IBCI BUILDING CONTROL CONFERENCE 2017

QUALITY CONTROL IN AGGREGATES/CONCRETE/CEMENT

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Quality Control of Aggregates

DEFINITION & TYPES

- Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel, crushed stone, slag, recycled concrete and geosynthetic aggregates.

- Naturally occurring aggregates (aggs) from rock and gravel deposits would be most common in Ireland.

- Recycled concrete/manufactured aggs (Lytag)/Lightweight aggs (Pumice) are less common – would account for very small % of total aggs used in construction in Ireland.
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COMMON TYPES OF NATURAL AGGS IN IRELAND

- Limestone – construction fill, bituminous mixtures & concrete
- Sandstone – concrete(fines agg) & decorative
- Mudstone – cement manufacture, brick
- Basalt - construction fill, bituminous mixtures & concrete
- Granite - decorative
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- Swanlinbar Limestone quarry (Co. Cavan)
- Crushed rock
- Used for Cement manufacture, unbound materials, coarse and fine (CRF) aggregates for concrete
- Blasting - Crushing - Screening processes involved to produce aggregates and a further washing process for aggregates for concrete
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- Derrylin Gravel Pit (Co. Fermanagh)
- Mixture of fine and coarse sandstone aggregate
- Fine aggregate for concrete. Coarse aggregate for decorative uses and reprocessed to produce fine aggregate
- Excavation – Screening & Washing – Milling – Cyclones
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AGGREGATE STANDARDS

- Aggregate Applications & Standards
- Aggregates for unbound & hydraulically bound materials
  - SR 21:2014
- Aggregates for Concrete
  - SR16:2016
- Aggregates for Bituminous Mixtures
  - IS EN 13043:2002
  - SR17:2004
- Aggregates for Mortar
  - IS EN 13139:2002
  - SR18:2006
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AGGREGATES FOR UNBOUND AND HYDRAULICALLY BOUND APPLICATIONS

Aggregates for unbound & hydraulically bound materials
SR21:2014
NATIONAL ANNEX

SR21 Annex A
Pipe bedding, haunching, surrounding material
NRA SHW Series 500

SR21 Annex B
Backfilling filter drains
NRA SHW Series 500

SR21 Annex C
General Fill
NRA SHW Series 600

SR21 Annex D
Unbound sub bases for road pavements
NRA SHW Series 800

SR21 Annex E
Unbound granular fill(hardcore) for use under concrete floors and footpaths
NRA SHW Series 800

SR21 Annex F
Cement bound materials
NRA SHW Series 800
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AGGREGATES FOR CONCRETE

Aggregates for Concrete
SR16 NATIONAL ANNEX

IS EN 206:2013
Concrete, specification, performance.....
NA IS EN 206

IS EN 771-3:2011
Aggregate Masonry Units

IS EN 1168:2005
Hollowcore slabs

IS EN 14843:2007
Concrete Stairs

IS EN 13225:2013
Linear Structural Elements

IS EN 12737:2004
Cattle Slats

IS EN 12794:2005
Foundation Piles

IS EN 490:2011
Concrete Roofing Tiles
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QUALITY CONTROL, CERTIFICATION, FPC & CE MARKING

- Quality control is a system of maintaining standards in manufactured products by testing a sample of the output against the specification. It is normally an integral part of any certification scheme.

- Various types of certification from product quality to management systems.

- Examples of Product Quality certification: BSI Kitemark, BBA, IAB certificates.

- Examples of system certification are: ISO 9001, ISO 14001, FPC
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What is Factory Production Control (FPC) & CE marking?

- FPC covers the procedures which are put in place to allow a manufacturer to maintain consistency in quality and to keep records of non-conforming products, processes or materials, in order to make improvements.

- Any product manufactured to the requirements of a harmonised European standard (hEN) and placed on the market as such is subject to FPC and CE marking. These requirements are outlined in a number of annexes within that standard. FPC is the first stage of CE marking.

- Products may have both FPC/CE and additional product quality certification. The FPC/CE is mandatory whereas the product quality is ‘voluntary’.

- As part of CE marking the manufacturer must produce and make available a Declaration of Performance (DoP). The DoP declares that the product complies with essential requirements.

- While all products manufactured to hEN’s must have FPC, produce a DoP and affix a CE mark to their product, they may have different levels of ‘Attestation and verification of constancy of performance’ – AVCP.

