ProRail

**Asset management**

# Product specification

## Aggregates for quartzless railway ballast

Ballast free of crystalline silica and asbestos - Clarification

This document is a translation of the Dutch version ref.: SPC00353-2-V001 e
An English translation of the Dutch version has been made available for market parties participating in this market consultation. In the event of unexpected discrepancies, the original Dutch version shall in all cases have precedence.

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# 2 Introduction

This product specification contains the clarification of the requirements and delivery conditions that ProRail sets for the direct and/or indirect supply to ProRail of "***Quartzless railway ballast"*** that contains *no crystalline silica or asbestos*.
Because crystalline silica occurs in various forms, including quartz, the term *quartzless* does not suffice. Terms such as "*quarts-free*" or "*low-quartz*" cannot be used because they exclude other forms of crystalline silica (e.g. tridymite and cristobalite). These forms of crystalline silica (quartz, tridymite and cristobalite) are carcinogenic under certain circumstances (subject to concentration and time duration) and thus included in the *List of legal limit values for carcinogenic substances, determined based on the limit value effect*" (Official Gazette of the Kingdom of the Netherlands; publication 02-12-2019 09:00; Ministry of Social Affairs and Employment; Official Gazette 2019, 65293; Decrees of a general nature).

Exposure to respirable crystalline silica may cause lung fibrosis and eventually lung cancer. This is why crystalline silica dust is classified as a carcinogenic substance. The Working Conditions Regulations, Annex 13, list B/B1, "*List with legal limit values for carcinogenic substances, determined based on the limit value effect*", includes *respirable crystalline silica dust* (quartz, cristobalite and tridymite) with a limit value of 0.075 mg/m$^3$ (TGG 8 hours). This means that no negative health effects were found with concentrations below this threshold at a time-weighted average of 8 hours.

Due to article 4.17 of the Working Conditions Decree (see 2.2), however, ProRail opted for rock where *no crystalline silica* occurs whenever possible and if available, to eliminate the risk of presence and exposure to respirable crystalline silica dust during production, processing, maintenance and disposal of this railway ballast.

Another carcinogenic substance that may occur in rock and has also been included in the "*List of legal limit values for carcinogenic substances, determined based on the limit value effect*" is ***asbestos***. Once again, ProRail applies article 4.17 of the Working Conditions Decree and opts for rock without asbestos.

## 2.1 Purpose

The purpose of this clarification to product specification SPC00353-1 is to provide insight into the background and where necessary the substantiations of the requirements with regards to certification of "Quartzless railway ballast" i.e. railway ballast free of crystalline silica and asbestos.

Whether this document refers to ***ballast, quartzless ballast or railway ballast***, the intended meaning is *railway ballast free of crystalline silica and asbestos*.

## 2.2 Scope and context

Due to dust formation and the associated respirable crystalline silica-related health issues that emerge during the production, transportation, processing and maintenance (including disposal) of railway ballast for the rail infrastructure of ProRail, specification SPC00353-1 was drafted for railway ballast free of crystalline silica and asbestos.
Dutch working conditions legislation currently sets a legal limit value for exposure to respirable crystalline silica dust. When inhaled, crystalline silica dust may cause lung conditions such as silicosis. In addition, crystalline silica dust is a proven carcinogenic for humans. This also applies to the dust of asbestos. For asbestos present in building materials, a limit value was set of 100 mg/kg mass (0.01% m/m) and a limit value for the concentration of asbestos fibres in the air of 2000 fibres per cubic metre was calculated over a reference period of 8 hours per day.
Based on Article 4.17 of the Working Conditions Decree, which states that carcinogenic materials must be replaced with non-carcinogenic materials insofar as this is technically feasible, ProRail observes this principle for both crystalline silica and asbestos. As such, any railway ballast applied must contain no

crystalline silica or asbestos in accordance with the most currently advanced test methods (with the result crystalline silica and asbestos *not detectable*). SPC00353-1 was drafted because specific requirements must be set for railway ballast that contains no crystalline silica or asbestos.

## 2.3 Scope and interfaces with other products

Quartz, cristobalite and tridymite are crystalline forms of silicon dioxide ($SiO_2$). Silicon dioxide is also referred to as silica. Crystalline silica occurs in most types of rock in varying concentrations. The requirements in SPC00353-1 are intended to approve rock with a crystalline silica content below the detection limit of the method with X-ray diffraction (XRD) only. That is when the rock is considered crystalline silica-free.

