortar



Lime mortar

MORTARS

Mortars are categorized also based on the type of binding materials, which affect the quality and the strength of the final product itself:

- **GYPSUM MORTAR:** The binder is **plaster (gypsum)**. This type of mortar had low durability in moist condition.
- **GAUGED MORTAR:** A composite of **lime, cement and sand**, which combines the plasticity of the lime with the strength of cement,
- **SURKHI MORTAR:** the binder is the **lime**, whereas the **aggregate is surkhi** (finely-powdered burnt clay). This provides more strength than the sand.



Gypsum mortar



Gauged mortar



Surkhi mortar

MORTARS

European reference:

EN 998 – 1 Rendering/plastering

EN 998 – 2 Masonry mortar

(EN 1504 - Products and systems for the protection and repair of concrete structures)

	BS EN 998-1 Rendering/plastering	BS EN 998-2 Masonry mortar
According to location of finished manufacture	(i) Factory made (ii) Semi-finished (iii) Site made	(i) Factory made (ii) Semi-finished (iii) Pre-batched (iv) Premixed lime sand (v) Site made
According to concept	(i) Designed (ii) Prescribed	(i) Designed (ii) Prescribed
According to properties and uses	(i) General purpose (GP) (ii) Lightweight* (LW) (iii) Coloured (CR) (iv) One coat for external use (OC) (v) Renovation [#] (R) (vi) Thermal insulating (T)	(i) General purpose (G) (ii) Thin layer [†] (T) (iii) Coloured (CR)

* A lightweight mortar is required to have a dry hardened density of less than 1300kg/m³

[†] A thin layer masonry mortar is required to have a maximum aggregate particle size of 2mm

[#] A renovation rendering mortar is designed for use on moist masonry walls containing soluble salts

The European Standards for both rendering mortars and masonry mortars require that **constituent raw materials shall have characteristics which permit the finished product to conform to the requirements of the Standard**. The European Standards require that constituent materials of established suitability be used.

RENDERING AND PLASTERING MORTARS

The manufacturer of the mortar is required to declare the workable life when the mortar contains an admixture to control the setting, testing should be undertaken in accordance with BS EN 1015-9. It is a requirement of the Standard that the air content be tested and declared when relevant to the end use of the mortar.

Main requirements:

Technical
performance:
strength



Technical
performance:
durability



Technical
performance:
energy



Property	Type	Mean values
Compressive strength at 28 days	CS.i CS.ii CS.iii CS.iv	0,4 - 2,5N/mm ² 1,5 - 5,0N/mm ² 3,5 - 7,5N/mm ² > 6N/mm ²
Capillary water absorption	W 0 W 1 W 2	Not specified $c \leq 0,40\text{kg/m}^2 \text{ min } 0,5$ $c \leq 0,20\text{kg/m}^2 \text{ min } 0,5$
Thermal conductivity	T 1 T 2	$\leq 0,1\text{W/m.K}$ $\leq 0,2\text{W/m.K}$

RENDERING AND PLASTERING MORTARS

Specific requirements depending on the type (some examples, not exhaustive):

Test Parameter	Method of test	GP	LW	CR	OC	R	T
Dry bulk density (kg/m ³)	BS EN 1015-10	Declared range of values 1300 Kg/m ³	Declared range of values	Declared range of values	Declared range of values	Declared range of values	Declared range of values
Compressive strength (categories)	BS EN 1015-11	CS I - IV	CS I - III	CS I - IV	CS I - IV	c	CS I - II
Adhesion (N/mm ² and fracture pattern (FP) A, B or C)	BS EN 1015-12	≥ Declared value and fracture pattern	≥ Declared value and fracture pattern	≥ Declared value and fracture pattern	-	≥ Declared value and fracture pattern	≥ Declared value and fracture pattern
Adhesion after weathering cycles (N/mm ² and fracture pattern (FP) A, B or C)	BS EN 1015-21	-	-	-	Declared value and fracture pattern	-	-
Capillary water absorption (kg/(m ² .h. ^{0.5})). For mortars intended to be used in external elements	BS EN 1015-18	W0 - W2	W0 - W2	W0 - W2	W1 - W2	≥0.3kg/m ² after 24 hours	W1
Water penetration after capillary water absorption test (in mm)	BS EN 1015-18	-	-	-	-	≤5mm	-
Water permeability on relevant substrates after weathering cycles (ml/cm ² after 48 hours)	BS EN 1015-21	-	-	-	≤1ml/cm ² after 48 hours	-	-

RENDERING AND PLASTERING MORTARS

Let's compare this list with the technical sheet of a commercial product:

Technical Data compliant with Kerakoll Quality Standard			
Type of mortar	performance-guaranteed masonry mortar for general purpose use (G) in external applications subject to structural requirements	CLASSIFICATION	
Chemical nature of binder	pure Natural Hydraulic Lime NHL 3.5		EN 459-1
Grading	0 – 1,4 mm		EN 1015-1
Apparent density of powder	≈ 1.57 kg/dm³		UEAtc
Shelf life	≈ 12 months from production in the original sealed packaging, protect from humidity		
Pack	25 kg bags		
Mixing water	≈ 4.5 l / 1 x 25 kg bag		
Consistency of wet mortar	≈ 165 mm	EN 1015-3	
Apparent density of wet mortar	≈ 1.97 kg/dm³	EN 1015-6	
Apparent density of dry, hardened mortar	≈ 1.8 kg/dm³	EN 10	
pH of the mixture	≥ 12		
Temperature range for application	from +5 °C to +35 °C		
Coverage	≈ 1.7 kg/dm³		
Values taken at +20 ± 2 °C, 65 ± 5% R.H. and no ventilation. Data may vary depending on specific conditions at the building site.			

CLASSIFICATION BY SCOPE

Bic COMPRESSIVE STRENGTH

Certified, eco-friendly, natural mortar containing pure NHL 3.5, EN 459-1 intended for highly breathable rough rendering and pointing of masonry.

Biocalce Pietra is an M5 class mortar, suitable for the construction of exposed vertical walls and for pointing brick or natural stone coverings. Internal, external.