- AVCP 2+ - requires notified body

- AVCP – self certification
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Why do some products require a notified body and others not?

- Depends upon how critical/important it is within its intended uses. Eg. structural elements such as blocks, hollowcore etc require a 2+ system.
- Concrete roofing tiles is system 4.
- Each product standard will identify the system required.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Conformity attestation EU numbering system</th>
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<tr>
<td></td>
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<tr>
<td>Further testing of samples taken at a factory according to a prescribed test plan</td>
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<td>Initial type testing</td>
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<td>Surveillance of factory production control</td>
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</table>

![CE Mark Certification Image]
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QUALITY CONTROL OF AGGREGATES FOR UNBOUND & HYDRAULICALLY BOUND MATERIALS

- IS EN 13242 – Sections 4 to 7 outline all testing required. Basis of Quality Control in aggs for unbound and hydraulically bound material.......

- Annex C outlines the requirements for FPC and in this are Tables C1 and C2 which states the minimum test frequencies for all tests required

- SR 21 is the Standard Recommendation document/National Guidance which outlines what the specific requirements in Ireland: Nationally defined parameters

- Unlike the UK, SR21 has more onerous requirements of the aggregates for particular end use applications – specifically that outlined in Annex E of SR21 for material beneath concrete pavements and footpaths which requires a 2+ system whereas other materials and in the UK this is system 4

- Chemical testing increased from twice yearly to quarterly

- Limiting values for various tests such as LA have been improved
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**Why we use a 2+ system – brief history/sequence of events?**

- Initially SR21 was issued in 2007 in the wake of the pyrite problem

- Annex E at that time had a recommended material which increased the amount of chemical testing however it was low in fines content which would not readily compact and this could lend itself to problems encountered with expansion if expansion were to occur

- Instead engineers were specifying clause 804 material (NRA SHW) with chemical requirements to Annex E

- NRA developed 2 new clauses: Cl 808 material < 500mm of concrete and Cl 809 material < 500mm of steel

- Many specifiers started using Cl 808 material with Annex E chemical requirements

- NSAI Aggregate panel reviewed SR21 Annex E – wanted to produce a Super SR document which include aggs for concrete, bituminous materials, mortar etc

- Opted to keep these separate as they did not want to dilute the message being delivered by SR21 and especially Annex E. Recent withdrawal of FPC certs and replacement with certs highlighting the standard only so all I.S.EN13242 SR21 materials achieve 2+ and not just Annex E...............because material from same source subject to same level of testing
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QUALITY CONTROL OF AGGREGATES FOR UNBOUND & HYDRAULICALLY BOUND MATERIALS

Irish Concrete Federation SR 21 Guidance document available

How has Quality Control improved?(Product)

- Role of Competent Professional Geologist enshrined into resource and product certification – minimum assessment every 3 years

- Annex E sets out higher testing frequencies than normal – Professional Geologist can relax or increase the level of testing - cannot relax below minimum criteria for FPC compliance

- Key improvement is non-argillaceous requirement (10% mudrock maximum), supported by tightening of most other durability parameters

- Other durability characteristics tightened, e.g. LA value down to 30(40), water absorption max 2%, or declarations required, e.g. magnesium sulfate value to be declared

- Stockpile control important – identification, testing on finished stockpiles at required frequency
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Quality Control of Aggregates

**IMPROVEMENTS IN PRODUCT PROCUREMENT, TRACEABILITY..........**

*Irish Concrete Federation IS 888 Guidance document available*

- IS888:2016 – Code of Practice for the procurement and use of unbound granular fill (hardcore) material for use under concrete floors and footpaths

- Not yet referenced in the Building Regs – will be included in TGD C review 2016/17

- Published for first time in 2016 - ‘Weighbridge to placement’ management and traceability for hardcore under concrete and footpaths

- Assigns responsibility to the different contracting parties – important when disputes arise and will be relied upon by suppliers

- The product must be ordered correctly and site management control practices in place until placement

- IS888 Annex A sets out responsibilities of the contracting parties - attention to detail is required to identify any issues with respect to the right material being ordered and properly recorded, delivered and managed thereafter

- Requires more formal ordering arrangements – written procedure required for ordering material - Promotes pre-approval of materials prior to ordering. Different scenarios examined e.g: Builder orders directly from Manufacturer, intermediary.....
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IS 888:2016 CODE OF PRACTICE FOR PROCUREMENT OF UNBOUND MATERIAL FOR USE UNDER CONCRETE

Method statement to be compiled by builder to include

- Pre approval of materials
- Arrangements for documenting
- Arrangements for recording
- Appointment of designated person to manage and ensure implementation of this

PUTS A LOT OF RESPONSIBILITY ON THE BUILDER!!

