Technical Update:
Pyrite contamination

This technical update provides additional guidance on pyrite contamination. It is important that all workmanship carried out during construction is completed in accordance with the relevant tolerances.

Background

Pyrite (FeS2-iron sulphide) is a very common mineral. Traces of it are found in the sedimentary rock used to make crushed stone for backfill.

In the presence of humidity and oxygen, pyrite oxidizes and produces sulphuric acid. The acid reacts with the calcium carbonates (for example, limestone) found in the crushed stone.

This chemical reaction produces sulphate and can form gypsum whose crystallization will cause the stone to burst, the backfill to swell, and the concrete itself to crumble and swell. This is usually a slow process. On average, experience suggests it takes not less than two years before a perceptible damage is produced.

Swelling of pyritic backfill is relatively complex and has scientific, technical and legal implications for the developer, designer and building owner as well as significant claims potential for the insurer.

A number of signs indicating pyrite as the source of a problem in a concrete floor are as follows:

- Gradually spreading, often star or cross-shaped cracks in the concrete slabs.
- Heaving of the concrete slab in the form of bulges or domes or noticeable curvature of the floor.
- Presence of needle-like white crystals mixed with the concrete near the cracks. Observations with a magnifying glass should reveal the characteristic shape of crystals, resembling new flakes. These crystals are very fragile and disintegrate as soon as touched.
- When partition walls rest against the floor slab, they may show signs of cracking with cracks generally over doors and/or at wall junctions.
- Internal/external doors may stick and/or catch on the floor.

It should be stressed that it is the combination of the observable signs that are indicative of the phenomenon, not any of the observable signs in isolation.

There are no specific guidelines for visual detection of pyrite in hard-core filling. The qualitative method of detection is by chemical analysis. It should be noted that the presence of pyrite is only one of the factors. Other potential factors which may lead to a problem include the type of rock, other constituent minerals, depth and compaction of backfill, presence/availability of water/oxygen.

Details

Pyrite exists in different forms, namely massive (chemically stable) and “framboidal” (chemically unstable). The framboidal form is characterized by an agglomeration of very small cubic crystals (not visible to the naked eye) with a very large specific surface. In some conditions, this form of pyrite can oxidize in the presence of water and react with other minerals present in the same rock to form gypsum. Gypsum, when it forms, occupies a much greater volume than pyrite, causing swelling of the granular backfill. The swelling produces cracking and causes concrete floor slabs to heave. In some cases, especially in garages, the foundation walls may also crack and be displaced outwards.

The chemical solutions formed during pyrite oxidation can be absorbed by the concrete, causing the concrete floor slab to sulfatize and heave. The swelling thus has two constituent elements, namely swelling of the aggregate and intrinsic swelling of the concrete slab. This chemical reaction is generally slow and it takes between 10 and 15 years after the building is constructed before it is visible to the occupants. Slab displacement levels vary, but can be as high as 5 mm per year.

The chemical reaction can remain active over long periods (more than 40 years, for example). The speed and extent of the reaction will depend on several factors, including the depth of the backfill, the percentage and type of pyrite present, the water content and porosity of the materials, and so on.

The presence of backfill liable to swelling because of pyrite has no impact on the environment or the health of the building in question.

Problematic aggregate is generally composed of significant percentages of argillaceous limestone and argillaceous shale. These rocks are composed mainly of clay minerals and carbonates (CaCO3), in varying proportions. They also contain variable percentages of pyrite, but generally not more than 1%. Because these types of rock contain significant percentages of clay minerals, they are more permeable to air and water and less resistant to gypsum crystallization.

The percentages of these types of rock in aggregate can vary considerably. For example, materials with very high swelling potential may be mixed with others that have negligible swelling potential, and there are, of course, many intermediate materials between these two extremes. The geographical sectors most affected by swelling are located close to geological formations rich in that particular type of rock, which is mined locally and may be used as granular backfill under concrete floor slabs.

Most aggregates used as underfloor backfill contain pyrite and other sulphurs, but a very large percentage of buildings will never exhibit symptoms of pyrite-related problems. This is because pyrite found in hard rock with low clay mineral contents does not oxidize and the materials remain stable.

Swelling of granular backfill under concrete floor slabs occurs as a result of chemical reactions involving some of the minerals present in the aggregates used. In particular, reactions such as this tend to involve iron sulphide (pyrite, pyrrhotite, etc.) and carbonates.

A reaction is influenced by a number of factors, including the presence of clay minerals that facilitate water absorption and iron sulphide oxidation, grain size classification and water content, the presence of bacteria, temperature, and so on. The depth of the backfill will also have an impact on the extent of the swelling. Swelling of the backfill generates pressure under the concrete floor slabs, which heave and crack as a result.

The by-products generated by the chemical reaction can also lead to sulfatizing of the concrete slabs, causing obvious additional swelling. In some cases, the damage observed may be related solely to sulfatizing. In other, more severe cases, mainly where there is a thick backfill layer between the foundation walls (e.g. in a garage), lateral pressure may also occur, causing cracks in the foundation walls.

Occasionally, raised floor slabs may be due not to the granular backfill but to swelling of the underlying rock. Where there is a risk that rock located near the surface will swell, the usual precautions should always be taken when constructing on the site.

Recommendations

The risk management surveyor shall satisfy him/herself as to the suitability of the ground conditions for the purpose of supporting the development, by requiring the developer to carry out necessary site investigations including chemical analysis of soils to ensure that there are no harmful contaminants or hazards, which could cause deterioration of any element of the development.

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Hard-core materials used in backfill, excavations, floors, and road bases, etc. should be certified by a competent laboratory that they are of a suitable nature and quality in relation to the purpose and conditions of their use. They should be chemically analysed to check if such materials contain any chemicals, which should also include the petrographic indicator of swelling potential. In all cases the Rrisk management surveyor should ensure that copies of this analysis are received and that were applicable any backfill materials are certified as fit for purpose.

The Petrographic Swelling Potential Indicator (PSPI) varies from 0 to 100 but is not a percentage. It is intended to be a visual evaluation of the sulphatic swelling potential of the materials used. An indicator of between 0 and 10 suggests a negligible potential, while at the other extreme an indicator of between 80 and 100 suggests a very high potential.

The following figures present the petrographic swelling potential that may generally be associated with the different PSPI values.

PSPI Petrographic Swelling Potential (information purposes only)

0 – 10 Negligible
11 – 20 Low
21 – 40 Low to medium
41 – 60 Medium to high
61 – 80 High
81 – 100 Very high

Any materials with a PSPI in excess of 20 will not be acceptable for insurance purposes.

Additional references:

Building Regulations:	Regulation 7: Materials and Workmanship. Approved Document C: Clause C4.7 a)
Technical Manual:	Section 20: Ground conditions
BRE Digest DG 522:	Hard-core for supporting ground floors of buildings: Part 1: Selecting and specifying materials Part 2: Placing hard-core and the legacy of problem materials. (Replaces BRE Digest 276 which has been withdrawn.)

Every care was taken to ensure the information in this article was correct at the time of publication (March 2021). Guidance provided does not replace the reader's professional judgement and any construction project should comply with the relevant Building Regulations or applicable technical standards. For the most up to date Premier Guarantee technical guidance please refer to your Risk Management Surveyor and the latest version of the Premier Guarantee Technical Manual.

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