DENSITY

AND OTHER RELEVANT INFORMATIONS

MASONRY MORTARS

Main requirements both at the **fresh and hardened states**

Property	Test	Requirement
Workable life	BS EN 1015-9	$\geq$ Declared value
Chloride content (i)	BS EN 1015-17	$\leq$ Declared value
Air content (ii)	BS EN 1015-7	Within declared range

Property	Performance level	Test method	Requirement to provide data
Bond strength	Declared value	BS EN 1052-3, alternatively a tabulated value in accordance with Annex C of BS EN 998-2 may be declared	Only applicable to designed masonry mortar subjected to structural requirements
Water absorption	Declared value	BS EN 1015-18	Only applicable to masonry mortar used in external situations
Water vapour permeability	Declared value	Calculation of tabulated values in accordance with BS EN 1745, Annex A, Table 12	Only applicable to masonry mortar used in external situations
Dry density of hardened mortar	Declared value	BS EN 1015-10	When relevant to the use for which the mortar is placed on the market
Thermal conductivity	Declared value	BS EN 1745, Table A12 alternatively measured values in accordance with BS EN 1745 Clause 4.2.2 may be declared	Only applicable to masonry mortars subject to thermal requirements

MASONRY MORTARS

For designed masonry mortars, the compressive strength classes illustrated are: M1, M2.5, M5, M10, M15, M20.

It is possible to have further strength classes where the manufacturer may declare other values in class Md. The compressive strength shall be determined on samples taken in accordance with BS EN 1015-2 and tested in accordance with BS EN 1015-11.

Mortar designation	Prescribed mortars (traditional proportion of materials by volume) ^A				Mortar class that may be assumed	Suitable for use in environmental condition
	Cement ^B : lime : sand with or without air entrainment	Cement ^B : sand with or without air entrainment	Masonry cement ^C : sand	Masonry cement ^D : sand		
(i)	1:0 to 1/4 :3	1:3	Not suitable	Not suitable	M12	Severe (S)
(ii)	1:1/2 :4:4 1/2	1:3 to 4	1:2 1/2 to 3 1/2	1:3	M6	Severe (S)
(iii)	1:1:5 to 6	1:5 to 6	1:4 to 5	1:3 1/2 to 4	M4	Moderate (M)
(iv)	1:2:8 to 9	1:7 to 8	1:5 1/2 to 6 1/2	1:4 1/2	M2	Passive (P)

^A When the sand portion is given as, for example, 5 to 6, the lower figure should be used with sands containing a higher proportion of fines, whilst the higher figure should be used with sands containing a lower proportion of fines

^B Cement or combinations as detailed in the National Annex BS EN 998-2

^C Masonry cement (organic filler other than lime) as detailed in the National Annex BS EN 998-2

^D Masonry cement (lime) as detailed in the National Annex BS EN 998-2

MASONRY MORTARS

Example:

Type M12 of this table: 1 part of cement / 3 part of sand (hydration not provided, but may be assumed as 1 part of water / 2 part of cement) → typical relation known as 1:2:3

Mortar designation	Prescribed mortars (traditional proportion of materials by volume) ^A				Mortar class that may be assumed	Suitable for use in environmental condition
	Cement ^B : lime : sand with or without air entrainment	Cement ^B : sand with or without air entrainment	Masonry cement ^C : sand	Masonry cement ^D : sand		
(i)	1:0 to 1/4 :3	1:3	Not suitable	Not suitable	M12	Severe (S)
(ii)	1:1/2 :4:4 1/2	1:3 to 4	1:2 1/2 to 3 1/2	1:3	M6	Severe (S)
(iii)	1:1:5 to 6	1:5 to 6	1:4 to 5	1:3 1/2 to 4	M4	Moderate (M)
(iv)	1:2:8 to 9	1:7 to 8	1:5 1/2 to 6 1/2	1:4 1/2	M2	Passive (P)

^A When the sand portion is given as, for example, 5 to 6, the lower figure should be used with sands containing a higher proportion of fines, whilst the higher figure should be used with sands containing a lower proportion of fines

^B Cement or combinations as detailed in the National Annex BS EN 998-2

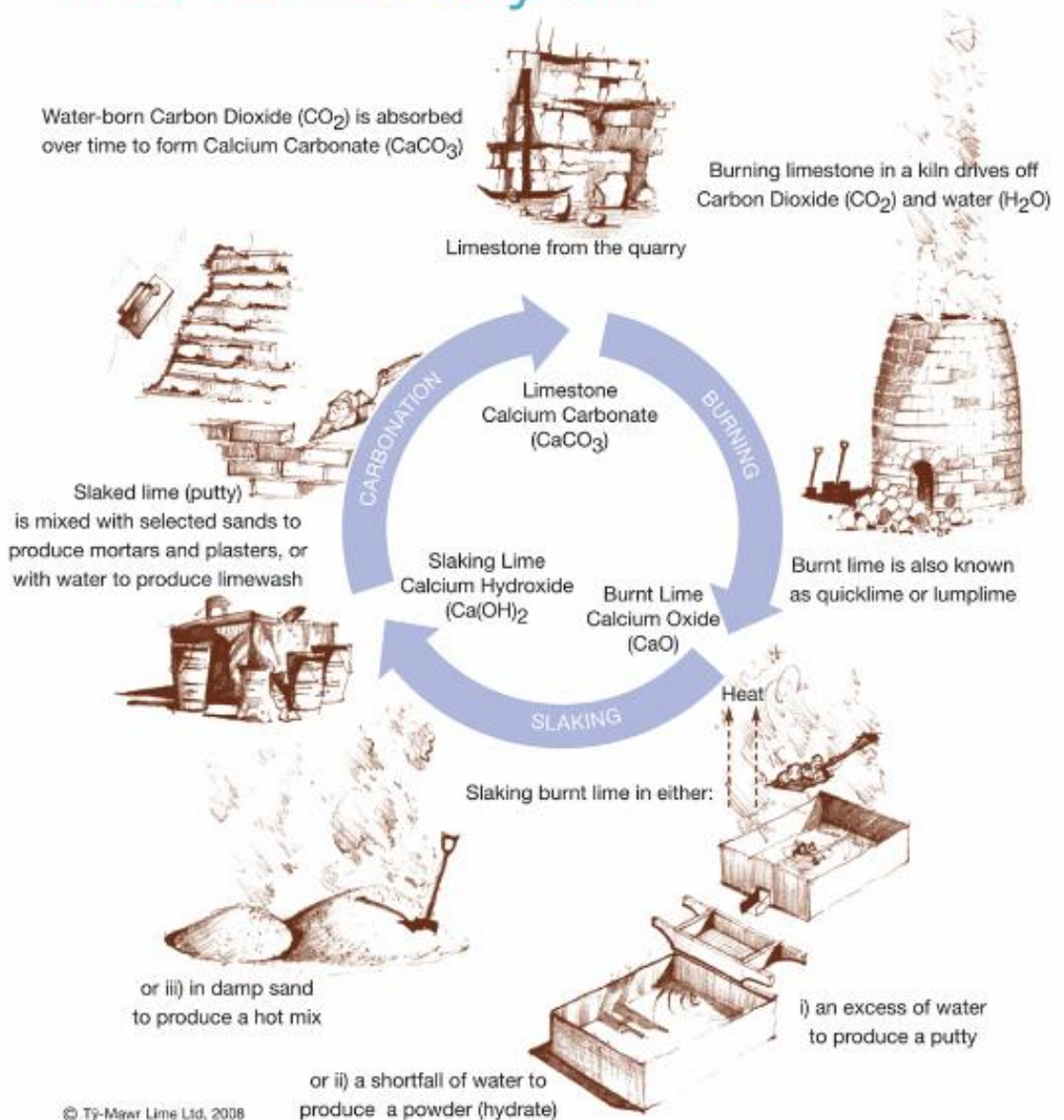
^C Masonry cement (organic filler other than lime) as detailed in the National Annex BS EN 998-2