Irish Concrete Federation SR 16 Guidance document available

- Requirements similar to that of IS EN 13242:2002 in relation to the geometrical, physical and chemical testing and is the basis for quality control in aggs for concrete. In house testing, Testing out sourced, Professional geologist………..list

- Within current TGD A(Structure) section 1.1.5.2 it is stipulated that aggs for readymix concrete must comply with IS EN 12620 & SR16

- Current issue(2016) calls up an AVCP System 2+ for FPC/CE marking but ONLY for aggs being placed for sale in marketplace. Not a requirement for a readymix supplier using their own aggs

- Is likely that all producers of concrete aggs will have a 2+ system in place eventually

- Deadline for having 2+ system in place is January 2018

- The inclusion and role of a professional geologist is again a significant change to previous requirements

- Increased test frequency for total sulfur and acid soluble sulfate from annually to twice yearly
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- Annex A outlines general requirements for aggs for concrete

<table>
<thead>
<tr>
<th>Property</th>
<th>IS EN 206 Exposure Classes</th>
<th>Values/Categories</th>
<th>Test method</th>
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<tbody>
<tr>
<td>Resistance to freeze/thaw - Magnesium sulfate value</td>
<td>XF 3</td>
<td>MS_{3a}</td>
<td>I.S. EN 1367-2</td>
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<tr>
<td></td>
<td>XF 4</td>
<td>MS_{3b}</td>
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</table>

- Annex B gives details of requirements for more specialist applications

Table B.4 — Concrete subject to freeze/thaw attack

Table B.5 — Masonry units’ subject to freeze/thaw attack
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EN 771-3:2011 Specification for Aggregate Concrete Masonry Units with additional requirements (national parameters) on foot of TGD A, EC6 and SR325

- For dense aggregate concrete blocks – only aggregates complying to IS EN 12620 and SR16 permitted

- In Ireland Category 1 blocks - declared mean compressive strength with a probability of failure not exceeding 5% and requires AVCP 2+ system for FPC/CE

- Compressive strength of blocks to be tested in accordance with IS EN 772-1:2011. Conditioned as air dry and tested with mortar capping…….change from IS20……now strength class for standard blocks 7.5N and not 5N

- As well as having certification with a notified body such as NSAI, BSI etc, statistical analysis of concrete strengths is required. GNB-PDP position paper from SG10 – evaluation of conformity for masonry units

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<th>Sample Identity</th>
<th>Date Manufacture</th>
<th>Sampling Date</th>
<th>Test Date</th>
<th>Age at test</th>
<th>Type</th>
<th>Cement Content (Kg)</th>
<th>Condition</th>
<th>Length (mm)</th>
<th>width (mm)</th>
<th>Height (mm)</th>
<th>Mass (Kg)</th>
<th>Density (Kg/m³)</th>
<th>Compressive Strength (N/mm²) Fibreboard</th>
<th>Compressive Strength (N/mm²) Capped</th>
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<th>x̄</th>
<th>sx</th>
<th>K1u</th>
<th>Kc</th>
<th>K1k</th>
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</table>

Fractile P(%) 50
Confidence y(%) 95
Inspection lots 1 15
Start Correction 30
End Correction 60
Declared Value(N/mm²) 7.5
Analysis Type Rolling Inspection, Progressive Sampling (Example 6 Page 56 on Guidance Document)
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Revisions of standards has brought about:

- More intense testing regimes hopefully resulting in improved confidence in product quality
- System to improve practices of procurement, delivery, handling.....
- Traceability & Accountability
- Professional Quarry Industry has being behind making these standards consistent and being implemented
- Irish Concrete Federation - http://www.irishconcrete.ie
- Irish Concrete Society – Concrete Ticket Course - http://concreteticket.ie/

The Concrete Ticket is a course that provides education and guidance on the correct handling, finishing, curing, ordering and delivery of ready-mixed concrete for construction. It also provides essential information on the properties of the material. If successful in the test you will receive a photo based card which is valid for 5 years.

Forthcoming events:

- Kilkenny 19th April
- Limerick 3rd May
- Dublin 18th May
- Cork 31st May
- Monaghan June
- Dublin June
Quality control in cement
Overview

• What is cement?
• Raw materials
• Production process
• Final product
• Which cement to use?
• Accreditations
What is cement?

