NSAI Standards

Irish Standard
I.S. 465:2018

Assessment, testing and categorisation of damaged buildings incorporating concrete blocks containing certain deleterious materials

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I.S. xxx: Irish Standard – national specification based on the consensus of an expert panel and subject to public consultation.

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Údarás um Chaighdeáin Náisiúnta na hÉireann

DECLARATION

OF

SPECIFICATION

ENTITLED

ASSESSMENT, TESTING AND CATEGORISATION OF DAMAGED BUILDINGS

INCORPORATING CONCRETE BLOCKS

CONTAINING CERTAIN DELETERIOUS MATERIALS

AS

THE IRISH STANDARD SPECIFICATION FOR

ASSESSMENT, TESTING AND CATEGORISATION OF DAMAGED BUILDINGS

INCORPORATING CONCRETE BLOCKS

CONTAINING CERTAIN DELETERIOUS MATERIALS

NSAI in exercise of the power conferred by section 16 (3) of the National Standards Authority of Ireland Act, 1996 (No. 28 of 1996) and with the consent of the Minister for Business, Enterprise and Innovation, hereby declare as follows:

1. This instrument may be cited as the Standard Specification (Assessment, testing and categorisation of damaged buildings incorporating concrete blocks containing certain deleterious materials) Declaration, 2018.

2. (1) The Standard Specification set forth in the Schedule to this declaration is hereby declared to be the Standard Specification for Assessment, testing and categorisation of damaged buildings incorporating concrete blocks containing certain deleterious materials.

(2) The said Standard Specification may be cited as Irish Standard 465:2018 or as I.S. 465:2018.

Contents

Foreword

This Irish Standard was developed by the NSAI Concrete Blocks Committee (NSAI/TC 063).

Arising from the Report of the Expert Panel on Concrete Blocks (June 2017) [1] this Irish Standard has been developed for use by those who intend to provide assessment and testing services for dwellings that are suspected of being affected by defective concrete blocks.

This is the first edition of this Irish Standard.

This Irish Standard is not intended for:

a) the specification, manufacture and testing for compliance of new concrete blocks (aggregate concrete masonry units) in accordance with I.S. EN 771–3 (and associated testing Standards) or as a replacement to the guidance provided in Standard Recommendation S.R. 325; and

b) dwellings not exhibiting structural damage consistent with defective concrete blocks, see Clause 4.

Compliance with this Irish Standard does not of itself confer immunity from legal obligations.

In line with international standards practice the following representation of numbers and numerical values apply:

- The decimal point is shown as a comma (,) throughout this Irish Standard.
- Each group of three digits reading to the left or to the right of a decimal sign are separated by a space from the preceding digits or following digits respectively.

0 Introduction

0.1 General

The Report of the Expert Panel on Concrete Blocks (June 2017) [1], commissioned by the Minister of Housing, Planning and Local Government, to investigate the problems emerging in the concrete blockwork of certain dwellings in County Donegal and County Mayo concluded that “the nature of the problem is manifested primarily by the disintegration of concrete blocks used in construction of affected dwellings in Counties Donegal and Mayo which in turn results in a pattern of cracking in the external render of these dwellings”.

The Expert Panel was of the opinion that “the reason for the widespread pattern cracking in private dwellings in Counties Donegal and Mayo is primarily due to the excessive amount of deleterious materials in the aggregate used to manufacture the concrete blocks. The deleterious material in County Donegal was primarily muscovite mica, while in County Mayo it was primarily reactive pyrite".

Deleterious materials (undesirable constituents [2]) are those constituents of an aggregate that may comprise or include materials which could have an adverse effect on the properties of any concrete into which that aggregate was incorporated. The adverse effects mainly include:

1) chemical interference with the setting of cement;

2) physical prevention of good bond between the aggregate and cement paste;

3) modification of the properties of the fresh concrete to the detriment of the durability or strength of the hardened material;

4) interaction between the cement paste and the aggregate which continues after hardening, sometimes causing expansion and cracking of the concrete; and

5) weakness and poor durability of the aggregate particles themselves.

Concrete blocks manufactured from aggregates containing certain potentially deleterious materials, and subject to substantial ingress of moisture and/or freeze thaw conditions can have reduced strength and durability resulting in disintegration. Concrete masonry which remains in a dry state will not suffer from freeze thaw effects.

0.2 Mica

The minerals muscovite mica and biotite mica are "common constituents of many rock types, including granites, gneisses and sandstones, forming distinctive platy crystals. When mica occurs as discrete (or 'free') flaky grains in fine aggregates, it usually increases the water demand of concrete and also reduces the cohesiveness of the mix, which can adversely affect the final strength and durability of the hardened concrete" [2]. In particular cases, these disadvantageous effects of mica can be adequately compensated by slightly increasing the contents of cement in the mix design or by using an admixture. Excessive quantities of free muscovite mica in aggregate can render the blocks susceptible to freeze thaw degradation when saturated.

0.3 Pyrite

Pyrite, Iron Sulfide (FeS_2), is a naturally occurring mineral commonly found in most rock types. When some forms of pyrite are exposed to moisture and oxygen, a series of chemical reactions can occur. In such conditions, pyrite will oxidise to form sulfuric acid (H_2SO_4) and other products. The acid may in turn react with other minerals found in the aggregate. Calcium sulfate in the form of gypsum ($CaSO_4.2H_2O$)

may be produced when calcium carbonate ($CaCO_3$), commonly known as calcite, is present in the aggregate, typically calcareous mudstones, and is available to react with the sulfuric acid. Gypsum has a significantly greater volume than the original pyrite and calcite, thus the growth of its crystals can cause expansion.

Internal sulfate attack in concrete does not require an external source of sulfate and is caused by the inclusion of materials containing sulfide minerals in the concrete mix. Typically, this can be where non-compliant aggregate with excessive quantities of reactive pyrite is used, which over time may, in unfavourable conditions oxidise to produce sulfate. The degradation of concrete blocks in Mayo appeared to occur from the oxidation of fine pyrite and bulk expansion of the mudstone aggregate. The expansion is caused by the growth of secondary minerals (gypsum) in veinlets parallel with bedding and/or cleavage in the mudstone and the interface between the aggregate and cement.

0.4 Expert panel recommendations

The Report of the Expert Panel on Concrete Blocks [1] made a number of recommendations for the development of technical documents and strengthening of existing regulations. The first of these recommendations was for NSAI to develop a simple standardised protocol to:

(a) assess and categorise the damage;

(b) establish the extent of the problem;

(c) identify the scope of any testing required; and

(d) aid selection of an appropriate remedial solution.

NOTE All concrete blocks currently manufactured in Ireland are required to meet the requirements of I.S. EN 771-3, and the relevant guidance is included in S.R. 325. The aggregate used in the manufacture of these concrete blocks are required to comply with I.S. EN 12620 [3], and the guidance for use in Ireland is in S.R. 16. These standards contain limits which control properties affecting end use performance, along with a requirement for geological and petrographic assessment of the aggregates.

Schedule

Assessment, testing and categorisation of damaged buildings incorporating concrete blocks containing certain deleterious materials

1 Scope

This Irish Standard:

a) establishes a protocol for assessing and determining whether a building has been damaged by concrete blocks containing excessive amounts of certain deleterious materials (aggregate containing free or unbound muscovite mica or potentially deleterious quantities of pyrite);

b) describes methods for establishing the extent of the problem and categorises dwellings;

c) describes the scope of any testing required and evaluation of the findings; and

d) provides the Chartered Engineer with guidance on the selection of appropriate remedial works to be undertaken.

This Irish Standard is not intended for:

a) the specification, manufacture and testing for compliance of new concrete blocks (aggregate concrete masonry units) in accordance with I.S. EN 771-3 (and associated testing Standards) or as a replacement to the guidance provided in Standard Recommendation S.R. 325; and

b) dwellings not exhibiting structural damage consistent with defective concrete blocks, see Clause 4.

The protocol addresses the issue of defective concrete blocks but does not rule out other potential defects in a dwelling which may for other reasons require remedial attention.

The use of this Irish Standard is limited to concrete block-built dwellings exhibiting signs of distress consistent with damage caused by blocks containing certain deleterious materials.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

I.S. EN 197-1, *Cement – Part 1: Composition, specifications and conformity criteria for common cements*

I.S. EN 771-3, *Specification for masonry units – Part 3: Aggregate concrete masonry units (Dense and lightweight aggregates)*

I.S. EN 772-1, *Methods of test for masonry units – Part 1: Determination of compressive strength*

I.S. EN 1744-1:2009+A1:2012, *Tests for chemical properties of aggregates – Part 1: Chemical analysis*

I.S. EN 12504-1, *Testing concrete in structures – Part 1: Cored specimens – Taking, examining and testing in compression*

S.R. 325, *Recommendations for the design of masonry structures in Ireland to Eurocode 6*

BS 1881-124:2015, *Testing concrete – Part 124: Methods for analysis of hardened concrete*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

aggregate(s)
crushed rock or processed sand and gravel materials used for construction purposes

aggregate concrete masonry unit
concrete block masonry unit manufactured from cementitious binder, aggregates, and water and which may contain admixtures and additions and colouring pigments and other materials incorporated or applied during or subsequent to unit manufacture

calcite
mineral, calcium carbonate ($CaCO_3$), which is the main component of limestone

Chartered Engineer
competent and Chartered Engineer, as defined by the Institution of Civil Engineers of Ireland (Charter Amendment) Act, 1969, or an equivalent professional body

Chartered Geotechnical Engineer
person possessing sufficient training, relevant experience, and knowledge appropriate to the nature of the work to be undertaken having regard to the task he/she is required to perform and taking into account the complexity of the work

Note 1 to entry: In the context of this Irish Standard, the competent person will be listed as a Chartered Engineer, Engineers Ireland, or an equivalent professional body, with an established record of a minimum of five years of practical assessment of geological resources, with particular experience in sampling, testing, and assessment of concrete and concrete-making materials.