^D Masonry cement (lime) as detailed in the National Annex BS EN 998-2

LIME

Stages from quarrying the limestone through to the production of mortars and plasters for our buildings and how it slowly, through the re-absorption of Carbon Dioxide, reverts to its original chemical form (Calcium Carbonate) in the wall. Carbonation phenomenon depends on the type of lime.

The Lime Cycle



LIME

Limestone (Calcium Carbonate – CaCO_3) is burnt in a kiln giving off Carbon Dioxide (CO_2) gas and forming Calcium Oxide (CaO). Depending on the type of the raw material, it is possible to obtain two products: **aerial-lime or hydraulic lime.**

Aerial lime derives from the cooking (calcination) of limestone consisting mainly of **calcium carbonate**. The higher is the content of limestone, the higher is the purity of the aerial lime (known as “calce grassa”).



Hydraulic lime derives from the firing of a "marl", a **sedimentary limestone where, together with calcium carbonate, percentages of earthy, clayey or ferrous impurities** containing hydraulic charges are naturally present. These fillers, mainly silicates and aluminates, combine with the calcium oxide created after cooking, giving rise to calcium silicates and calcium aluminates, i.e. insoluble hydraulic bonds allowing the mixture to harden both in air and in a humid environment or in waterfall.

LIME

Burning phase: The material needs to be burnt at 900°C to ensure a good material is produced. The temperature at which it is burnt will affect its reactivity in all other stages of the lime cycle – slaking and carbonating. The resulting lime is at its most volatile and dangerous at this stage.

Slaking phase: The Burnt Lime or Quicklime is then combined with water (slaked) as quickly as possible. From the moment it is burnt the material starts to degrade by 'air-slaking'. Combining Quicklime (CaO) and water (H_2O) produces Calcium Hydroxide (Ca(OH)_2) - slaked lime and heat. There are three main ways of slaking the Quicklime:

- in an excess of water to produce a putty;
- in a shortfall of water to produce a powder - hydrated or bag lime;
- in damp sand to produce a hot mix.

LIME

Lime carbonation (aerial): Lime sets by absorbing water soluble Carbon Dioxide from the air. This process is called carbonation. The 'set' or carbonation must occur slowly – the slower the set the better (it is not a case of just drying), therefore direct heaters or dehumidifiers do not help and may cause failures – it is therefore vitally important that the conditions are right to enable the water-borne Carbon Dioxide (CO₂) to be absorbed.

This material can be found both in POWDER FORM or as PASTE.



LIME

USES: not only as construction materials!

IDEAS?



1

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2

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Codice evento
NEUDBC

 [Copiare il link di partecipazione](#)

CONCRETE

What is a GOOD concrete? It is easier to say **what is a bad concrete**:

a material with the consistency of a soup, hardening into a honeycombed, non-homogeneous and weak mass, and made with only cement, aggregates and water.

Surprisingly, a GOOD concrete can be made with the same materials, but the difference relates to the know-how.

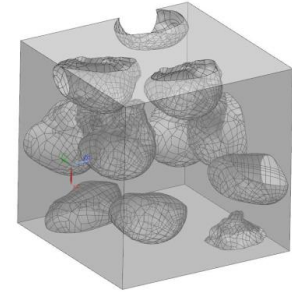
Requirements to cast a good concrete relates to both **the fresh and hardened states**:

- the consistency of the mix should allow concrete to be compacted, and the cohesiveness should allow it to be mixed, transported and placed without any segregation phenomena;
- in the hardened state, the most used requirement deals with the compressive strength. However, important properties are also: density, impermeability, durability, resistance to abrasion, resistance to impact, tensile strength, durability, no shrinkage and not necessarily creep.

CONCRETE

Concrete can be seen as a multi-phase material, made by at least two different phases: the **cementing matrix** and the **aggregates**.

This has a clear influence on the elastic modulus of the composite material, depending on the elastic properties of its components.