- Active ingredient in concrete
- Hydraulic cements harden when mixed with water
- The “glue” that holds aggregates together in concrete

Basic chemical components in Portland cement
- Calcium oxide \( \text{CaO} \)
- Silica \( \text{SiO}_2 \)
- Alumina \( \text{Al}_2\text{O}_3 \)
- Iron \( \text{Fe}_2\text{O}_3 \)
Raw materials

- Major constituents:
  - Limestone
  - Shales
  - Clays

- Chemical analysis of the raw materials and fuels

- Proportioning of raw materials based on analysis

- Minor constituents:
  - Gypsum
  - Limestone fines
  - PFA
Production process

• Fine grinding and mixing of raw materials to produce the **raw meal**
• High temperature calcination in the kiln at ~ 1450°C to produce **clinker**
• Kiln bypass system for removal of undesirable content
• Cooling, milling, and mixing of the clinker with gypsum and/or limestone to produce **cement**
Clinker

- **EN 197**: Cement (specification and standard for cement)
- **EN 196**: Methods of testing cement
- Continuous sampling and testing of cement in robotic auto-lab
- Chemical composition by X-ray fluorescence **EN 196-2**
- Various control parameters, e.g.
  - Lime saturation factor
  - Silica ratio
  - Alumina ratio
  - Bogue equations
Cement

Physical testing

- Compressive strength  EN 196-1
- Setting time  EN 196-3
- Soundness  EN 196-3
- Specific surface area  EN 196-6
## CEMENT CERTIFICATE

**Portland Cement (Class S2,SN)**

**ISSUE DATE:** 20th March 2017

### PHYSICAL & CHEMICAL TESTING INFORMATION

<table>
<thead>
<tr>
<th>Date of Despatch</th>
<th>Compressive Strength (N/mm²) (Mortar Prisms)</th>
<th>Specific Surface (M²/kg)</th>
<th>Setting Time (Min)</th>
<th>Soundness (mm)</th>
<th>Certified Average Magnesia (%)</th>
<th>Chlorides (%)</th>
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<td>144</td>
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<td>142</td>
<td>0.5</td>
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This certificate is based on cement manufactured by Quinn Cement, and tested in accordance with EN 196: 2005.
Final product

- Product types:
  - Bulk cement
  - Bagged cement

- Cement types according to EN 197-1: Composition, specifications and conformity criteria for common cements
  - CEM I 95 - 100% clinker 0 – 5% other
  - CEM II A-L 80 – 94% clinker 6 – 20% limestone
### Table NA.2 — Cements for which specific suitability is established

<table>
<thead>
<tr>
<th>Designation in I.S. EN 197-1</th>
<th>Description</th>
<th>Composition (percentage by mass)</th>
<th>Minor additional constituents</th>
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<tr>
<td></td>
<td></td>
<td>Clinker</td>
<td>Blastfurnace slag</td>
</tr>
<tr>
<td></td>
<td></td>
<td>K</td>
<td>S</td>
</tr>
<tr>
<td>CEM I</td>
<td>Portland cement</td>
<td>95-100</td>
<td></td>
</tr>
<tr>
<td>CEM II/A-L</td>
<td>Portland-limestone cement</td>
<td>80-94</td>
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<tr>
<td>CEM II/A-LL</td>
<td>Portland-limestone cement</td>
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<tr>
<td>CEM II/A-S</td>
<td>Portland-slag cement</td>
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<tr>
<td>CEM II/A-V</td>
<td>Portland-fly ash cement</td>
<td>80-94</td>
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**NOTE 1** See subclause NA.2.7 for advice on use of these cements with additions.

**NOTE 2** The slag content of the combination of a cement and addition must not exceed 70%.
Which cement to use?

**Depends on concrete specification**

- Application
- Environment
- Exposure class
- Depth of concrete element (thermal cracking)
- Location and availability
NOTE 3: All cements and combinations (see sub clauses NA.2.2 and 2.7) may be used, but for the wearing surface of concrete pavements, cements or combinations containing more than 50 % GGBS or more than 31 % pfa may not be suitable due to the possibility of surface scaling. The limit of 50 % GGBS may be increased to 65 % if CEM I is used.