competent person
person, company, or partnership having sufficient theoretical and practical training, relevant experience, and knowledge appropriate to the nature of the work to be undertaken, having regard to the task he/she is required to perform and taking into account the complexity of the work

damp proof course
DPC
layer of sheeting, masonry units or other material used in masonry to resist the passage of water

deleterious materials
constituents of a proposed aggregate that may comprise or include materials which could have an adverse effect on the properties of any concrete into which that aggregate was incorporated

diffraction peak
peaks in a diffraction pattern obtained from an X-ray Diffraction (XRD) analysis and used in the identification of crystalline substances in a powdered sample being analysed

framboidal pyrite
form of pyrite that typically occurs as loosely packed clusters of very small sized crystals of constituent pyrite microcrystallites < 1 μm in diameter

free muscovite mica
fine monomineralic mica grains which are typically < 63 μm in size

gypsum
hydrated calcium sulfate, $CaSO_4.2H_2O$

limestone
rock made up of mainly calcite, derived from marine invertebrate shells, shell debris, and chemical precipitation of calcium carbonate

lithology
character of a rock in terms of its structure, colour, mineral composition, and grain size, as determined by eye or with a low power magnifier

masonry
assemblage of units jointed with mortar

mica schist
schist primarily composed of mica

mineral
naturally occurring inorganic element or compound, having an orderly internal structure and characteristic chemical composition, crystal form, and physical properties

mudstone
rock formerly composed of normal mud (clay minerals and water), that has been compacted and solidified into solid rock

muscovite mica
potassium aluminium silicate forming in thin sheets

oxidation
chemical process involving a reaction(s) resulting in the loss of electrons, or an increase in oxidation state, by a molecule, atom, or ion

petrographic analysis
detailed examination and description of rocks using specialised microscopes, rock thin sections, and other techniques such as electron microscopy, undertaken by a competent Petrographer

Petrographer
person possessing sufficient training, relevant experience, and knowledge in petrographic analysis

Note 1 to entry: In the context of this Irish Standard, the Petrographer shall have five years of documented equivalent experience in the application of petrographic analysis to evaluations of concrete-making materials and concrete products in which they are used and in cementitious-based materials.

phyllite
low to medium grade metamorphosed mudstone/shale

Professional Geologist
person possessing sufficient training, relevant experience, and knowledge appropriate to the nature of the work to be undertaken, having regard to the task he/she is required to perform, and taking into account the complexity of the work

Note 1 to entry: In the context of this Irish Standard, the competent person (Professional Geologist) is a Professional Member of the Institute of Geologists of Ireland, or an equivalent professional body, with an established record of a minimum of five years of practical assessment of geological resources, with particular experience relating to the sampling, testing and assessment of recovered petrographic samples of concrete and concrete-making materials.

pyritic heave
upward pressure to constructed works (including floor slabs) and lateral pressure to the rising walls in buildings, resulting specifically from swelling of hardcore initiated by oxidation of reactive pyrite

render
mix of one or more inorganic and/or organic binders, aggregates, water and sometimes admixtures and/or additions used for protective and/or decorative reasons to obtain a surface finish which is applied to walls and ceilings

reactive pyrite
pyrite in a form that is readily oxidised

Rietveld analysis
semi-quantitative analysis technique utilised to interpret data derived from an XRD analysis

schist
medium grade metamorphic rock medium grained strongly foliated with and readily split into flakes or slabs due to the preferred orientation of the majority of minerals

Scanning Electron Microscope
SEM
method that examines and analyses the physical information (such as secondary electron, backscattered electron, absorbed electron and X-ray radiation) obtained by generating electron beams and scanning the surface of the sample in order to determine the structure, composition, and topography of the sample

sound
showing no, or only rare evidence of deterioration

sulfate
oxidised form of sulfur in which the sulfur atom is surrounded by four oxygen atoms

sulfide
compound of sulfur and another element

thin section
thin slice of rock, about 30 μm thick, mounted on a glass slide for microscopic inspection

total sulfur
sum of all sulfur species in a solid material, including sulfide and sulfate

unsound
lacking physical coherence and/or showing common or abundant evidence of matrix deterioration, also concrete too deteriorated to be sampled intact

X-ray Diffraction
XRD
non-destructive analysis technique that uses the diffraction pattern of X-rays projected at a powdered sample to obtain information on the structure of the crystal or the identity of a crystalline substance

4 The protocol

4.1 General

The overall aim of the protocol is to guide investigation and diagnosis of damage due to defective concrete blocks, enabling the categorisation of buildings, in accordance with this Irish Standard, providing Chartered Engineers with guidance on the selection of the appropriate remedial works to be taken.

The process to be followed in assessment, sampling and testing is outlined in Figure 1 and detailed in the relevant clauses covering each stage of the process.

4.2 Symptoms

In a dwelling which is exhibiting structural damage manifesting as a particular pattern of external wall cracks and where defective concrete blocks are suspected, a Chartered Engineer should visually inspect and report on the dwelling, recording cracking present (externally and internally), as described in Clause 5 and Figure 2.

The particular external wall crack pattern includes cracks (above the damp proof course (DPC)) on combined horizontal and vertical and/or significant vertical cracks near wall ends. They are often accompanied by bulging render, change of profile on either side of cracks and displacement of the wall relative to window/door frames, see Figure 2.

4.3 Investigation

Potential causes of cracking [4] other than deleterious materials [5] should be considered, including but not limited to, defective design, workmanship, other defective materials and lack of maintenance or up keep. Examples of other causes of cracking include foundation settlement [6] inadequate movement joints, shrinkage, defective render (quality, thickness, and type), failure of wall ties, inappropriate insulation systems, sub-floor pyritic heave [7], etc.

The Chartered Engineer should, after completing the Building Condition Assessment, provide an opinion as to the suspected or likely cause(s) of cracking. If the defects recorded are suspected or likely due to defective concrete blocks, then the Chartered Engineer should assign the damage to a Group as set out in Clause 5. If the defects noted are not consistent with defective concrete blocks, but are likely due to other potential causes, then the Chartered Engineer should recommend that the owner pursue appropriate investigations which are outside the scope of this Irish Standard.

Clause 6 sets out the recommended sampling procedure with guidance on the minimum number of samples required and the most suitable sampling locations.

For multi-unit dwellings (MUDS) it is preferable that the building be assessed as a whole and the Chartered Engineer's report should cover the entire building that is made accessible for inspection.

4.4 Testing

Clause 7 sets out the appropriate testing required based on the Building Grouping (see 5.3) assigned by the Chartered Engineer. Petrographic assessment and/or physical or chemical tests should be used to establish whether the problem arises from potentially defective aggregate. Defective aggregate may contain deleterious materials such as sulfides (reactive pyrite), or excessive free muscovite mica, or a combination of both.

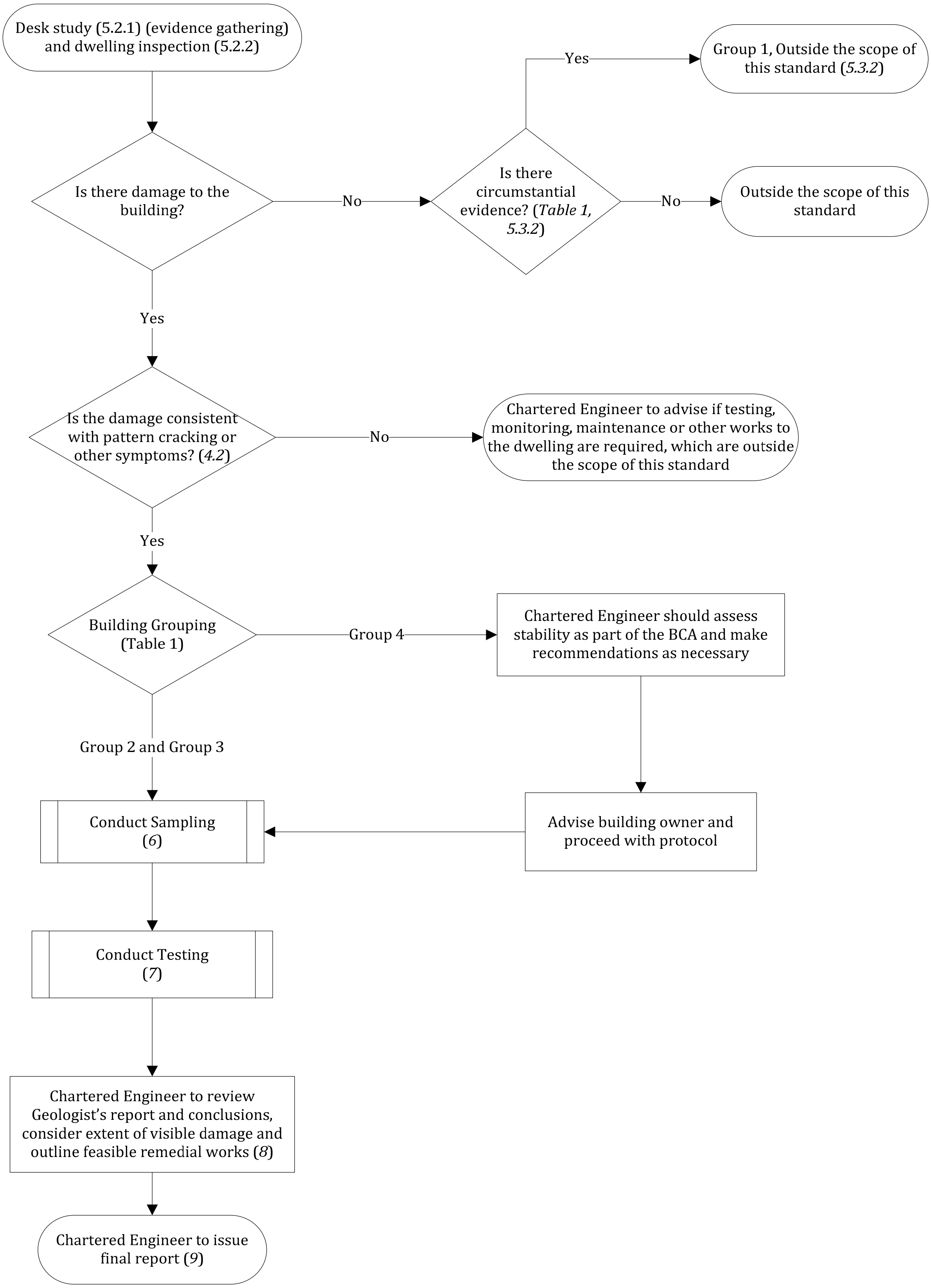
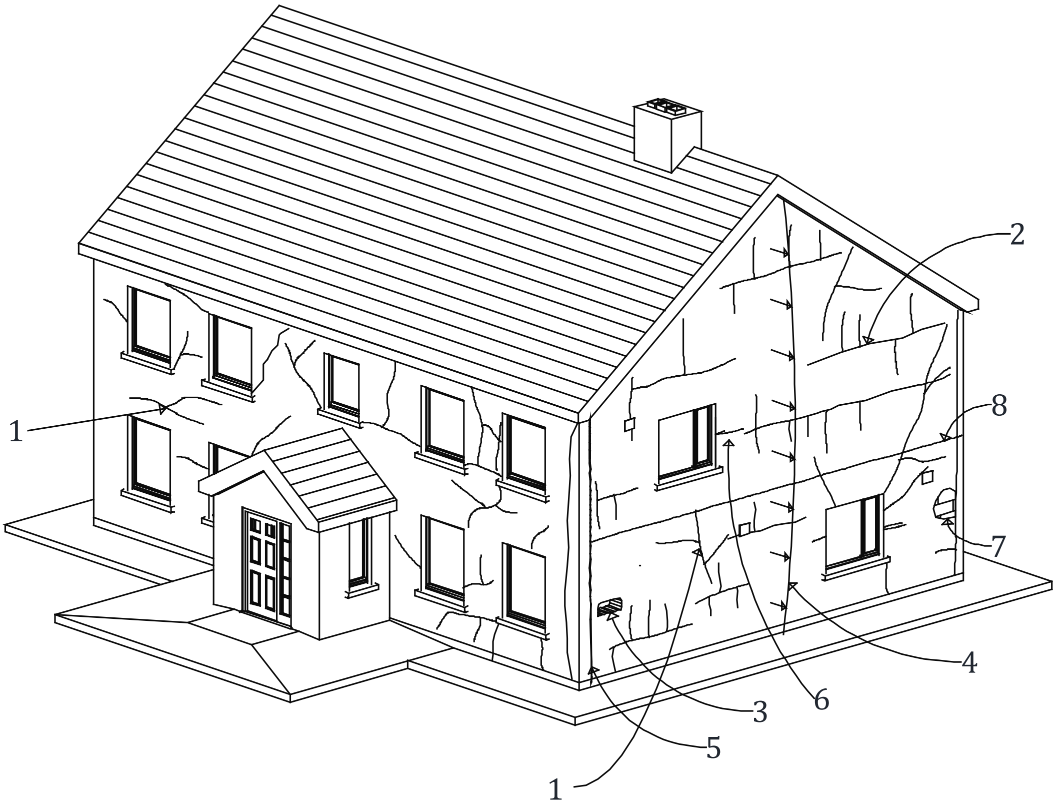