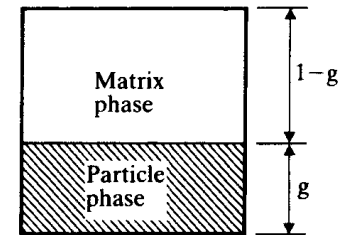
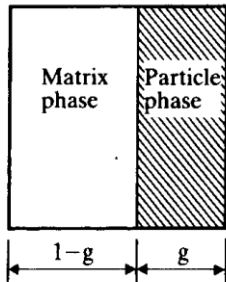
Composite “hard”

vs

Composite “soft”



$$E = (1 - g)E_m + gE_p$$



AGGREGATES FOR CONCRETE

Almost $\frac{3}{4}$ of concrete volume is occupied by aggregates. Hence, their quality is extremely important.

Aggregate was originally intended as an **inert, inexpensive material**, dispersed through the cement paste, to increase its volume. However, aggregate is not truly inert, as its property may affect mechanical, durability properties of concrete, thermal properties, and even its performance in the fresh state. Many properties of the aggregate depend on their parent rock properties.

The main reference for aggregates in concrete (structural, for pavements and for precast structures) is the **EN 12620 (2008)**, which classifies aggregates in **natural, recycled and manufactured**. However, a great confusion exist on the current regulations available.



AGGREGATES FOR CONCRETE

DM 17/01/2018: Norme Tecniche per le Costruzioni

UNI EN 12620: 2008 – Aggregati per calcestruzzo

UNI 8520-1: 2015 - Istruzioni complementari per l'applicazione della EN 12620 – Parte 1: Designazione e criteri di conformità

UNI 8520-2: 2016 – Istruzioni complementari per l'applicazione della EN 12620 – Parte 2: Requisiti

UNI EN 206: 2016 - Calcestruzzo – Specificazione, prestazione, produzione e conformità

UNI 11104: 2016 - Calcestruzzo – Specificazione, produzione e conformità - Specificazioni complementari per l'applicazione della UNI EN 206

UNI EN 933-11 - Prove per determinare le caratteristiche geometriche degli aggregati - Parte 11: Prova di classificazione per i costituenti degli aggregati grossi riciclati

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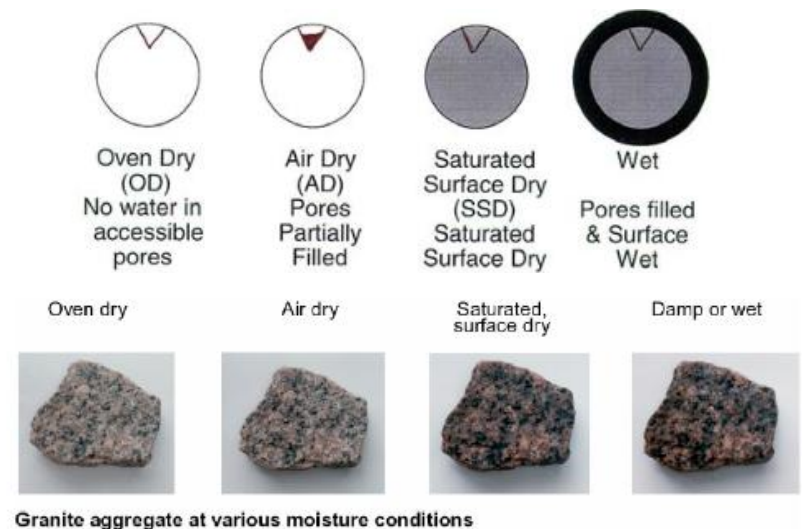
AGGREGATES FOR CONCRETE

Name	Classification			Description			Examples		
	Group			Surface Texture			Characteristics		
Basalt Group	Basalt	Andesite	Basalt	Basic porphyrites	Diabase	Dolerites of all kinds including theralite and teschenite	Epidiorite	Lamprophyre	Quartz-dolerite
Flint Group	Chert	Flint							
Gabbro Group	Basic diorite	Basic gneiss	Gabbro	Hornblende-rock	Norite	Peridotite	Pierite		
Depending on their origin, size, density, shape and									
Granite Group	Rounded			Fully water-worn or completely shaped by attrition			River or seashore gravel; desert,		
Gneiss	Irregular			Naturally irregular, o	attrition and having				
Granite	Flaky			Material of which the	relative to the other				
Granodiorite	Angular			Possessing well-define	at the intersection of	planar faces			
Granulite	Elongated			Material, usually ang	the length is consid	than the other two			
Pegmatite	Flaky and			Material having the l	larger than the wid	considerably larger			
Quartz-diorite									
Syenite									
Limestone Group									
Dolomite									
Limestone									
Marble									
Schist Group									
Phyllite									
Schist									
Slate									
All severely sheared rocks									

AGGREGATES FOR CONCRETE

A number of tests should be carried out to assess natural and manufactured aggregates properties:

- specific gravity (oven-dry, air-dry, saturated surface-dry, moist);
- water absorption;
- porosity;
- thermal properties;
- presence of deleterious substances;
- organic impurities;
- grading;
- soundness;
- fineness modulus;
- compressive strength.



Additionally, for recycled aggregates further tests to assess their composition should be made.

AGGREGATES FOR CONCRETE

	Property	Relative Importance for End Use*		
		concrete	Asphalt	Base
<u>Physical characteristics</u>	Particle shape (angularity)	MI	VI	VI
	Particle shape (flakiness, elongation)	MI	MI	MI
	Particle size—maximum	MI	MI	MI
	Particle size—distribution	MI	MI	MI
	Particle surface texture	MI	VI	VI
	Pore structure, porosity	VI	MI	UI
	Specific gravity, absorption	VI	MI	MI
	Soundness—weatherability	VI	MI	MI
	Unit weight, voids—loose, compacted	VI	MI	MI
	Volumetric stability—thermal	MI	UI	UI
	Volumetric stability—wet/dry	MI	UI	MI
	Volumetric stability—freeze/thaw	VI	MI	MI
	Integrity during heating	UI	MI	UI
	Deleterious constituents	VI	MI	MI
<u>Chemical characteristics</u>	Solubility	MI	UI	UI
	Surface charge	UI	VI	UI
	Asphalt affinity	UI	VI	MI
	Reactivity to chemicals	VI	UI	UI
	Volume stability—chemical	VI	MI	MI
	Coatings	MI	MI	UI
<u>Mechanical characteristics</u>	Compressive strength	MI	UI	UI
	Toughness (impact resistance)	MI	MI	UI
	Abrasion resistance	MI	MI	MI
	Character of products of abrasion	MI	MI	UI
	Mass stability (stiffness, resilience)	UI	VI	VI
	Polishability	MI	MI	UI
*VI = Very important; MI = Moderately important; UI = unimportant or importance unknown				

AGGREGATES FOR CONCRETE

SHAPE AND TEXTURE

- Determines how material packs into a dense configuration.
- Determines mobility of aggregates within a concrete/asphalt mix (also known as **workability**).