Table NA.6 — Recommended limiting values for freeze thaw exposure classes

<table>
<thead>
<tr>
<th>Exposure Class</th>
<th>Min. Strength Class</th>
<th>Max. W/C Ratio</th>
<th>Min. air content and min. cement content for 20 mm max aggregate size (see NOTE 2)</th>
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<td>XF1 (see NOTE 1)</td>
<td>C25/30</td>
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<td>3.5, 300</td>
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<td>C28/35</td>
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<td>XF2</td>
<td>C30/37</td>
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<td>3.5, 320</td>
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<td>C35/45</td>
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<td>-</td>
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<td></td>
<td>C40/50</td>
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Accreditations

- **CE conformity marked (1+ system) - NSAI**

<table>
<thead>
<tr>
<th>System type</th>
<th>Responsibility</th>
<th>Type of notified body</th>
<th>Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>System 1+</td>
<td>Notified Body</td>
<td>Product certification body</td>
<td>Initial inspection of the fpc system, Continuous surveillance of the fpc system, Determination of product type, Audit testing</td>
</tr>
<tr>
<td></td>
<td>Manufacturer</td>
<td></td>
<td>Factory Production Control, Further testing of samples</td>
</tr>
<tr>
<td>System 1</td>
<td>Notified Body</td>
<td>Product certification body</td>
<td>Initial inspection of the fpc system, Continuous surveillance of the fpc system, Determination of product type</td>
</tr>
<tr>
<td></td>
<td>Manufacturer</td>
<td></td>
<td>Factory Production Control, Further testing of samples</td>
</tr>
<tr>
<td>System 2+</td>
<td>Notified Body</td>
<td>Factory production control certification body</td>
<td>Initial inspection of the fpc system, Continuous surveillance of the fpc system</td>
</tr>
<tr>
<td></td>
<td>Manufacturer</td>
<td></td>
<td>Factory production control, Further testing of samples</td>
</tr>
<tr>
<td>System 3</td>
<td>Notified Body</td>
<td>Test laboratory</td>
<td>Determination of product type</td>
</tr>
<tr>
<td></td>
<td>Manufacturer</td>
<td></td>
<td>Factory production control</td>
</tr>
<tr>
<td>System 4</td>
<td>Manufacturer</td>
<td>No independent involvement</td>
<td>Factory production control, Determination of product type</td>
</tr>
</tbody>
</table>
## Accreditations (II)

**Table ZA.3 — Assignment of evaluation of conformity tasks for cement under system 1+**

<table>
<thead>
<tr>
<th>Tasks under the responsibility of the manufacturer</th>
<th>Content of the tasks</th>
<th>Evaluation of conformity clauses to apply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factory production control (FPC)</td>
<td>Parameters related to all characteristics of Table ZA.1* relevant for the intended use</td>
<td>Clause 9 of this standard and EN 197-2:2000, Clause 4</td>
</tr>
<tr>
<td>Further testing of samples taken at factory</td>
<td>All characteristics of Table ZA.1* relevant for the intended use</td>
<td>Clause 9 of this standard and EN 197-2:2000, Clause 4</td>
</tr>
<tr>
<td>Initial type testing</td>
<td>Those characteristics of Table ZA.1* relevant for the intended use</td>
<td>Clause 9 of this standard and EN 197-2:2000, Clauses 5 and 7</td>
</tr>
<tr>
<td>Initial inspection of factory and of FPC</td>
<td>Parameters related to all characteristics of Table ZA.1*, relevant for the intended use</td>
<td>Clause 9 of this standard and EN 197-2:2000, Clauses 5 and 7</td>
</tr>
<tr>
<td>Continuous surveillance, assessment and approval of FPC</td>
<td>Parameters related to all characteristics of Table ZA.1*, relevant for the intended use</td>
<td>Clause 9 of this standard and EN 197-2:2000, Clauses 5 and 7</td>
</tr>
<tr>
<td>Audit testing of samples taken at factory</td>
<td>Those characteristics of Table ZA.1* relevant for the intended use</td>
<td>Clause 9 of this standard and EN 197-2:2000, Clauses 5 and 7</td>
</tr>
</tbody>
</table>

* Except durability.
Accreditations (III)

- ISO 9001 Quality Management Systems - BSI
- ISO 14001 Environmental Management Systems - Certification Europe
- BES 6001 Responsible Sourcing of Construction Products - CPC
- Independent testing and auditing a number of times per year
Quality Control of Aggregates

THANK YOU FOR YOUR ATTENTION