Figure 1 — Process flow for application of Standard



Key

1 Web like cracking
2 Pattern like cracking (combined horizontal and vertical)
3 Disintegrated blocks leaving void in external leaf
4 Outward bowing of external leaf
5 Wide vertical crack, typically 200 mm from corner
6 Displacement at window/door reveals
7 Render blown or missing
8 Horizontal cracks (possibly attributable to day joint in blockwork)

Refer to the Report of the Expert Panel on Concrete Blocks [1] for examples of the typical defects encountered.

Figure 2 — Typical defects encountered

4.5 Remedial works

Taking account of the Building Condition Assessment and the test results, the Chartered Engineer should outline remedial options guided by the recommendations in Clause 8.

This protocol addresses the issue of defective concrete blocks but does not rule out other potential defects in a dwelling which may for other reasons require remedial attention.

5 Building Condition Assessment

5.1 General

The Building Condition Assessment shall be carried out by a Chartered Engineer and shall comprise of a desk study and a dwelling inspection composed of a non-invasive external and an internal visual inspection of the dwelling.

The purpose of the desk study is to obtain relevant information, prior to the dwelling inspection.

The purpose of the dwelling inspection is to determine the presence or absence of apparent damage, that is consistent with defective blocks, and to record the extent and significance of such damage. As noted in 4.3 the possibility of alternative probable causes should be given due consideration.

5.2 Procedure

5.2.1 Desk study

The desk study shall be carried out by a competent person taking into consideration the following:

— history of known occurrences of similar damage in local area or estate;

— information on the design and construction of the dwelling, including location of services e.g. utility services (water, electricity, gas, sewage);

— information on the geographical location, including wind driven rain exposure from S.R. 325, etc.;

— review of the initial planning and certification documentation (where available and if deemed relevant);

— outline construction details of the building, from the dwelling owner/proprietor (where available); and

— the form of construction and common defects which may arise there from.

The above information should be recorded on the Building Condition Assessment Report Form. An example template of the form is provided in Annex A.

5.2.2 Dwelling inspection

Following the completion of the desk study, a dwelling inspection shall be carried out by a Chartered Engineer and documented (see Annex A). The dwelling inspection requires the Chartered Engineer to familiarise themselves with the overall site and consider other potential causes of the cracking identified, see 4.3.

As a minimum, the dwelling inspection report shall include:

a) details of the general site features e.g. location, exposure, slopes, trees, watercourses, orientation, etc.;

b) any apparent similar damage in local area or estate;

c) a description of the form of construction of the dwelling (e.g. cavity wall construction), noting the following:

  — rendering;

  — painted;

  — insulation arrangement if known;

  — approximate date of construction (year);

  — date (year) when cracking was first noted;

— movement joints; and

— workmanship, if notably less than standard;

d) information in chronological order, on any building damage issues that may have arisen, including any repair work, where such information is available;

e) an inspection of the exterior and interior of the dwelling for evidence of damage consistent with defective concrete blocks such as:

— pattern cracking of external walls above the DPC, see Figure 2;

— lateral movement (displacement) of external walls;

— wall displacement around window/door frames;

— wide vertical cracks at corners; and

— cracking and/or bulging of internal or external walls;

f) an inspection of each room internally, locating and describing cracks in walls etc; and

g) the location and number of samples to be taken for testing (see 6.2).

Chartered Engineers should use a suitable spirit level to measure bulges in walls and a suitable 'crack width gauge' to measure crack widths. It is not necessary to record all crack widths, but significant cracks should be measured at their maximum width and noted, including viewing distance and weather conditions at the time of inspection.

Cracks and damage visible, both externally and internally (insofar as possible) of the dwelling, shall be noted on sketches, dated photographs and documents. Cracks which are consistent with damage caused by defective concrete blocks shall be identified. Chartered Engineers should also record other visible blockwork damage arising from other structural defects and include them in the interim report (see Annex A).

The condition of the face of all elevations which are to be sampled, (including the rising wall) shall be recorded and photographed by the Chartered Engineer (see Clause 6).

Where the Chartered Engineer has concerns regarding lack of structural stability (local or otherwise) in the dwelling he/she should assign the building to Group 4, see Table 1, and advise the owner of any necessary immediate actions.

5.3 Building Grouping

5.3.1 General

The Chartered Engineer should, after completing the Building Condition Assessment as detailed in 5.2, assign the dwelling into one of the Groups detailed in Table 1. The aim of the Grouping is to assist the Professional Geologist, in consultation with the Chartered Engineer, in selecting the appropriate Test Suite (see Clause 7).

Table 1 — Building Grouping

Group	Damage	Building Condition Assessment
Group 1	Undamaged	Pattern cracking is not present, however some or all the circumstantial evidence [a] is recorded in the Chartered Engineer's Report
Group 2	Damaged	Pattern cracking is present in at least one elevation (but insufficient evidence of other damage to classify the building as Group 4, see Group 4, a) to e)), and no circumstantial evidence [a] is recorded in the Chartered Engineer's Report
Group 3	Damaged	Pattern cracking is present in at least one elevation (but insufficient evidence of other damage to classify the building as Group 4, see Group 4, a) to e)), and some or all the circumstantial evidence [a] is recorded in the Chartered Engineer's Report
Group 4	Significantly damaged	Pattern cracking on at least one elevation, and at least two of the following further items of damage present on same or adjacent elevation: a) vertical cracks near corners > 5 mm in width; b) crumbling concrete blocks; c) severe displacement of reveals with cracking; d) wall leaning or bulging noticeably i.e. local deviation of slope in the horizontal or vertical plane of external walls of > 1 in 100 [4], and e) cracking of widths > 1 mm on internal leaf where damage is also present on the corresponding external leaf (Figure 2), or multiple cracks of concrete masonry walls in one room of > 0,5 mm. Where circumstantial evidence is available it shall be recorded in the Chartered Engineer's Report.

[a] Circumstantial evidence (risk factors) suggesting the possible presence of deleterious materials in concrete blocks includes:

- information that blocks came from manufacturer(s) reported to have supplied blocks to other damaged dwellings likely to have arisen from deleterious material in concrete blocks,
- construction within the date range of constructions mentioned in the Report of the Expert Panel on Concrete Blocks [1], and in the geographic areas reported to be affected; and
- documented information (e.g. Chartered Engineer's Report) that other dwellings in the same estate or locale have exhibited signs of damage likely to have arisen from deleterious material in concrete blocks.

5.3.2 Group 1 dwellings

Group 1 dwellings are outside the scope of this Irish Standard. However, the process outlined in this Irish Standard may be used for assessing these dwellings.

5.4 Interim reporting

The Chartered Engineer should issue an interim report on the results of the Building Condition Assessment and make recommendations for sampling and testing of dwellings in Group 2, Group 3 and Group 4.

The appropriate reports that are required to be completed are defined in Clause 9.

6 Sampling requirements

6.1 General

The purpose of the sampling procedure is to obtain representative samples of the concrete block material, ensure that the samples are preserved, and that their characteristics are substantially unaltered between sampling and testing.

