

# Aggregates in Building Construction

What are we using, Why and What specifications are we using?

# Construction Aggregates

# Construction Aggregates

- Defined as:
  - *Coarse particulate materials used in construction including sand, gravel, crushed stone and also recycled materials such as slag and recycled concrete.*



# Construction Aggregates

- Aggregate is typically used in:
  - Concrete
  - Asphalt
  - Armour stone
  - Railway Ballast
  - Sub-base



# Sub-base

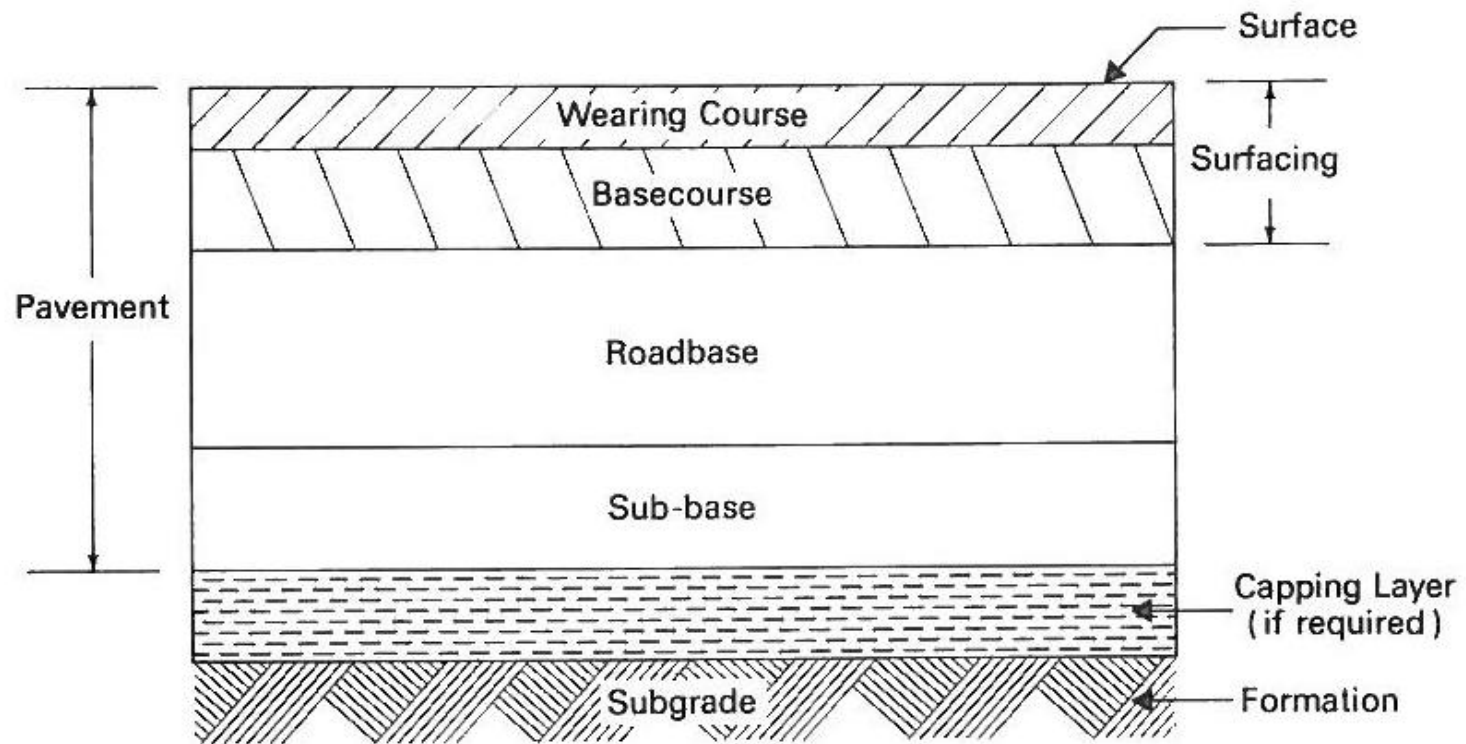


FIG. 10.1. Typical flexible pavement construction layers.