There are two considerations in the shape of the material:

- Angularity
- Flakiness index

ANGULARITY: How angular are the individual particles?

- Angular
- Sub-angular
- Sub-round
- Round

Angular aggregates have high strength and high stability. Used in base and subbase course layer of roadways.

E.g. Crushed aggregates.

Rounded aggregates have low stability and high workability. Used in self-compacting concretes.

E.g. River aggregates

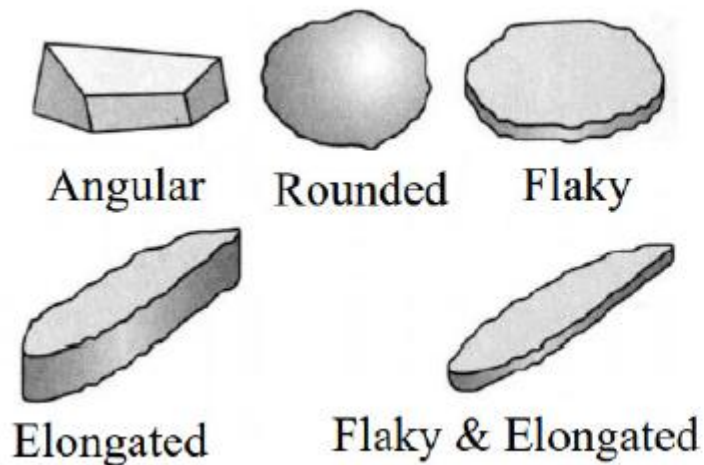


AGGREGATES FOR CONCRETE

SHAPE AND TEXTURE

FLAKINESS INDEX measures the flaky and elongated aggregates. There are:

- **Rounded particles:** Have no original fracture faces. They are fully water-worn or complete wear-molded, e.g. River gravel.
- **Angular particles:** Possess well define fracture faces and edges. They show little evidence of wear, e.g. crushed stone.
- **Flaky particles** are those which have small thickness relative to the other two dimensions.
- **Elongated particles** are those which have lengths considerably larger than the other two dimensions



AGGREGATES FOR CONCRETE

EXAMPLE: testing water absorption of a sand, according to EN 1097-6.

Sample size for sand, alternatively depend on grading.



Dimensione massima degli aggregati mm	Massa minima delle porzioni di prova kg
31,5	5
16	2
8	1
Nota Per dimensioni differenti, la massa minima della porzione di prova può essere ricavata per interpolazione dalle masse specificate nel prospetto 2.	

Procedure:

1. CLEAN the aggregates
2. PUT the aggregates inside the pycnometer with water. Remove the air. Maintain the pycnometer at the control temperature, and clean it externally. Weight M2.
3. REMOVE the aggregates from the pycnometer, let it dry slowly until reaching the condition of saturated-surface dry. Help with hot air + mini-cone. Weight M1.
4. Take the pycnometer with ONLY water at the same level than in step 2. Weight M3.
5. OVEN-dry the aggregate at 110 ± 5 °C until reaching no-mass change.
6. Calculations...

AGGREGATES FOR CONCRETE

EXAMPLE: testing water absorption of a sand, according to EN 1097-6.

apparent specific gravity

oven-dry specific gravity

saturated surface-dry

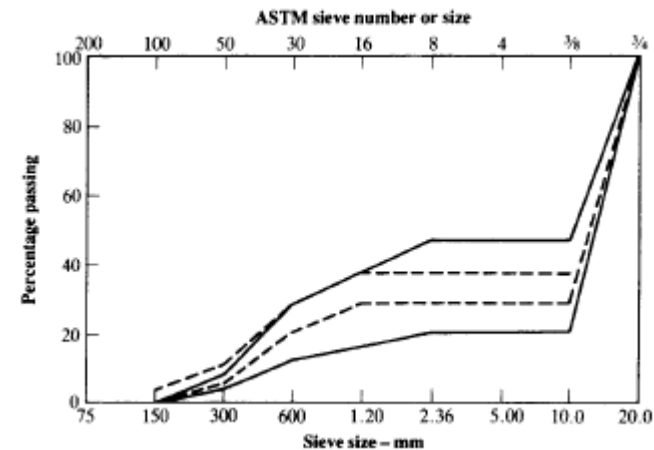
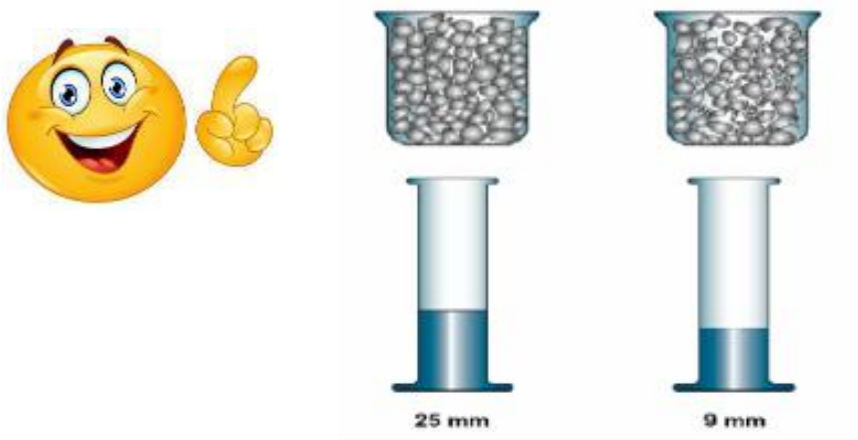
water absorption

EXERCISE: calculate WA24 for a type of sand.
Values expressed in (g).