Samples taken may be subjected to petrographic, chemical, strength and other testing, as part of an investigation into the potential for future degradation of the concrete blocks and to help provide guidance on remedial works.

6.2 Sampling locations

The Chartered Engineer shall exercise professional judgment in specifying the number and specific location of samples to be taken. As a minimum, eight samples (core or cut) shall be taken to avoid repeat visits and to allow for additional testing where required.

The following is a list of where samples shall be taken:

— at least two samples taken from the rising wall below ground level (one for compressive strength test);

— one sample from each main elevation between ground and first floor level; and

— at least two samples taken from the inner leaf in the case of cavity wall construction (one for compressive strength test).

Other samples should be taken where considered necessary by the Chartered Engineer.

The initial inspection of the overall condition of the dwelling may indicate areas of the walls that are at risk from the most advanced deterioration, thus readily suggesting locations for sampling. Where samples taken from these areas are intact, the surrounding render should be removed to possibly locate damaged blocks and a second sample should be taken.

Samples shall be taken from undamaged areas where blockwork is intact, this allows comparisons between samples to be made by the Petrographer.

Samples shall not be taken from any chimney breast as chemical test results may be influenced by the presence of sulfates due to the burning of fossil fuels.

6.3 Sampling procedure

6.3.1 Sampling shall be carried out by a competent person and in accordance with the requirements of this Irish Standard. The samples shall be recorded and detailed on a sample record and chain of custody form, and then submitted to the Petrographer. An example of the sample record and chain of custody form is included in Annex B.

NOTE See I.S. EN 12504-1 for further guidance on methods for sampling, examining and testing cored specimens in compression.

The competent person shall note the location, diameter, length, and condition of the samples, and include a signature on the sample record and chain of custody form to indicate that he/she has extracted the samples in accordance with this Irish Standard.

6.3.2 A dry-core sampling procedure is required, for which the competent person will need specialised equipment. A dry core sampler bit of 100 mm minimum internal diameter and capable of drilling a depth of at least 150 mm shall be used by the competent person when extracting the samples.

6.3.3 Where possible, core samples should be taken entirely within one block and be free from mortar joints.

6.3.4 The external surface of core samples shall not be washed on site to improve their visual appearance, because this may compromise the analysis.

6.3.5 Cut samples can be taken as an alternative under certain circumstances where difficulty in extracting core samples is experienced. This shall be recorded on the sample record and chain of custody form. It should be noted that when taking cut pieces by chisel, hammer blows may cause micro-cracking, which might not always be easy for the Petrographer to distinguish from cracking resulting from other causes.

6.3.6 As the supervising competent person is responsible for each extracted sample, it is necessary to ensure that these samples are collated accurately and packaged individually in sealable plastic bags. Labelling and numbering each sample, including the date, address and location, should be completed before leaving the site, and a signed and dated sample record and chain of custody form, (see Annex B), to indicate where the samples have been taken from, shall be included with the samples for dispatch to the laboratory.

6.3.7 Tools shall be cleaned following sampling of each concrete block, to avoid cross contamination of samples.

6.3.8 Samples shall be stored in sealable plastic bags, out of direct sunlight and in a cool environment. Waterproof marker pens should be used to clearly identify the sample number, date, address, and location.

6.4 Repair of the sampling hole

Repair of the core-holes shall be carefully undertaken, with particular care of the exposed cavity area. A fresh supply of quick-set dry mix (cement/fine aggregate) and tools for backfilling holes in walls created by sampling will be required. Existing insulation in the cavity should be repaired or replaced as required. Back spacers are required to avoid new fill debris bridging or falling into the cavity. Shrinkage of the repair material should also be avoided.

NOTE Shrinkage-compensated proprietary repair materials are available from several manufacturers.

6.5 Sample inspection and storage

Upon receipt of samples in the laboratory, a visual inspection shall be carried out by the Professional Geologist on each sample and this information shall be recorded.

As a minimum, the visual inspection shall note:

- colour;
- grading/particle size;
- particle shape;
- thickness of render; and
- moisture condition.

A dated photograph shall be taken of each sample and uniquely identified and documented. Samples shall be placed in suitable, airtight, uniquely identified containers, and stored in suitable conditions (see 6.3.8).

7 Testing of samples

7.1 Introduction

Testing laboratories shall ensure that they are familiar with this Irish Standard.

The assessment of samples is subdivided into Test Suites. The Test Suites classify the samples in terms of risk factors and susceptibility to deterioration/degradation. The aim of all the Test Suites is to provide sufficient information to determine if the presence of certain potentially deleterious materials in the concrete block aggregate has, or is likely to have, resulted in the deterioration of the concrete blocks and the damage to the dwelling identified in the Building Condition Assessment.

A sample assessment overview is outlined in Figure 3 and the route taken by the Professional Geologist will be dictated by the results of Test Suite A.

The condition of the sample may also dictate which Test Suites and testing are employed.

Test Suite A will produce a basic description of the sample material using simplified petrography.

Test Suite A requires the sample to be prepared as appropriate, see APG special report [8] (e.g. by cutting with a diamond saw along the axis of the core, which gives a flat, clean surface for simplified petrography). The coarse and fine aggregate types, the fragment sizes and distribution within the examined section shall be identified, with particular emphasis on the presence of sulfide and/or mica minerals. Void dimensions, distribution and concentration should be recorded, and an evaluation of the cement matrix and its condition should be made. The assessment should focus on any cracking, secondary deposits and condition of the concrete. Simplified petrography should be completed on render, if it was recovered with the sample.

Simplified petrography may be sufficient to conclude that the cracking damage identified in the Building Condition Assessment is likely to have been caused by the presence of certain deleterious materials in the concrete block aggregate. In cases where the Professional Geologist/Petrographer finds that simplified petrography is inconclusive, additional testing shall be carried out (Test Suite B).

Test Suite B includes detailed (thin section) petrography which employs thin section microscopy and provides additional information on the sample material at higher magnifications. Thin sections are examined with a petrographic microscope under transmitted and reflected light and should provide information on the aggregate, the cement matrix, voids and cracking. Emphasis should be placed on evidence of deterioration associated with the presence, concentration, form, size and condition of sulfide and/or mica minerals.

In cases where the Professional Geologist/Petrographer finds that Test Suite B is inconclusive, additional testing may be recommended including physical, chemical, and other analytical techniques (Test Suite C).

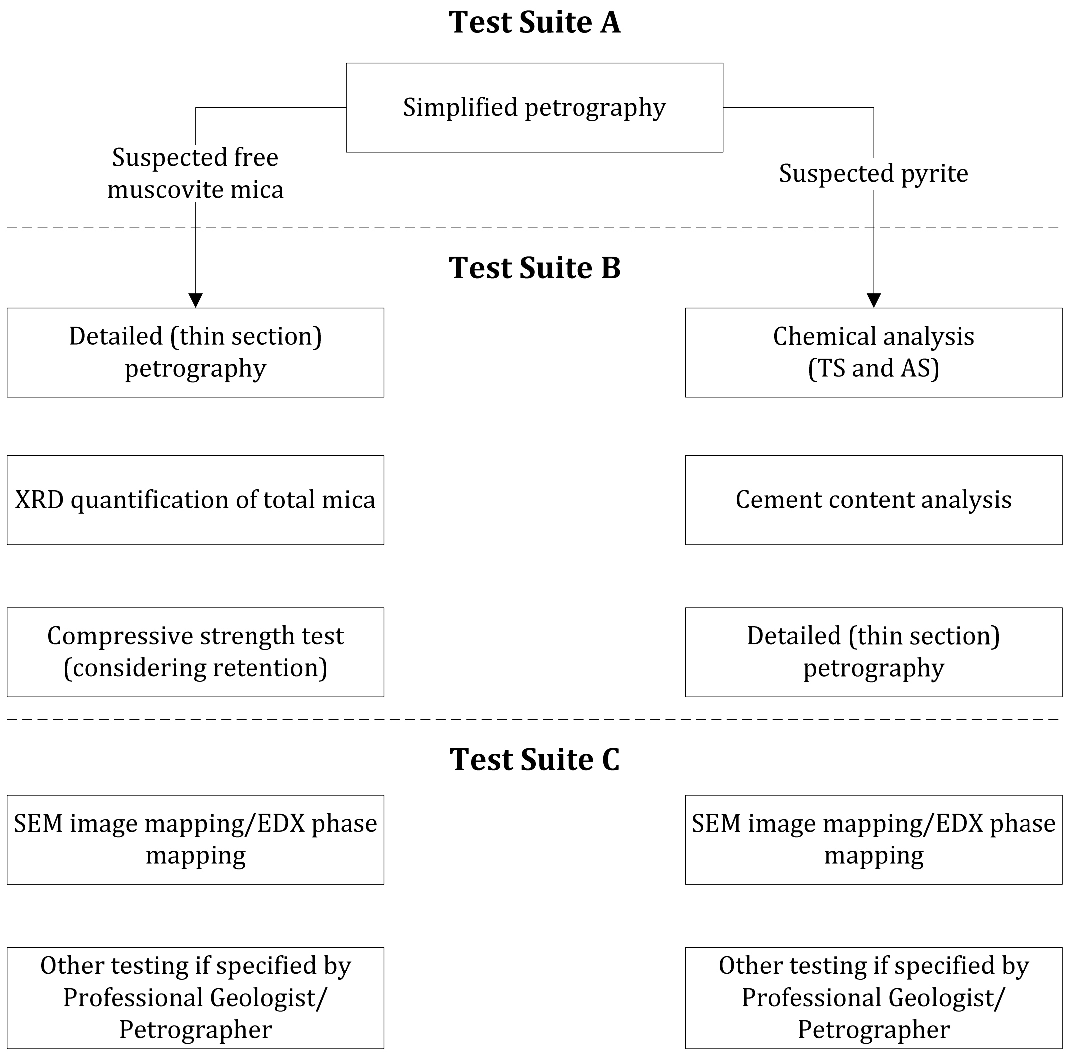


Figure 3 — Sample assessment overview

7.2 Test Suite A – Simplified petrography (pyrite and mica)

Test Suite A involves a visual assessment of the concrete blocks (with/without render) samples. The initial examination of the sample in-hand specimen should be carried out with the aid of a hand lens and/or binocular microscope in order to determine the principal characteristics of the sample. Samples shall be washed to remove loose material generated by the drilling process. They should then be subjected to examination while still wet using the same methods.