From the Geological Society Engineering Geology Special Publication No. 9 – Aggregates: Sand, gravel and crushed rock for construction purposes (2<sup>nd</sup> Edition), edited by MR Smith and L Collis

# Sub-base

- The material which has come under the most scrutiny has been sub-base.
- This is because it is a fairly ubiquitous material
- It has been not only been used beneath roads, but also beneath floor slabs
- It is this material which, when it contains pyrite, leads to the damage seen in a number of buildings in the greater Dublin area.
- What was called up or specified for use beneath floor slabs?



# Specifications



# What Was Typically Specified?

- Hardcore
- Crusher Run
- 70mm Down/4” Down
- Granular Material Type B
- Clause 804/804



# Specifications

Hardcore – Crushed Rock Only

Crusher Run – Material which has had one pass through a crusher

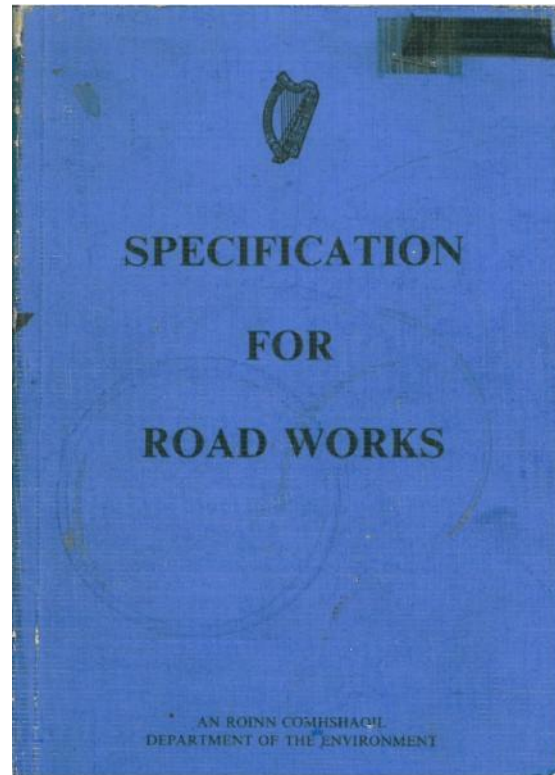
70mm Down/4” Down – Grading only

Granular Material Type B/804 – Fulfills the requirements of NRA Specification for Roadworks Series 800, Clause 804 Specification for Sub-Base

# Civil Specifications

## Series 800 – Sub-base

- Civil
- DoE Specification for Roadworks – Series 800
- 1979 – First Issued



# DoE Specification For Roadworks – 1979 - 2000

- Originally adapted from UK Guidance
- Known as the DoE Green Book
- Introduces Specification for Clause 804

Requirement	804
Material	Crushed Rock
Fines	Non Plastic
CBR	N/A
Moisture Content	N/A
Ten % Fines	50kN
Within 400mm of road surface (Frost Heave)	<13mm Heave
Within 500mm of Concrete (sulfate attack)	2.5g/l SO <sub>3</sub> 1% SO <sub>3</sub>

# Clause 804 in NRA Specification for Roadworks

	804 - 2000	804 - 2004	804 - 2013
Liquid Limit	20/21%	20/21%	20/21%
Moisture content	OMC to OMC-2%	OMC to OMC-2%	OMC to OMC-2%
Ten Percent Fines/LA Abrasion (from 2004)	130kN	LA <sub>30</sub>	LA <sub>30</sub>
Flakiness Index	<35	<35	<35
Magnesium sulfate soundness	>75 (This is equivalent to <25 according to current test methods)	<25	<25
Water Absorption	2%	2%	2%
If within 500mm of Concrete	1.9g/l SO <sub>3</sub>	AS <sub>0.2</sub>	See Clause 808

# What happened the Sulfate Requirement?

- Materials within 0.5m of concrete – See Clause 801 –  $AS_{0.2}$
- 2010 revision removed  $AS_{0.2}$  from Clause 801 and introduced two new materials
  - Clause 808 – Unbound Materials placed adjacent to Cement-Bound Materials
  - Clause 809 – Unbound Materials placed adjacent to Metallic Structural Elements