M2	M3	M1	M4
2518	1555	1322	1307

AGGREGATES FOR CONCRETE

Aggregates grading is the distribution of particles of granular materials among various sizes. It depends on: proportions of coarse and fine aggregates; and it affects: Paste content (cost economy), workability. Recommendations exist to allow good concrete design (next classes).



GAP-GRADED aggregates

Fineness Modulus (FM): is the Index of Fineness of an aggregate. It is computed by adding the cumulative percentages of aggregate retained on each of the specified series of sieves, and dividing the sum by 100.

AGGREGATES FOR CONCRETE

In general, the aggregates are classified as:

- **Coarse aggregate** (**gravel**) ≥ 4 mm
- $0,063 \text{ mm} \leq$ **Fine aggregate** (**sand**) < 4 mm
- **Filler** $< 0,063$ mm

Coarse aggregate is defined as aggregate that is retained on sieve UNE No. 4 (4mm).

Fine aggregate is defined as aggregate that passes the sieve UNE No. 4 (4mm).



River Coarse
aggregate



Crushed Coarse
aggregate



Crushed Fine
aggregate

AGGREGATES FOR CONCRETE

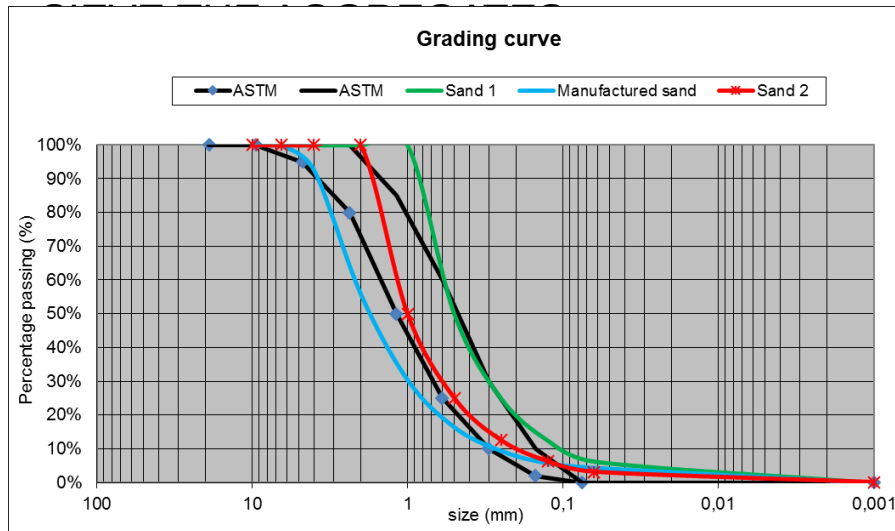
EXAMPLE: test grading of three types of sand (0-4 mm) according to ASTM requirements

Test sample: 300 g of DRY sand (for aggregates. depend on the maximum size)

Procedure:

CLEAN the aggregates

OVEN-DRY at 110 ± 5 °C



Sieve size		Percentage by mass passing sieve				
		BS 882: 1992				ASTM C 33-03
BS	ASTM No.	Overall limits	Additional limits*			
			C	M	F	
10 mm	$\frac{3}{8}$ in.	100	—	—	—	100
5 mm	$\frac{3}{16}$ in.	89–100	—	—	—	95–100
2.36 mm	8	60–100	60–100	65–100	80–100	80–100
1.18 mm	16	30–100	30–90	45–100	70–100	50–85
600 μ m	30	15–100	15–54	25–80	55–100	25–60
300 μ m	50	5–70	5–40	5–48	5–70	10–30
150 μ m	100	0–15†	—	—	—	2–10

* C = coarse; M = medium; F = fine.

† For crushed rock sands the permissible limit is increased to 20 per cent, except when used for heavy duty floors.

RECYCLED AGGREGATES FOR CONCRETE

In Italy, aggregates should **COMPLY** with EN 12620 standard (natural, recycled, manufactured). **RAs** are **QUALIFIED** for their use in concrete by **Chapter 11 of NTC 2018**, according to their origin and concrete strength class. No reference up to now to the durability class (even if a reference is present in the EN technical normative).

Tab. 11.2.III

Origine del materiale da riciclo	Classe del calcestruzzo	percentuale di impiego
demolizioni di edifici (macerie)	= C 8/10	fino al 100%
demolizioni di solo calcestruzzo e c.a. (frammenti di calcestruzzo ≥ 90%, UNI EN 933-11:2009)	≤ C20/25	fino al 60%
	≤ C30/37	≤ 30%
	≤ C45/55	≤ 20%
Riutilizzo di calcestruzzo interno negli stabilimenti di prefabbricazione qualificati - da qualsiasi classe	Classe minore del calcestruzzo di origine	fino al 15%
	Stessa classe del calcestruzzo di origine	fino al 10%



Tabella E.2 EN 206 - Massima percentuale di sostituzione dell'aggregato grosso (% in massa)

Tipologia di aggregati riciclati	Classi di esposizione			
	X0	XC1, XC2	XC3, XC4, XF1, XA1, XD1	Tutte le restanti classi di esposizione
Tipo A: (Rc ₉₀ Rcu ₉₅ Rb ₁₀ - Ra ₁ FL ₂ XRg ₁) ^{a)}	50%	30%	30%	0%
Tipo B: (Rc ₅₀ Rcu ₇₀ Rb ₃₀ - Ra ₅ FL ₂ XRg ₂) ^{b)}	50%	20%	0%	0%

a) Aggregati riciclati di Tipo A derivanti da una fonte nota possono essere usati in classi di esposizione in cui il calcestruzzo originale era progettato con una percentuale massima di sostituzione del 30%.

b) Aggregati riciclati di Tipo B non possono essere usati in calcestruzzo con classi di resistenza a compressione > C30/37.