The dimensions and characteristics of the samples shall be recorded using photographs and drawings to appropriate scales and shall include the following features:

— Coarse and fine aggregate;

— Distribution and size range;

— Lithology;

— Porosity;

— Indicative strength;

- Texture;
- Character and distribution of both macro and fine cracks;
- Compaction and voids (void sizes, shapes and distribution);
- Cement matrix (colour, colour variations, relative hardness, and condition);
- Superficial evidence of deleterious processes and/or secondary products affecting the concrete;
- Presence and nature of any exudations on surfaces, voids or in cracks;
- Sulfide minerals (presence, preliminary identification, form, abundance, and evidence of reaction);
- Mica minerals (presence, preliminary identification, form, and abundance);
- Concrete condition (sound/unsound); and
- Render (type (smooth/rough), thickness (number of coats/layers), constituents, carbonation, reaction products, as per block sample description).

NOTE It may not be possible to identify all of these characteristics for each sample using Test Suite A.

7.3 Test Suite B – Detailed (thin section) petrography (pyrite and mica)

The objective of the detailed (thin section) petrography is to further characterise the sample and to identify any features not clearly recognisable in the in-hand specimen and to aid in the determination of any deterioration within the sample.

In the case of suspected pyrite degradation, chemical analysis (see 7.5.1) and cement content analysis (see 7.5.2) should be carried out prior to the detailed petrography, as these tests may assist in sample selection for detailed (thin section) analysis.

As concrete blocks are heterogeneous, the petrographic sections should be representative of the cement and aggregate. If the concrete block appears particularly heterogeneous or where coarse aggregate is large relative to the size of the thin section, more than one thin section should be prepared and examined. Where sulfides are identified or suspected from Test Suite A, a polished thin section shall be prepared to aid in determining the presence, form, and abundance of any sulfides present.

The thin section preparation and examination shall be carried out in accordance with a recognised method or Standard e.g. APG Special Report [8], ASTM C856-04 [9], RICS, The Mundic Problem 3rd Edition [10] and BS 1881-211:2016 [11].

In addition to the features listed in the Test Suite A assessment, the following shall be recorded:

- Details of the rock types present in both the coarse and the fine aggregate and, in particular, structures seen within those components and their degree of weathering;
- Potentially deleterious substances (presence, identification, form and abundance);
- Cement paste;
- Cement type;

- Presence of unreacted cement;
- Portlandite (size, form, and distribution);
- Microtexture and matrix condition (assess the extent of any carbonation);
- Reaction products;
- Sulfate minerals occurrence;
- Secondary iron oxides occurrence;
- Cracking (of the aggregate, of the cement matrix or as a result of sample preparation);
- Cracking (the width and location of the cracking and the relationship to the aggregate or the cement paste); and
- Voids (size, shape, distribution, abundance and reaction products).

7.4 Test Suite B – Further testing for mica

7.4.1 XRD (quantification of total mica)

The XRD analysis requires the sample to be ground to a fine powder and analysed to determine mineral composition. Mineral phases shall be identified by comparing the location and intensities of the diffraction peaks with those of mineral reference from Standards in the International Centre for Diffraction Data (ICDD) [12] database, following Rietveld analysis or other appropriate analysis methods selected by the Professional Geologist/Petrographer. Peaks shall be labelled in the X-ray diffractograms with the appropriate mineral name and they shall be included in the Professional Geologist's report.

In most cases XRD will, at best, only report a semi-quantitative value from a bulk concrete block sample with no information on the form of any mica present, be it bound or free. If the phases are not crystalline, it is not possible to get a unique diffraction pattern from amorphous substances. It is generally accepted that the XRD may have difficulty in detecting quantities of minerals less than 2 %.

7.4.2 Compressive strength tests

Compressive strength determination shall be performed on core samples or on individual concrete blocks. At least one sample below the DPC and one internal leaf sample (minimum 100 mm diameter) shall be tested. Compression tests on core specimen samples shall be performed in accordance with I.S. EN 12504-1.

Compression tests on concrete blocks (full or part) shall be performed in accordance with I.S. EN 772-1, using the immersion method and mortar capped. Information on the specimen shall be recorded (e.g. maximum nominal size aggregate, voids, non-cylindrical shape etc) in conjunction with density and maximum load at failure. The measured compressive strength (N/mm^2) shall be reported to I.S. EN 771-3 and converted to I.S. 20-1 [13] if required.

7.5 Test Suite B - Further testing for pyrite

7.5.1 Chemical analysis

The objective of chemical testing is to quantify the sulfur containing compounds in the sample. The concentration of total sulfur (TS) and acid soluble sulfate (AS) should be measured in representative samples. The concrete block sample shall be crushed to < 125 μm and tested in accordance with I.S. EN 1744-1. Total sulfur (TS) shall be expressed as % S with acid soluble sulfate (AS) expressed as % SO_4. Water soluble sulfate (WS) can also be determined to further aid the interpretation of chemical properties.

NOTE For further information see Annex E.

7.5.2 Cement content analysis

Cement content shall be determined in accordance with Clause 6.5 of BS 1881-124:2015. A minimum of two samples shall be analysed and laboratories shall be requested to state any assumptions made in analysis (e.g. for cement and aggregate), as required in BS 1881-124:2015.

Results of cement content testing should be treated with caution by the Chartered Engineer. The Chartered Engineer should consider the results for cement content as not definitive and should consider the results in conjunction with other test data (e.g. compressive strength, petrographic analysis etc.) to establish their comparability and consistency.

The cement content can be calculated by assuming the presence of CEM 1 Portland Cement, in accordance to I.S. EN 197-1, containing 20,2 % and 64,5 % by mass of soluble silica (SiO_2) and calcium oxide (CaO) respectively, unless more specific information is available. Cement content by SiO_2 and CaO contents (% m/m) shall be reported with calculated Preferred Cement Content (% m/m).

Assumed figures for SiO_2 in aggregates can typically range from 0,2 % to 0,5 %. In the absence of more specific data a figure of 0,25 % may be used.

Cement content analysis in accordance with BS 1881-124:2015 depends both on the accuracy of assumptions of chemistry (for cement and aggregates) as well as on sampling and testing variability. A review of test results for concrete, where all details were known, indicate significant variation in results [14]; where this information is assumed, greater levels of inaccuracy would be expected (see Foreword and Clause 6 of BS 1881-124:2015). The variation in results can be significant for concrete blocks, where the cement content normally used in production is low compared to 'normal concrete' mixes (on which comparisons were made).

7.6 Test Suite C - Additional testing

7.6.1 Mineralogical composition by scanning electron microscope (SEM)/EDX phase mapping

SEM/EDX may be recommended by the Professional Geologist/Petrographer for quantitative mineralogical analyses, and their morphology and distribution. Where appropriate, this should include examination and evaluation of sulfide (pyrite) or mica minerals. Special care is required in the preparation of samples. Backscatter electron images and elemental spectra shall be included in the Laboratory Analysis Report. Refer to Annex C for further guidance.

7.6.2 Compressive strength test for pyrite

Refer to 7.4.2.

7.7 Interpretation of concrete block testing with suspected deterioration due to the presence of free muscovite mica

7.7.1 Test Suite A – Simplified petrography

For a concrete block sample to be classified as negligible risk (see 7.7.3), the sample should be shown to be sound with no evidence of deterioration and the simplified petrography should confirm the rare presence or the absence of suspected problematic lithologies/minerals (micaceous schists/free muscovite mica).

For a block sample to be classified as low/medium or high risk, the sample should be shown to be sound or contain common or numerous problematic lithologies.

For a block sample to be classified as high or critical risk, deterioration of the sample should be observed, and/or the presence of abundant potentially problematic lithologies/minerals identified.

In some cases where deterioration is observed it may be required to proceed to Test Suite B to identify and confirm the presence of potentially problematic lithologies/minerals.

Where conclusive evidence of deterioration has not been observed or the absence of any potentially problematic lithologies/minerals have not been confirmed the Professional Geologist/Petrographer shall further evaluate the concrete block samples by applying Test Suite B.

NOTE Multiple aggregate sources may have been used during the manufacture of concrete blocks.

7.7.2 Test Suite B – Detailed (thin section) petrography

In Test Suite B, the results of the detailed (thin section) petrographic analysis and XRD, if deemed required, shall be evaluated. Table 2 provides guidance on the aspects of the test findings that will assist in assessing the potential for increased susceptibility to deterioration due to freeze thaw as a result of the presence of problematic lithologies/minerals (micaceous schists/free muscovite mica), for samples that have failed to be classified by Test Suite A.

The XRD should be evaluated in conjunction with the detailed (thin section) petrography in an attempt to quantify the abundance of potentially problematic lithologies/minerals.

NOTE XRD will only report a semi-quantative value from a bulk concrete block sample with no information on the form of any mica present, be it bound or free.

Table 2 — Test Suite B – Detailed evaluation for mica degradation in concrete blocks

Risk Factor	Derived from	Considerations when assessing the susceptibility for deterioration from free muscovite mica
Presence of mica bearing lithologies	Detailed (thin section) petrography X-Ray Diffraction (if required)	Presence, type, form, and abundance. Particular emphasis should be based on the abundance of free muscovite mica in the 0 mm to 4 mm sized fraction.
Distribution of macro and micro cracks	Detailed (thin section) petrography	Cracking in aggregate, cement paste or as a result of sample preparation.
Microporosity	Detailed (thin section) petrography	Increase in microporosity contributing to greater susceptibility to freeze thaw action.
Cement paste	Detailed (thin section) petrography	Excessive leaching of the cement paste.
Concrete condition	Detailed (thin section) petrography	Sound/Unsound

7.7.3 Conclusions

Table 3 classifies the risk of mica degradation of concrete blocks according to the interpretation of the test results. The final classification will be made by the Professional Geologist/Petrographer based on their interpretation of the risk factors.