# Clause 808 and 809 - 2010

	Clause 808	Clause 809
Main Specification	804	804
Acid Soluble sulfate (AS)	AS <sub>0.2</sub>	-
Water Soluble sulfate (WS)	-	300mg/l SO <sub>4</sub>
Oxidisable sulfides (OS)	-	0.06% SO <sub>4</sub>

- These figures were further amended in 2013

# Clause 808 and 809 - 2013

	Clause 808	Clause 809
Main Specification	804	804
Acid Soluble sulfate (AS)	-	-
Water Soluble sulfate (WS)	1500mg/l SO <sub>4</sub>	300mg/l SO <sub>4</sub>
Oxidisable sulfides (OS)	0.3% SO <sub>4</sub>	0.06% SO <sub>4</sub>

The NRA Notes for Guidance on the Specification for Roadworks state the following:

*The use of the material may be permitted as structural backfill if it can be established with the written approval of the Employer's Representative that:*

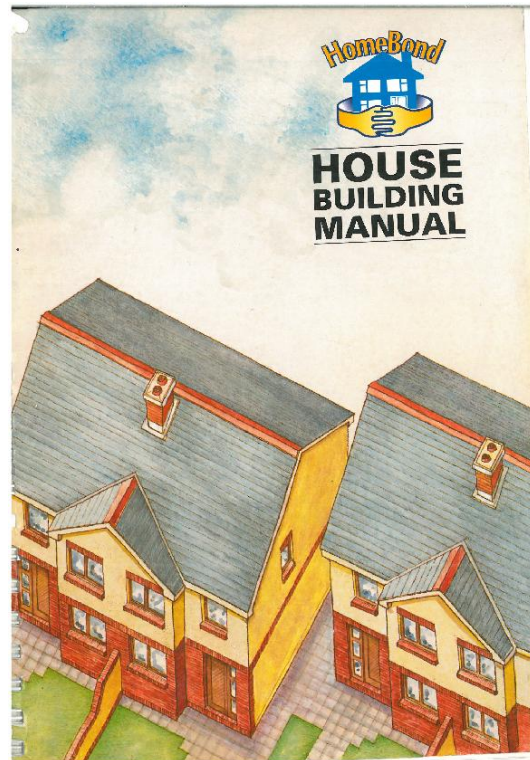
- (i) the material has been used in the past as structural backfill without leading to problems with sulfur compounds; and*
- (ii) the reason why the material will not cause a problem is known, based on an understanding of its chemistry and mineralogy.*



# Structural Specification

## Homebond - Hardcore

- Structural
- Homebond Specifications
- 1993 – First Issued



# Homebond Specification

- In 1993 the Homebond manual was published.
- Published to provide guidelines to those building both single houses or housing developments who wished to avail of the Homebond certification
- Requirement for granular material as fill beneath slabs.
- Referred to as *hardcore* or *crushed rock*
- Suppliers would provide products such as 3” *Down* or 5” *Clean*.

## INTRODUCTION

Hardcore should be placed and compacted in accordance with the guidance given on these pages. Failure to observe this simple guidance can result in expensive and disruptive remedial work.



Unacceptable fill material.



Failure of fill

1

Hardcore material should be clean graded crushed stone, free from shale, 100mm maximum size. Demolition material, site rubbish or pit run gravel must not be used. Excavated material must not be placed inside line of perimeter walls.

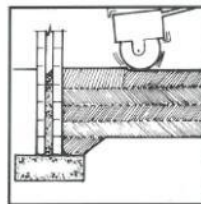


Dry rot material in fill

2

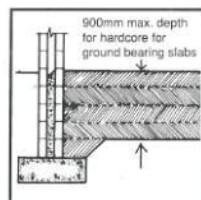
Consolidate hardcore in layers not exceeding 225mm in thickness.

This is essential to avoid subsequent settlement of hardcore. Particular attention should be paid to compacting hardcore where depth increases locally e.g. foundation trenches.



3

Total depth of hardcore should not exceed 900mm, except where a suspended floor is being used.



Where site conditions require a depth of fill of hardcore in excess of 900mm, a suspended floor construction should be used. Suspended floors can be of timber, in-situ reinforced concrete or precast concrete.