RECYCLED AGGREGATES FOR CONCRETE

RAs should also comply with the following requirements, according to EN 206

Proprietà ^{a)}	Punto della EN 12620:2008	Tipo	Categoria secondo la EN 12620
Contenuto di fini	4.6	A + B	Categoria o valore da dichiarare
Indice di appiattimento/forma	4.4	A + B	$\leq FI_{50}$ or $\leq SI_{55}$
Resistenza alla frammentazione	5.2	A + B	$\leq LA_{50}$ or $\leq SZ_{38}$
Massa volumica delle particelle essiccate in stufa prd	5.5	A B	$\geq 2\,100\text{ kg/m}^3$ $\geq 1\,700\text{ kg/m}^3$
Assorbimento d'acqua	5.5	A + B	Valore da dichiarare
Costituenti ^{b)}	5.8	A B	$RC_{90}\,RCu_{95}\,Rb_{10-},\,Ra_{1-}\,FL_{2-}\,XRg_{1-}$ $RC_{50}\,RCu_{70}\,Rb_{30-}\,Ra_{5-}\,FL_{2-}\,XRg_{2-}$
Contenuto di solfati idrosolubili	6.3.3	A + B	$\leq SS_{0,7}$
Contenuto di ioni cloruro solubili in acido	6.2	A + B	Valore da dichiarare
Influenza sul tempo di inizio presa	6.4.1	A + B	$\leq A_{40}$
a) La categoria NR (nessun requisito) si applica a tutte le altre proprietà non specificate nel presente prospetto per le quali può essere dichiarata una categoria NR in accordo alla EN 12620. b) Per applicazioni speciali che richiedono una finitura superficiale di qualità il costituente FL dovrebbe essere limitato alla categoria $FL_{0,2-}$.			

RECYCLED AGGREGATES FOR CONCRETE

Types:

- **Recycled Concrete Aggregates (RCA)** is a special type of CDW, mainly obtained from concrete.
- Mixed CDW contains:
 - concrete waste,
 - mortar,
 - drywal,
 - ceramic,
 - asphalt,
 - glass,
 - plaster,
 - paper, wood,
 - metals and other impurities



Masonry waste



Ceramic waste



Drywall



Construction and Demolition Wastes (CDW)



Concrete waste



Mortar waste



Excavation material



Others:

- Asphalt
- Wood
- Metals
- Polymers
- Glass
- Cardboard/Paper

- Separation at source, transport and reception.
- Crusher (impact crusher).
- Separators: Magnetic for metal; Pneumatic for light materials (hydro cyclones and blowers); Hydraulic for soluble materials.
- Sieves.
- To limit the sulphate content it is important

Stages for production (we will deal more in detail in the technological process next time!)

RECYCLED AGGREGATES FOR CONCRETE

- **RCA** is an aggregate generated from recycled concrete. It usually has the origin in precast concrete industry when some pieces are not valid for structural purposes and the pieces are rejected, so, the quality of this aggregate is quite good.
- This aggregate has greater water absorption and less resistance to wear and abrasion than a natural aggregate.
- Used in making concrete, bituminous mixtures, granular layers, concrete masonry and backfills.



Recycled Concrete Aggregates (RCA)

RECYCLED AGGREGATES FOR CONCRETE

- **Reclaimed Asphalt Pavement (RAP)** is the term given to removed and/or reprocessed pavement materials containing asphalt and aggregates. These materials are generated when asphalt pavements are removed for reconstruction, resurfacing, or to obtain access to buried utilities.
- When it is properly crushed and screened, RAP consists of high-quality and well-graded aggregates coated by asphalt binder (bitumen).
- Although the majority of old asphalt pavements are recycled at central processing plants, asphalt pavements may be pulverized in place and incorporated into granular or stabilized base courses using a self-propelled pulverizing machine.



Reclaimed Asphalt Pavement

RECYCLED AGGREGATES FOR CONCRETE

During the production of Steel in Blast Furnaces, several Steel slags are obtained:

BF Crystallized slag:

- is formed during a slow cooling of the liquid slag in large pits (**air cooled**)
- has a large number of internal pores, high permeability and low abrasion resistance.
- is useful for bituminous mixtures, granular layers, concrete masonry, insulated with mineral wool, cement, improving agricultural soils and backfills.

BF Vitrified-granulated slag:

- is formed during a cooling of liquid slag in a blast of **cold water (cooled with water)**
- is used for granular layers, roller compacted concrete, manufacture of cement (with additions) and improvement of agricultural soils.

BF Pelletized-vitrified slag:

- is formed during a cooling of the liquid slag into a drum watered with water (**cooling with water and air**)
- is useful for granular layers, masonry concrete, lightweight concrete, insulation and lightweight backfill.

GGBFS_Granulated Blast Furnace Slag:

- When water-cooled slag is crushed or milled to very fine cement-sized particles, GGBFS is obtained, which is very suitable as SCM or as a mineral additive to Portland cement.



Air cooled Blast Furnace Slag



Ground Granulated Blast Furnace Slag (GGBFS)

RECYCLED AGGREGATES FOR CONCRETE

- Liquid LD slag is produced during the Linz-Donawitz process as pig iron is processed into crude steel.
- It has high hardness, high coefficient of accelerated polishing.
- It is used in surface treatments, asphalt mixes, granular bases and sub-bases.
- It may have small expansions, so we must be cautious when it is used in products or layers confined or treated with hydraulic conglomerates.



Linz-Donawitz steel slag

RECYCLED AGGREGATES FOR CONCRETE

- Generated at the melting of raw materials stage of electric steelmaking industry in electric arc furnaces.
 - High density (from 3.1 to 4.5 t/m³), high porosity and angularity, lack of fine (it is usually combined with other aggregates).
 - Contain expansive compounds, have a risk of swelling and give place to basic leachates.
 - Mainly used in bituminous mixtures, granular layers and making concrete.
-
- Generated in the refining stage of Steel in ladle furnaces.
 - It is very expansive (should never be used in confined layers or stabilized with cement).
 - Used mainly in the cement industry but can also be used for soil stabilization, such as filling material or as filler of a bituminous mix.