Table 3 — Test Suite B – Risk factor assessment for mica degradation in concrete blocks

	Classification risk of concrete block [a]			Critical
	Negligible	Low/Medium	High	
Risk Factor	**Interpretation of results**			
Visible evidence of deterioration of the concrete blocks	Sound	Sound but potentially susceptible	Sound but potentially susceptible or Unsound	Unsound
Presence of “free muscovite mica” [b]	Absent/Rare	Common	Numerous	Abundant
Evidence of moisture ingress	Rare	Common	Numerous	Abundant
Microcracking	Rare	Common	Numerous/Common	Abundant or Pervasive
Degradation/Weakening of cement matrix (evidence of leaching of cement hydrates)	Rare	Rare	Common	Very Common or Pervasive
Microporosity	Normal	Moderate	High	Excessive

[a] Range of terms used to classify risk shall be quantified by the Professional Geologist/Petrographer and stated in their report.

[b] "free muscovite mica" as assessed by calculation or estimation by the Professional Geologist/Petrographer.

The concrete block sample shall be classified by the Professional Geologist or Chartered Geotechnical Engineer as displaying:

a) Critical deterioration as a result of the presence of problematic lithologies/minerals (micaceous schists/free muscovite mica), concrete block has significant existing damage with abundant problematic lithologies present;

b) High susceptibility to deterioration from freeze thaw due to the presence of potentially problematic lithologies/minerals, concrete block determined to be unsound or sound but numerous problematic lithologies are present;

c) Low/Medium susceptibility to deterioration from freeze thaw due to the presence of potentially problematic lithologies/minerals, concrete block determined to be sound but common problematic lithologies are present; or,

d) Negligible susceptibility to deterioration from freeze thaw due to the absence or rare presence of potentially problematic lithologies/minerals.

7.8 Interpretation of concrete block testing with suspected deterioration due to the presence of pyrite or other sulfides

7.8.1 Test Suite A – Simplified petrography

For a concrete block sample to be classified as negligible risk (see 7.8.3), the sample should be shown to be sound with no evidence of deterioration and the simplified petrography should confirm the rare presence or absence of suspected problematic lithologies/minerals (see S.R. 16 [15]) e.g. calcareous mudstones and shales.

For a concrete block sample which contains problematic lithologies classified as minor or major, but is shown to be sound, it should be classified as low/medium or high risk.

For a concrete block sample to be classified as high or critical, deterioration of the sample should be observed and the presence of abundant fine grained suspected problematic lithologies should be confirmed. In some cases where deterioration is observed it may be required to proceed to Test Suite B to identify and confirm the presence of reactive sulfide(s).

Where conclusive evidence of deterioration cannot be observed or the absence of any fine grained suspected problematic lithologies was not confirmed, the competent person shall further evaluate the concrete block samples by applying Test Suite B.

NOTE Multiple aggregate sources may have been used during the manufacture of concrete blocks.

7.8.2 Test Suite B – Detailed petrography

Table 4 sets out the key risk factors that should be considered when assessing the susceptibility of concrete to degradation due to pyrite or other sulfides, and the methods from which the pertinent information will be derived.

Table 4 — Test Suite B - Detailed evaluation for pyrite or other sulfide degradation in concrete blocks

Key Risk Factors	Derived from	Consideration when assessing susceptibility for degradation
Suspected problematic lithologies/minerals [a]	Simplified petrography and detailed (thin section) petrography	Presence and proportion
Bedding, fabric and laminations	Simplified petrography and detailed (thin section) petrography	Presence and proportion
Susceptibility for water absorption	Simplified petrography	Propensity of aggregate to absorb water
Calcite and clay minerals in aggregate	Detailed (thin section) petrography and XRD analysis	Presence, proportion and significance
Framboidal and fine crystalline forms of pyrite	Detailed (thin section) petrography	Form, distribution and significance of pyrite form in terms of alteration or expansion capability
Secondary reaction products (i.e. gypsum, thaumasite) from oxidation of pyrite or other sulfide	Detailed (thin section) petrography and XRD	Presence of secondary reaction products (within voids, bleed channels or bedding fabric.) Evidence of forceful gypsum growth giving rise to degradation
Total sulfur (TS)	Chemical analysis	Refer to Annex E for guidance
Acid soluble sulfate (AS)	Chemical analysis	Refer to Annex E for guidance
Water soluble sulfate (WS) (optional)	Chemical analysis	Refer to Annex E for guidance

[a] Further information is provided in S.R. 16 [15].

7.8.3 Conclusions

Table 5 classifies the risk of degradation of concrete blocks according to the interpretation of the test results. The final classification will be made by the Professional Geologist/Petrographer based on their interpretation of the risk factors.

Table 5 — Test Suite B - Risk factor assessment for pyrite or other sulfide degradation of concrete blocks

	Classification risk of concrete block [a]			Critical
	Negligible	Low/Medium	High	
Risk factor	**Interpretation of results**			
Visible evidence of deterioration or degradation of the concrete blocks/aggregate	Sound	Sound but potentially susceptible	Sound but potentially susceptible or Unsound	Unsound
Presence of problematic lithologies	Trace	Trace/Minor	Minor/Major	Major
Presence of gypsum or secondary sulfates	Absent/Rare	Few	Numerous	Abundant
Presence of framboidal form of pyrite or reactive forms of sulfide	Absent/Rare	Few	Numerous	Abundant
Cracking/microcracking	Absent/Rare	Few	Numerous/Common	Abundant or Pervasive
Degradation/Weakening of Block (with possible evidence of leaching of cement hydrates)	Absent/Rare	Rare	Common	Very common or Pervasive
[a] Range of terms used to classify risk shall be quantified by the Petrographer and stated in their report.				

The concrete block sample shall be classified by the Professional Geologist or Chartered Geotechnical Engineer as displaying:

a) Critical deterioration as a result of the major presence of problematic lithologies (e.g. calcareous mudstone)/minerals (pyrite/sulfide), concrete block has significant existing damage;

b) High susceptibility to deterioration due to the presence of potentially problematic lithologies/minerals, concrete block determined to be either unsound or sound but minor/major problematic lithologies are present;

c) Low/Medium susceptibility to deterioration due to the presence of potentially problematic lithologies/minerals, concrete block determined to be sound but trace/minor problematic lithologies/minerals are present; or,

d) Negligible susceptibility to deterioration from sulphide degradation/pyrite oxidation due to the absence/trace presence of potentially problematic lithologies.

7.9 Reporting

The report by the Professional Geologist should include photographs of the samples as received illustrating features of interest. Photographs of the key features of the thin section under crossed and plane polarized light shall be included.

The report shall include an evaluation of the findings and may include recommendations for further testing or examination of additional samples (e.g. compressive strength test, 7.4.2).

NOTE Testing to date has shown that samples from blockwork, taken from damaged buildings in accordance with Clause 6, and deemed to have a high susceptibility to deterioration under Table 3 or Table 5 may not always exhibit evidence of deterioration under petrographic examination. This does not rule out the possibility of actual damage having occurred in concrete blocks that have not been sampled or tested.

8 Remedial works

8.1 General

The Chartered Engineer in consultation with the Professional Geologist should review the Building Grouping (see 5.3), test results and the potential for future degradation of retained concrete blocks when recommending remedial works. Technical Options for remediation of dwellings are outlined in Table 5.1 and Table 5.2 of the Report of the Expert Panel on Concrete Blocks [1] and are appended in Annex D. When considering the remedial Options in Annex D, the Chartered Engineer should take into account the exposure conditions of blockwork 150 mm above and 150 mm below finished ground level. Consideration shall be given to the increased risk of saturation with freezing, the advice given in S.R. 325 for exposure conditions, and the advice in other relevant documents when specifying remedial works.

Alternative options for consideration by the dwelling owner may be available, these carry unknown levels of risk as there is, as yet, no available history or evidence of their implementation.

8.2 Dwellings exhibiting structural wall damage from deterioration of blocks made from aggregates containing excessive free muscovite mica

Table D.1, which comes from the Report of the Expert Panel on Concrete Blocks [1], outlines technical Options for remediation of dwellings exhibiting damage from deterioration of blocks made from aggregates containing excessive free muscovite mica.

The Chartered Engineer, in consultation with the Professional Geologist, should consider all factors including, but not limited to the extent of damage to date (see 5.3), the susceptibility for future degradation of the blocks (see 7.7.3), results of compressive strength tests, exposure conditions, structural stability, relative costs, etc. when making any recommendations and setting out remediation options. All dwellings should be examined on a case by case basis and proposed solutions not limited to Table D.1 should be considered.

The feasible remediation options, together with their associated risks, should be included in the final report. These options may be considered by a dwelling owner, in consultation with the Chartered Engineer.

Table 6, together with its requirements and recommendations, gives minimum remediation Options from Table D.1. Option 1 and Option 2 of Table D.1 are remedial works which can be signed off by the Chartered Engineer. Option 3 and Option 4 of Table D.1 may also be signed off, with caveats, subject to taking full cognisance of the findings of the Building Condition Assessment (see Clause 5) and of the conclusions of the testing carried out on the concrete blocks.

NOTE The Options included in Table D.1 are ordered in descending order from the most invasive option (Option 1) to the least invasive option (Option 5).

Table 6 — Selection of recommended remediation options (for dwellings with blockwork containing excessive free muscovite mica)

Results from Building Condition Assessment		Geologist classification risk of blockwork (Table 3) - High and blockwork sound but potentially susceptible to deterioration	Geologist Classification Risk of Blockwork (Table 3) - Critical or high and unsound
Rising wall	**Inner leaf**	**Minimum remediation Option** [a] (See Table D.1)	
Undamaged	Undamaged	Option 4 [b]	N/A
Undamaged	Damaged	Option 3	Option 2
Damaged	Damaged/ Undamaged	Option 2	Option 1

1. Works shall be incorporated which resist moisture ingress or otherwise protect against freeze thaw in retained blockwork, e.g. membranes, renders, insulation, etc.
2. The efficacy and longevity of remedial works options other than Option 1 and Option 2 of Table D.1 are as yet uncertain. Based on limited test data available to date, concrete blocks containing free muscovite mica will not deteriorate if they are kept dry in freezing conditions or are protected from freezing when wet.
3. Any sign off in respect of such remedial works shall acknowledge the risk inherent in retaining blockwork which could be susceptible to degradation if exposed to freeze thaw conditions.
4. Ongoing maintenance and monitoring of the dwelling's structural condition would be required if Option 3, Option 4 or Option 5 are implemented to assess if/when further structural action should be taken.