## INTRODUCTION

Hardcore should be placed and compacted in accordance with the guidance given on these pages. Failure to observe this simple guidance can result in expensive and disruptive remedial work.



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Failure of fill.



Good quality hardcore: clean, crushed, well graded stone.

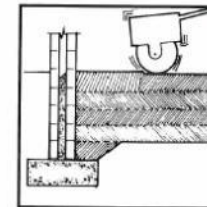
Where site conditions require a depth of fill of hardcore in excess of 900 mm, a suspended floor construction should be used. Suspended floors can be of timber, in-situ reinforced concrete or precast concrete.

1



Dry rot material in fill.

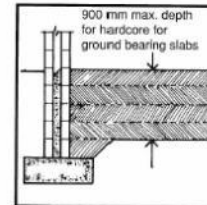
2



Consolidate hardcore in layers not exceeding 225 mm in thickness. Minimum depth of hardcore 150 mm.

This is essential to avoid subsequent settlement of hardcore. Particular attention should be paid to compacting hardcore where depth increases locally e.g. foundation trenches.

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Total depth of hardcore should not exceed 900 mm, except where a suspended floor is being used.



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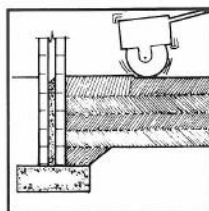


Dry rot material in fill.

## USE GOOD QUALITY HARDCORE

Hardcore material should be clean, graded, crushed stone, free from shale and 100 mm max. size. Site rubbish or pit run gravel must not be used and excavated material must not be placed inside the perimeter walls.

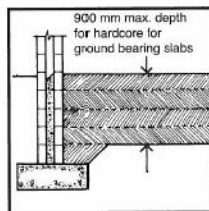
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Consolidate hardcore in layers not exceeding 225 mm in thickness. Minimum depth of hardcore 150 mm.

This is essential to avoid subsequent settlement of hardcore. Particular attention should be paid to compacting hardcore where depth increases locally e.g. foundation trenches.

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Total depth of hardcore should not exceed 900 mm, except where a suspended floor is being used.



Placed hardcore

## GRANULAR FILL MATERIAL FOR USE UNDER CONCRETE FLOORS

All granular fill material for use under concrete floors and footpaths should be fit for the purpose for which it is intended. The recommendations for such material and its use are as follows:

*The hardcore bed should be at least 150 mm thick. Hardcore should conform with IS EN 13242: 2002<sup>1</sup> and meet the specification as outlined in Annex E of the accompanying guidance document to this standard, SR 21: 2004 + A1: 2007<sup>2</sup>. The layer of hardcore should be well compacted, clean and free from matter liable to cause damage to the concrete. Specific guidance is given in Clause 3.4.2 of SR 21: 2004 + A1: 2007 on limiting the*

*presence of a reactive form of pyrite which may give rise to swelling or sulfate attack on concrete. A blinding layer should be provided in accordance with the specification given in Annex E of SR 21: 2004 + A1: 2007, for fines material. The blinding layer should be of adequate depth to fill surface voids thus creating an even surface and avoiding sharp projections, which may damage radon or damp-proof membranes.*

<sup>1</sup>Irish Standard IS EN 13242: 2002 - Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction

<sup>2</sup>Standard Recommendation (SR) 21: 2004 + A1: 2007 – Guidance on the use of IS EN 13242: 2002 – Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction (Incorporating Amendment 1: 2007).

IS EN 13242 and SR 21 are available from the National Standards Authority of Ireland [www.standards.ie](http://www.standards.ie).

Annex E from SR 21 is reproduced below.

## Annex E

(Informative)

An example format of a preferred specification for aggregate for unbound granular fill for use under concrete floors and footpaths.