Electric Arc Furnace Slag (EAFS)



Ladle Furnace Slag (LFS)

ADMIXTURES

Type of admixture	Water reduction, per cent	Consistence		Setting time		Compressive strength		Air content, per cent
		Slump, per cent	Retention	Initial	Final	Age	per cent	
Set-retarding (equal consistence)	–	100	–	≥ (control + 90 min)	≤ (control + 360 min)	7 day 28 day	≥ 80 ≥ 90	≤ 2 above ¹
Water-resisting (equal consistence or equal water/cement ratio) ⁵	–	–	–	–	–	28 day	≥ 85	≤ 2 above ¹
Set-retarding/water-reducing/plasticizing (equal consistence)	≥ 5	100	–	≥ (control + 90 min)	≤ (control + 360 min)	28 day	≥ 100	≤ 2 above ¹
Set-retarding/high range water-reducing/ superplasticizing (equal consistence)	≥ 12	100	–	≥ (control + 90 min)	≤ (control + 360 min)	7 day 28 day	≥ 100 ≥ 115	≤ 2 above ¹
Set-retarding/high range water-reducing/ superplasticizing (equal water/cement ratio)	–	≥ 100	60 min	–	–	28 day	≥ 90	≤ 2 above ¹
Set-accelerating/ water-reducing/plasticizing (equal consistence)	≥ 5	100	–	At 20 °C, ≥ 30 min At 5 °C, ≤ 60% control	–	28 day	≥ 100	≤ 2 above ¹

ADMIXTURES

Accelerators

Admixtures that accelerate concrete hardening and early-strength. They should however have NO effects on setting time (even though they have in the practice).

Most common: calcium chloride (CaCl_2) affects concrete early strength. Used at LOW-TEMPERATURE CONCRETING. For 1% of CaCl_2 the increase in heat of hydration is 6°C . Generally used at 1-2%. Generally used in aqueous solution. Overdose: flash set.

Pros: acceleration of strength gain; better abrasion resistance.

Cons: lower freeze/thaw strength; lower sulfate resistance; lower resistance to AAR; increase shrinkage and creep; increase in Cl concentration (potential corrosion).

Quick-setting accelerators also exist (e.g. sodium carbonate → promotes flash set in shotcrete; aluminum chloride; potassium carbonate; sodium fluoride; sodium aluminate; ferritic salts).

ADMIXTURES

Water-reducers (plasticizers)

Admixtures used for 3 purposes:

- achieve **higher strength concretes** with lower w/c ratios and maintaining the same workability;
- achieve the same workability lowering the cement dosage, to **reduce the heat of hydration**;
- to **increase workability** to place concrete in highly reinforced elements or in inaccessible places.

Principal active components: surface-active agents which are concentrated at the interface between two phases, altering physic-chemical forces between them. ➔ Great particles mobility, water becomes available to lubricate the mix. Generally acts only on slump (but not on the cohesiveness of the mix!)

Overall reduction of water required: between 5 and 15%

ADMIXTURES

Water-reducers (plasticizers)

Hydroxylated carboxylic acid: increase bleeding in high-strength concretes.

Lignosulphonic acid: improve also cohesiveness, allows entrain air.

Problem: often, the loss of workability in time is higher than in free-admixtures concretes.

Pros: higher strength both at early age and long term. Durability improves.

Superplasticizers

Known also as high range water reducing admixtures, they are more recent and efficient WRAs. Used at higher dosages, with less potential negative effects. Used for high-strength and ultra-high strength concretes and to realize SCCs. It allows reducing water content by 25-35%.

Sulfonated melamine formaldehyde condensates

Sulfonated naphthalene formaldehyde condensates (most effective)

ADMIXTURES

Superplasticizers

It allows increasing slump from 75 mm to 200 mm, reaching flow of 500 – 600 mm.

It works well without causing any bleeding, particularly when sand content is increased by 4-5%.

Its effects is short (about 30 - 90 min) and after workability loss is high.

It is fundamental to use it before placement, as the last addition of the mix, and ALWAYS a re-mixing of about 2 mins is NECESSARY. Never add in more times or it will cause segregation.

Pay attention when use in combination with other admixtures, mainly air-entrainer.

Disadvantage: COSTS!

ADMIXTURES

Air-entrainers

They cause small **stable bubbles of air to form uniformly** through a concrete mix. The bubbles are mostly below 1 mm diameter with a high proportion below 0.3 mm.

The benefits of entraining air in the concrete include increased resistance to freeze-thaw degradation, increased cohesion (resulting in less bleed and segregation) and improved compaction in low-workability mixes.

Care should be used: For every 1% of additional air entrained, concrete strength will fall by around 5%.

Air-reducers

Recommended for high strength concrete and grouts, and for high density concrete. It can also be used to counteract the air entrainment caused by water reducers and plasticizers.

ADMIXTURES

Fillers, supplementary cementing materials, gas foaming, bonding admixtures, etc. are types of additives.

Fillers: they can enhance Portland cement hydration acting as nucleation sites (e.g. fly ash, TiO_2 -rich ashes). Additional, CaCO_3 particles will be incorporated into CSH phase, having a beneficial effect on the hydrated cement paste. They have a physical effect, and hence they should be inert.

Gas-foaming: powdered zinc or aluminum produce hydrogen in the presence of alkalis of calcium hydroxide. Used to produce **aerated-concrete**.

Bonding admixtures: polymer emulsions improving fresh concrete adherence to hardened concrete (repair work). Known as **Latex-Modified Concrete**.

Water-proofing: make concrete hydrophobic (with stearic acid, or some fats)

Anti-bacterial admixtures: if environmental conditions require its use.

FIBERS

Mainly used in Fiber Reinforced Concrete (FRC).

Fibers of various shapes and sizes produced from steel, plastic, glass, and natural materials are being used. For most structural and nonstructural purposes, **steel fiber** is the most commonly used of all the fibers.



FIBERS

Generally used to improve concrete tensile strength and toughness.

They are characterized by the aspect ratio: $L/d = 50-100$ (for steel, ranges between 30 to 150). Maximum allowable rate: 2% by volume.

Polymeric and synthetic fibers alter the energy absorption properties of the composites significantly. Uniform fiber distribution at various size scales improves composite.

Small microfibers stabilize the microcracks and increase the strength reducing the porosity of the cement paste as well increases the strength.



ICEA

QUESTIONS?