[a] In certain circumstances, less invasive Options may need to be considered.

[b] Where damage is sufficiently localised, remediation Option 5 may be considered.

8.3 Dwellings exhibiting structural wall damage due to pyrite induced expansion in concrete blocks

In the case of a dwelling in Group 2, Group 3 or Group 4, which is exhibiting structural wall damage as a consequence of pyrite induced expansion, Option 1 in Table D.2, (demolish entire dwelling and rebuild) is an effective solution which can be signed off by the Chartered Engineer. For dwellings in Group 2 and Group 3, alternative options could be considered by a dwelling owner, in consultation with the Chartered Engineer, to try to reduce the potential rate of block deterioration. The efficacy, longevity and risk of such alternatives is not known. Ongoing maintenance and monitoring of the dwelling's structural condition would be required if such options are implemented to assess if/when further structural action should be taken.

NOTE The UK RICS Mundic reports contains other guidance and information which may be of assistance. In the UK, some houses built mainly before 1950 in the south west of England contained pyrites ("Mundic" material) in their concrete block or mass concrete walls. Structural deterioration occurred rapidly in some cases, but guidance on assessing surviving houses was first issued in 1994 and revised in the third edition in 2015 [10].

9 Reports and conclusions

9.1 General

The Chartered Engineer's final report shall be prepared based on the conclusions from the following:

a) Building Condition Assessment (see Clause 5), which includes:

- Desk study (see 5.2.1);
- Dwelling inspection (see 5.2.2); and
- Building Grouping (see 5.3).

b) A final Professional Geologist/Chartered Geotechnical Engineer's report based on the conclusions from the following:

- Block sampling records; and
- Laboratory analysis reports.

9.2 Final report

The Chartered Engineer's final report shall include the following:

a) A declaration that the he/she has exercised reasonable skill and care when:

- completing the dwelling inspection and choosing the sample locations;
- concluding that the sample material selected for concrete assessment is reasonably representative of the parts of the building inspected;
- commissioning of the sampling and testing procedures in line with this Irish Standard;
- considering the results and findings; and
- preparing the report in compliance with this Irish Standard.

b) An Executive Summary, which shall address the following points:

- The extent of damage to date (Building Grouping);
- The possible causes of damage, including:
  - i) The presence of deleterious materials in the concrete block
  - ii) Identification of the deleterious materials
  - iii) Clarification or estimation of the amount of deleterious materials
- Where retention of any blockwork is being considered, confirmation that the block compressive strengths are sufficient; and
- Indicate the potential for future deterioration of retained blocks in their current state.

c) An outline of the feasible remedial works and their associated risks, see Clause 8 for guidance;

d) A copy of the Building Condition Assessment report (see 5.4);

e) A copy of the interim report, where issued; and

f) A copy of the laboratory analysis reports (see 7.9).

Annex A
(informative)

Example Building Condition Assessment report template

Information on the building	
Address:	**Eircode:**
Type of building:	
Description of site location e.g. in a residential estate or private site**:**	
Orientation:	
Year built:	
Floor area (m^2):	
Year defects first appeared:	
Weather at time of assessment:	
Current owner:	
Other information e.g. brief history of development of damage**:**	
Site inspection of damage	
Chartered Engineer carrying out the inspection:	
Date:	**Qualifications:**
Circumstantial Evidence	
Source of concrete block materials:	
Is there information that the blocks in the dwelling came from manufacturer(s) reported to have supplied blocks to other dwellings exhibiting damage likely to have arisen from deleterious material in concrete blocks?	☐ Yes ☐ No
Was the dwelling constructed within the date range of constructions mentioned in the Report of the Expert Panel on Concrete Blocks [1], and in the geographic areas reported to be affected?	☐ Yes ☐ No
Is there documented information (e.g. Chartered Engineer's Report) that other dwellings in the same estate or locale have exhibited signs of damage likely to have arisen from deleterious material in concrete blocks?	☐ Yes ☐ No
Are other houses in the same estate exhibiting signs of damage likely to have arisen from deleterious material in concrete blocks?	☐ Yes ☐ No

Notes:

External sketches

Site plan

Notes:

- → Note general site features i.e. level/sloping site, orientation/local exposure conditions
- → Provide key (see example below)

↑ (1) Photograph Ref No.

Front elevation

Notes:

Web like cracking	☐ Yes ☐ No
Pattern like cracking (combined horizontal and vertical)	☐ Yes ☐ No
Disintegrated blocks leaving void in external leaf	☐ Yes ☐ No
Outward bowing of external leaf	☐ Yes ☐ No
Wide vertical crack, typically 200 mm from corner	☐ Yes ☐ No
Displacement at window/door reveals	☐ Yes ☐ No
Render blown or missing	☐ Yes ☐ No
Horizontal cracks (possibly attributable to day joint in blockwork)	☐ Yes ☐ No

Rear elevation	**Notes:**	
	Web like cracking	☐ Yes ☐ No
	Pattern like cracking (combined horizontal and vertical)	☐ Yes ☐ No
	Disintegrated blocks leaving void in external leaf	☐ Yes ☐ No
	Outward bowing of external leaf	☐ Yes ☐ No
	Wide vertical crack, typically 200 mm from corner	☐ Yes ☐ No
	Displacement at window/door reveals	☐ Yes ☐ No
	Render blown or missing	☐ Yes ☐ No
	Horizontal cracks (possibly attributable to day joint in blockwork)	☐ Yes ☐ No
Side elevation	**Notes:**	
	Web like cracking	☐ Yes ☐ No
	Pattern like cracking (combined horizontal and vertical)	☐ Yes ☐ No
	Disintegrated blocks leaving void in external leaf	☐ Yes ☐ No
	Outward bowing of external leaf	☐ Yes ☐ No
	Wide vertical crack, typically 200 mm from corner	☐ Yes ☐ No
	Displacement at window/door reveals	☐ Yes ☐ No
	Render blown or missing	☐ Yes ☐ No
	Horizontal cracks (possibly attributable to day joint in blockwork)	☐ Yes ☐ No

Side elevation	Notes:	
	Web like cracking	☐ Yes ☐ No
	Pattern like cracking (combined horizontal and vertical)	☐ Yes ☐ No
	Disintegrated blocks leaving void in external leaf	☐ Yes ☐ No
	Outward bowing of external leaf	☐ Yes ☐ No
	Wide vertical crack, typically 200 mm from corner	☐ Yes ☐ No
	Displacement at window/door reveals	☐ Yes ☐ No
	Render blown or missing	☐ Yes ☐ No
	Horizontal cracks (possibly attributable to day joint in blockwork)	☐ Yes ☐ No

Building Grouping per I.S. 465	
☐ **Group 1**	☐ **Group 2**
☐ **Group 3**	☐ **Group 4**

Location of sampling to be marked on he dwelling and/or on sketch elevations
e.g. Front Elevation Sketch

Annex B
(informative)

Example sample record and chain of custody

Custody form/Sampling schedule		Sampling company Details & Logo	
Owner:			
Address:		**Project No.:**	
Chartered Engineer:		**Sampling protocols:**	
Date Sampled:		**Technician:**	

Sample Ref. No.	Sampling Information						
	Sample Location	**Above DPC**	**Below DPC**	**>450mm Below DPC**	**I** (Inner leaf) **O** (Outer leaf) **S** (Single skin)	**Drilling Characteristics / Remarks**	**Photographs**

	Name	Company Name	Date
Samples taken by:			
Samples approved by:			
Samples received by:			
Notes/Comments:			

Annex C
(informative)

Guidance on further testing

C.1 Estimation of free muscovite mica

The free muscovite mica associated with phyllite aggregates is typically very fine and dominated by particles in the < 63 µm size fraction. Estimating free muscovite mica content from thin sections is greatly hindered by the following factors:

a) The detection of < 63 µm free muscovite mica in cement matrix is greatly hindered by carbonation, this is because carbonation reduces the contrast between the mica and matrix;

b) The small size of free muscovite mica flakes means that several mica crystals may be superimposed in a standard thin section of 30 µm thickness; and

c) Altered mica in the form of chlorite cannot always be reliably distinguished from unaltered mica where the particle size is < 30 µm

For the above reasons alternative techniques such as XRD or SEM/EDX analysis are required to estimate the amounts of free muscovite mica in the cement matrix of a concrete block.

C.2 SEM for mica

Backscattered secondary electron images of resin impregnated and polished concrete sections will provide visual information on the amount of < 63 µm free muscovite mica within the cement matrix. A number of sites in the sample should be examined under appropriate magnification and the percentage of free muscovite mica estimated visually or quantified/measured, by point counting or using elemental/phase mapping/image analysis techniques. The Petrographer's report should contain image(s) showing typical free muscovite mica concentration(s), quantification of it and the method used to obtain the value(s).

C.3 SEM/EDX for pyrite

Backscattered secondary electron images of resin impregnated and polished concrete sections will provide visual information on the form and distribution of pyrite and may show if there is evidence of oxidation and attendant cracking. Semi-quantitative energy dispersive X-ray microanalysis (EDX) should provide information on what degree of oxidation of pyrite has taken place. EDX analysis should be used in conjunction with phase mapping for sulfur (if appropriate) to show how sulfate is distributed in the cement matrix and to determine whether or not there is evidence for ettringite, thaumasite or gypsum formation as a result of internal sulfate attack. The Petrographer's report should contain image(s) showing the form(s) of pyrite, quantification of it and the method used to obtain the value(s). Where pyrite oxidation is found, EDX spectra of the oxidised and unoxidised areas should be included. The report should identify whether or not the SEM analysis shows evidence for expansion of the concrete block as a result of sulfate attack and/or framboidal alteration. Such evidence would include:

a) cracking linked to the growth of alteration rims around framboidal pyrite crystals;

b) gypsum formation in cracks in the aggregate particles; and/or,

c) sulfate attack of the cement matrix surrounding the aggregate particles.