Table E1 – Example specification for unbound granular fill for use under concrete floors and footpaths

Properties	Category to IS EN13242: 2002
Grading (Granular Course)	4/40 to Gc 85/15 or Gc 80/20 As per Table 3
Grading (Fines material for blinding top surface)	0/6.3 Gf 80 As per Table 4
Resistance to fragmentation	LA <sub>40</sub>
Water absorption* to IS EN 1097-6: 2000, Clause 7	WA <sub>24</sub> 2
For WA>2% magnesium sulphate* soundness value	MS <sub>25</sub>
Acid-soluble sulphate content: Aggregates other than air-cooled blastfurnace slag	AS <sub>0.2</sub>
Total sulfur: Aggregates other than air-cooled blastfurnace slag	S <sub>1</sub>

Note: Specifying values for all other properties described in IS EN 13242: 2002 is not necessary because, as specified in IS EN 13242: 2002, Clauses 4.1, 5.1, 6.1 and 7.1, they are not appropriate to the particular application at end-use or origin of the aggregate.

\*For Granular coarse material only.

## Notes:

- ♦ All granular material for use under concrete floors and footpaths should be fit for the purpose for which it is intended and recommendations for material to be used under concrete floors and footpaths are contained in IS EN 13242: 2002 and SR 21: 2004 + A1: 2007. Members should advise when ordering that the material is for use under floors and footpaths and obtain confirmation on the delivery docket that the granular fill material delivered to site for use in these areas is in accordance with these recommendations.
- ♦ Granular fill material should be placed and compacted in layers not exceeding 225 mm in thickness.
- ♦ Where site conditions require a depth of granular fill material in excess of 900 mm, a suspended floor construction should be used.

- Current NRA Clause 804/808/809 requirements are:

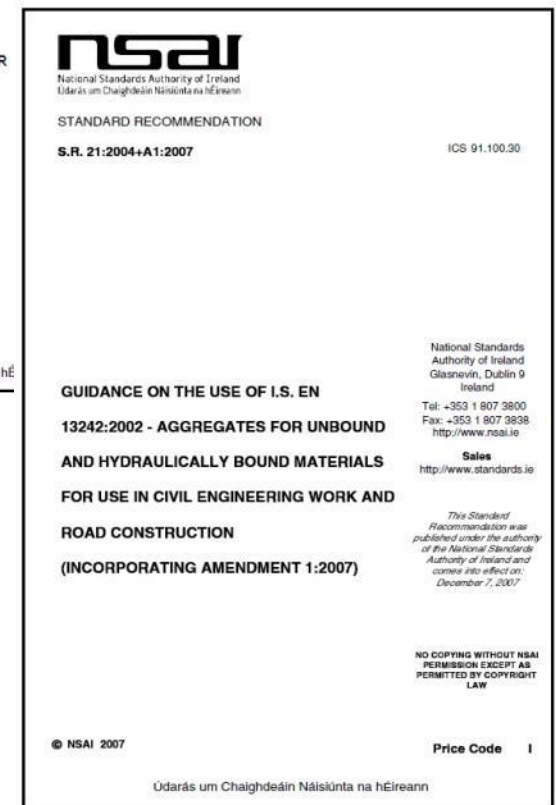
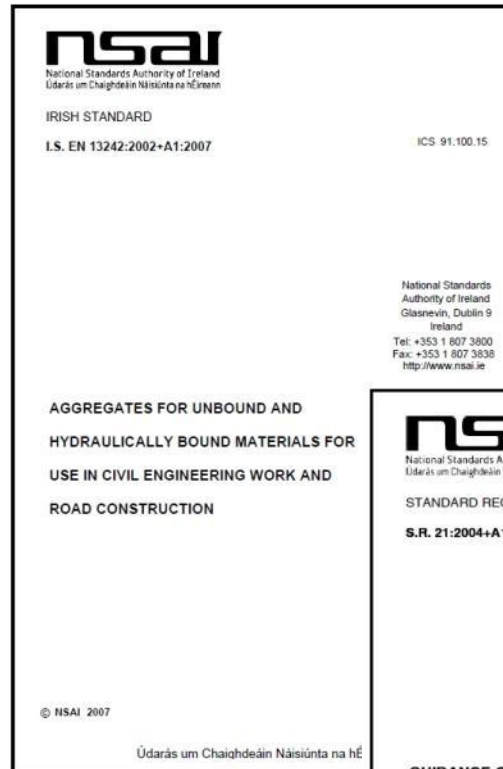
	804 - 2010	808 - 2013	809 - 2013
Fines/Liquid Limit	20/21%	20/21%	20/21%
Moisture content	OMC to OMC-2%	OMC to OMC-2%	OMC to OMC-2%
LA Abrasion	LA <sub>30</sub>	LA <sub>30</sub>	LA <sub>30</sub>
Flakiness Index	<35	<35	<35
Magnesium sulfate soundness	<25	<25	<25
Water Absorption	2%	2%	2%
Acid Soluble sulfate (AS)	NR	NR	NR
Water Soluble sulfate (WS)	NR	1500mg/l SO <sub>4</sub>	300mg/l SO <sub>4</sub>
Oxidisable sulfides (OS)	NR	0.3% SO <sub>4</sub>	0.06% SO <sub>4</sub>

- Current Homebond requirements are Annex E from SR21:2004 + A1:2007:

Granular fill material for use under Concrete floors	
Properties	Category to IS EN 13242:2002
Grading (Granular Course)	4/40 to Gc 85/15 or Gc 80/20 as per Table 3
Grading (Fines material for blinding top surface)	0/6.3 Gf 80 As per Table 4
Resistance to Fragmentation	LA <sub>40</sub>
Water Absorption	WA <sub>24</sub> 2
For WA>2% magnesium sulfate soundness value	MS <sub>25</sub>
Acid Soluble sulfate content: Aggregates other than air cooled blast furnace slag	AS <sub>0.2</sub>
Total sulfur: Aggregates other than air cooled blast furnace slag	S <sub>1</sub>

# Standards

- IS EN 13242:2002
- SR 21:2004



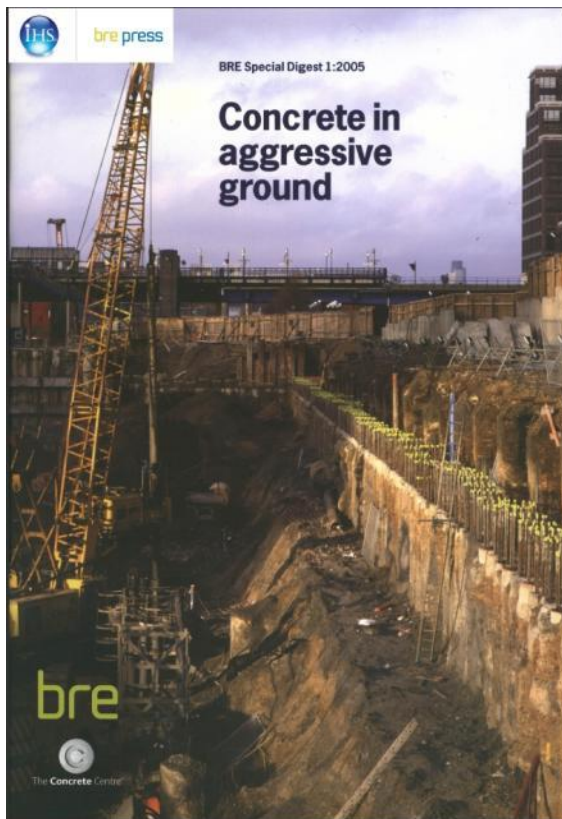
# SR 21:2004

- “*extensively uses the **NRA SRW** as a basis for comparison of the requirements of IS EN 13242:2002. This has been done in the **absence of any other guidance** on aggregates for unbound or hydraulically bound materials for use in civil engineering works and road construction. It is important to highlight that IS EN 13242:2002 is **not solely dedicated to the specification of road construction**, however the majority of usage would be within this general area”.*
- “*Producers and specifiers should be aware that the recommended category  $S_1$  ... **may not completely exclude the risk of swelling** due to the presence of a reactive form of pyrite. Where it is envisaged that material from a quarry may be used ... It is advised that a **suitably experienced petrographer** carry out a detailed **mineralogical examination**...*”
- However, SR21 is currently undergoing revision. Watch this space!