Annex D
(informative)

Remedial works

Table D.1 and Table D.2 have been taken from the Report of the Expert Panel on Concrete Blocks [1] commissioned by the Department of Housing, Planning, Community and Local Government.

Table D.1 — Technical options for remediation of affected dwellings - County Donegal - (Table 5.1 from Report of the Expert Panel on Concrete Blocks)

Option No.	Description	Pros	Cons
1.	Demolish entire dwelling to foundation level and rebuild.	Removal of all concrete blocks susceptible to deterioration. Sign off of works by a competent professional, without reservation is possible.	This is the most expensive remediation option. Longest programme duration and may involve making a planning application. Alternative accommodation will be required for duration of works.
2.	Demolish and rebuild external walls (both outer and inner leafs) down to foundation on a phased basis and re-render.	10 % to 25 % less expensive than Option 1. Sign off of works by a competent professional without reservation is possible.	Elaborate temporary works necessary. Alternative accommodation will be required for duration of works.
3.	Demolish and rebuild external walls (both outer and internal leafs) down to top of rising wall on a phased basis and re-render.	15 % to 30 % less expensive than Option 1. Sign off of works by a competent professional may be possible.	Detailed assessment of the condition of any retained rising wall (above and below the DPC level) required. Elaborate temporary works necessary. Possible reservations to sign-off regarding long term durability of rising walls. Alternative accommodation will be required for duration of works.
4.	Demolish and rebuild external walls (outer leaf only) down to top of rising wall on a phased basis and re-render.	70 % to 75 % less expensive than Option 1. Occupant relocation may not be necessarily essential. Sign off of works by a competent professional may be possible.	Detailed assessment of the condition of any retained rising wall/ inner leaf (above and below the DPC level) required.
5.	Take down and rebuild outer leaf of affected walls only and re-render.	Less expensive than Option 4. Occupant relocation not necessary.	Detailed evaluation of the retained rising wall/inner leaf (above and below the DPC level) required. Reluctance to sign-off by competent professionals. Problems may emerge in other walls.

NOTES:

The cost comparison presented in the Table is based on a preliminary costing commissioned by the Panel for:

a) Dormer Bungalow, 3 Bedroom, 187,7 m^2 (2 021 sq.ft), and

b) Two Storey, 4 Bedroom, 141 m^2 (1 520 sq.ft).

Other technical solutions may exist.

Table D.2 — Technical options for remediation of affected dwellings - County Mayo - (Table 5.2 from Report of the Expert Panel on Concrete Blocks)

Option No.	Description	Pros	Cons
1.	Demolish entire dwelling and rebuild.	Removal of all concrete blocks susceptible to deterioration. Sign off of works by a competent professional, without reservation is possible.	This is the most expensive remediation option. Longest programme duration and may involve making a planning application. Alternative accommodation will be required for duration of works.
2.	Demolish and rebuild external walls (both outer and internal leafs) down to foundation on a phased basis and re-render.	10 % to 25 % less expensive than Option 1. Sign off of works by a competent professional without reservation may be is possible.	Elaborate temporary works necessary. Alternative accommodation will be required for duration of works.
3.	Demolish and rebuild external walls (both outer and internal leafs) down to top of rising wall on a phased basis and re-render.	15 % to 30 % less expensive than Option 1. Sign off of works by a competent professional may be possible.	Detailed assessment of the condition of any retained rising wall (above and below the DPC level) required. Elaborate temporary works necessary. Possible reservations to sign-off regarding long term durability of rising walls. Alternative accommodation will be required for duration of works.
4.	Demolish and rebuild external walls (outer leaf only) down to top of rising wall on a phased basis and re-render.	70 % to 75 % less expensive than Option 1. Occupant relocation not necessary.	Detailed assessment of the condition of any retained rising wall/inner leaf (above and below the DPC level) required. Reluctance to sign-off by competent professionals. Problems may emerge in the future of the inner leaf.

NOTES:

The cost comparison presented in the Table is based on a preliminary costing commissioned by the Panel for:

a) Dormer Bungalow, 3 Bedroom, 187,7m^2 (2 021 sq.ft) and

b) Two Storey, 4 Bedroom, 141m^2 (1 520 sq.ft).

Other technical solutions may exist.

Annex E
(informative)

Guidance on elevation of degradation of concrete blocks due to pyrite/sulfides

E.1 General

This Annex provides guidance on assessing results of chemical tests undertaken on samples of concrete blocks from damaged dwellings.

The chemical tests recommended in 7.5 and Table 4 are for acid soluble sulfate (AS) and total sulfur (TS).

The main sources of sulfur/sulfate are from the aggregates and the cement used in the manufacture of the concrete blocks.

E.2 Acid soluble sulfate (AS)

This test is used to determine the total of all acid soluble sulfates (AS) that may be present. Pyrite is generally left untouched by the acid extraction [16].

Aggregates which are compliant with I.S. EN 12620 [3] and S.R. 16 [15] are restricted to a maximum level of sulfate (as SO_4) of 0,2 %.

The level of sulfate will be proportionately influenced by the amount of cement in the block mix and its sulfate (SO_3) content. However, these values are usually unknown/uncertain where investigations are being undertaken on samples from damaged dwellings which are several years old.

For example, the sulfate content for a standard block (5,0 N/mm^2 to I.S. 20-1; 7,5 N/mm^2 to I.S. EN 771-3), with an average cement content of 6,5 % (by oven dry weight) and using CEM I Portland Cement, with an SO_3 content of 3,3 % (limit for CEM I 42,5R (RH cement) is 4,00 %) would be approximately 0,44 % (as SO_4), when aggregates with 0,2 % maximum limit are used. This level would be exceeded if cement contents were increased to allow for earlier handling requirements or the SO_3 content of cement was higher than average (e.g. for RH cement, often used in winter). The RICS Guidance on the Mundic Problem [10] acknowledges that values of AS up to 0,5 % (as SO_4) are not considered abnormal for CEM I Portland Cement concrete mixes.

NOTE The convention in reporting sulfate in cement is to report it as SO_3. The convention in reporting sulfate in aggregates is to report it as SO_4. Conversion of SO_3 to SO_4 is achieved by multiplying SO_3 by a factor of 1,2.

For blocks of higher strength, and consequently higher cement content than standard blocks, or for special blocks, the level of sulfate would be increased.

It is recommended to consider the results of tests for AS in conjunction with tests for other properties. In the case of standard blocks (5,0 N/mm^2 to I.S. 20-1; 7,5 N/mm^2 to I.S. EN 771-3), a value of AS above 0,5 % (as SO_4), together with evidence from detailed (thin section) petrography, should confirm the presence of sulfate/sulfides in aggregates. Where this occurs the Professional Geologist/Petrographer should confirm the potential or evidence of damage to the concrete block as evidence of sulfide degradation. For blocks of higher strength or special blocks the value of 0,5 % (arising from compliant aggregates and cement) is likely to be exceeded.

Results from other methods (e.g. detailed (thin section) petrography, SEM/EDX, XRD) and results for cement content, see 7.5.2 for reliability, should also be considered in conjunction with the above.

E.3 Total sulfur (TS)

Total sulfur is defined as the total of all sulfur present as sulfate, plus any present as sulfide (including pyrite), and any that is present in any organic matter [14].

Aggregates which are compliant with I.S. EN 12620 [3] and S.R. 16 [14] are restricted to a maximum level of total sulfur (as S) of 1,0 %, (with caveats).

The level of total sulfur determined in a sample from a block will also be influenced by the amount of cement and its sulfate (SO_3) content (which is considered to be acid-soluble). The contribution to total sulfur from cement for a standard block (with the parameters as outlined in the example given in E.2) would be approximately0,1 %. For blocks other than standard (5,0 N/mm^2 to I.S. 20-1 [13]; 7,5 N/mm^2 to I.S. EN 771-3) the contribution of cement to total sulfur would be expected to be somewhat higher.

The Professional Geologist shall ensure that they can account for the total sulfur (S) concentration of the concrete as a combination of the sulfur in the cement and the sulfur in the aggregate, which if present, shows negligible potential for the cause of degradation. If the sulfur is considered elevated, the Professional Geologist should consider other data such as the AS test results (see E.2), evidence from detailed (thin section) petrography, SEM/EDX or XRD analysis.

The RICS Guidance on the Mundic Problem [10] states that "the numerical difference between the determined percentage of total sulfur (S) and the determined percentage of acid-soluble sulfate (also expressed as S) gives a measure of the 'sulfide' content, including pyritic sulfur and sulfide".

If the presence or origin of sulfate minerals cannot be determined by optical microscopy, then supplemental methods should be utilised e.g. SEM/EDX or XRD analysis.

E.4 Water soluble sulfate (WSS)

This optional test may be used to measure soluble sulfate (SO_4) or aqueous extract sulfate (2:1 water crushed concrete extract) that may be present in concrete blocks as a result of pyrite oxidation and degradation.

The test may be used for the assessment of the potentially aggressive concentration of sulfate ions that may be readily leached. It can provide evidence of pyritic reaction and formation of secondary sulfate reaction products (e.g. gypsum) where presence of potentially problematic lithologies/minerals is known. There will be a contribution of sulfates from the cement which will vary dependent on cement type and quantity.

The crushed concrete block sample is tested in accordance with Clause 10 of I.S. EN 1744-1:2009+A1:2012, which is a test used to measure water soluble sulfates in aggregates. The results are expressed in mean soluble sulfate content (as SO_3) by mass of aggregate (%) or as water soluble sulfate content (as SO_3) in mg/l.

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This 9th day of November 2018

L. S.

Geraldine Larkin

Chief Executive

Patrick Bracken

Secretary to the Board of the NSAI

The Minister for Business, Enterprise and Innovation hereby gives his consent under Section 16 of the National Standards Authority of Ireland Act, 1996 to the above declaration.

Nina Brennan

9/11/2018

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