# Other Relevant documents

- Best practice in the UK as opposed to EN's:
  - BRE Special Digest 1 – Concrete in Aggressive Ground
  - TRL 447 – Sulfate Specification for Structural Backfills
  - BRE DG 522 – Hardcore for Supporting Ground Floors of Buildings

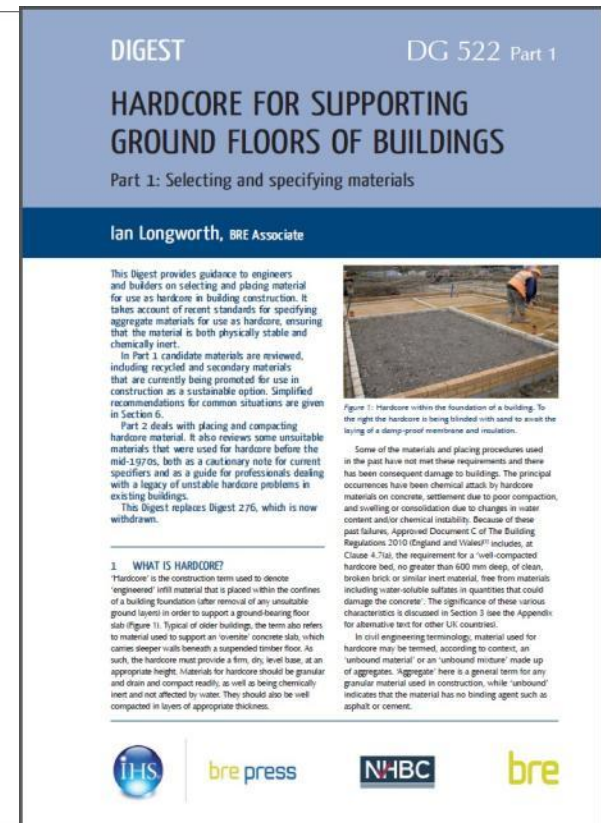


## Sulfate specification for structural backfills

Prepared for Quality Services, Highways Agency

J M Reid (TRL Limited), M A Czerewko and J C Cripps (University of Sheffield)

TRL Report TRI.447 (Updated)



# Chemical Limits

- These documents provide suggestions to assess the generation of potential sulfate through the oxidation of sulfides!
  - Total Potential sulfates (TPS) = Total sulfur (TS)\* 3
  - Oxidisable sulfates (OS)= TPS – Acid soluble sulfates (AS)
- These provide an indication of the potential pyrite present in a sample
- TRL 447 includes recommended limits in relation to avoiding Sulfate attack on concrete
- BRE DG 522 presents a sample specification for crushed rock/hardcore

# Chemical Limits

	TRL 447	BRE DG 522
Water Soluble sulfate (WS)	1500mg/l SO <sub>4</sub>	1500mg/l SO <sub>4</sub>
Oxidisable sulfides (OS)	0.3% SO <sub>4</sub>	0.8% SO <sub>4</sub>

- TRL 447 States:
- *If the material is classified as unacceptable because of OS or TPS values but has been used satisfactorily as structural backfill in the past, seek expert advice, consider history of material and carry out detailed testing*
- BRE DG 522 states:
- *In practice, this limit could be raised further for particular materials if it can be established (eg by petrographic study) that pyrite is predominantly present in a non-reactive form.*

# Summary

- Specifications commonly used in Ireland contained sulfate limits to prevent sulfate attack on concrete
- BRE SD1 and TRL 447 deal with sulfate attack on concrete and/or metallic elements. They also look at the potential for the generation of sulfate from the oxidation of sulfides
- BRE DG 522 also looks at the likelihood of sulfate attack but also considers expansion problems associated with pyrite. The limits proposed within are also conservative and may be relaxed if the mineralogy of the rock is assessed and understood.
- However, there is no single test that assesses a material for pyrite. A combination of chemical and petrographic tests as well as the standard aggregate tests are required to fully understand the behaviour of an aggregate

## Summary - Continued

- Therefore a series of tests are used to examine the material and determine if it is suitable for use.
- Two main specifications currently being called up.
  - Clause 808 material coming from the NRA SRW
  - Annex E from SR21:2004 + A1:2007.
- SR21 is undergoing review and the updated version shall be issued soon.

Thank you, questions...

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