Because rocks without crystalline silica differ from the crystalline silica-containing rocks most commonly used by ProRail to date, such as quartz microdiorite (porphyry), meta-sandstone, granite gneiss, granodiorite and quartz diorite, other and additional requirements must be drawn up in order to prevent health and performance risks such as the presence of fibrous components (asbestos) and a possibly shorter lifespan. Furthermore, some types of rock require additional examination of potential conversion reactions and the products they form. Mafic rocks contain a lot of magnesium (Mg) and iron (Fe) and lower levels of silicon dioxide ($SiO_2$), but can react with moisture and air in carbonation reactions. The products resulting from the transformation of the original rock must be assessed as well. This is cause for some additional requirements.

The presence of asbestos in the certified quarries in accordance with SPC00033 was analysed with dust simulation measurements performed by TNO (report R11703 of 31 August 2021). This revealed that the quartz-containing rock that was certified until 2021 contains no asbestos.

## 2.4 Definitions and abbreviations

Flakiness Index

The Flakiness Index is a measure for the content of flat rock particles and applies to pieces of rock with a particle size between 4 and 100 mm (sieve size). In the first sift, a 31.5/50 sample is separated into 12 samples of various sizes. Each size is associated with a bar sieve of certain dimensions. Each particle size category undergoes a second sieve with the bar sieves, see “Table 1 – Bar sieves” below.

Table 1 — Bar sieves

| Particle size fraction $d_i/D_i$ mm | Width of slot in bar sieve mm |
|---|---|
| 80/100 | 50 ± 0,5 |
| 63/80 | 40 ± 0,5 |
| 50/63 | 31,5 ± 0,5 |
| 40/50 | 25 ± 0,4 |
| 31,5/40 | 20 ± 0,4 |
| 25/31,5 | 16 ± 0,4 |
| 20/25 | 12,5 ± 0,4 |
| 16/20 | 10 ± 0,2 |
| 12,5/16 | 8 ± 0,2 |
| 10/12,5 | 6,3 ± 0,2 |
| 8/10 | 5 ± 0,2 |
| 6,3/8 | 4 ± 0,15 |
| 5/6,3 | 3,15 ± 0,15 |
| 4/5 | 2,5 ± 0,15 |

For example, the 40/50 part is separated in the first sift (among others). This is the size (mass) that does not pass the #40 mm sieve but does pass the #50 mm sieve. This size requires a bar sieve with a width of 25 ± 0.4 mm between bars. This is always half of the maximum particle size of that category, in this case half of 50. The portion of the 40/50 mass that passes this bar sieve is considered flat stones that break more easily. This is determined for all sizes from “Table 1” and results in an average for the entire sample.

The mass percentage of flat stone pieces must be limited (depending on the application) due to its greater tendency to break under stress (formation of settlements and smaller particles). The percentage of flat pieces also affects the result of various test methods such as the Los Angeles value

(LA), Micro Deval (MD) and the Aggregate Impact Value (AIV) or Schlagzertrümmerung (SZ). By subjecting the flat piece content to strict requirements, the values of e.g. the LA become more accurate and consistent. ProRail opted for the $FL_{15}$ category which means that a maximum of 15 mass percent of flat stone pieces may be present in the railway ballast. NEN-EN 13450 does not offer a stricter class for the Flakiness Index (FI).
In NEN-EN 13450, the Flakiness Index is the reference test for the shape of the stones in railway ballast.

Shape Index:
The Shape Index is a measure for the content of “non-cubic” stones and applies to pieces of rock with a particle size between 4 and 100 mm (sieve size). The length L (the greatest distance between two parallel surfaces) and the thickness E (the smallest distance between two parallel surfaces) of the pieces of rock from a monster, e.g. 31.5/50, are determined. If L/E exceeds 3, the piece is considered non-cubic. The Shape Index number is the total mass of particles where the length divided by the thickness exceeds 3 (SI value). These are non-cubic stones. The Shape Index, however, also indicates what percentage of the stones is cubic (namely 100-SI). Cubic stones are more resistant to fragmentation and create a sound hook resistance and a stable particle skeleton. The percentage of cubic and non-cubic pieces (SI value) also affects the result of various test methods such as the Los Angeles value (LA), Micro Deval (MD) and the Aggregate Impact Value (AIV) or Schlagzertrümmerung (SZ). By subjecting the non-cubic content to (strict) requirements, the values of e.g. the LA become more accurate and consistent. ProRail opted for the $SI_{20}$ category which means that a maximum of 20 mass percent of non-cubic stone pieces may be present in the railway ballast.

Quartzless railway ballast – ballast free of crystalline silica and asbestos:
Quartzless railway ballast refers to railways ballast free of crystalline silica and asbestos, made of broken natural stone from natural stone quarries where 100% of the surface of the stone can be described as completely broken **and** the presence of crystalline silica has been excluded with X-ray diffraction (XRD) **and** the presence of asbestos has been excluded with SEM/EDX.
Both the XRD and SEM/EDX methods have a certain detection limit below which the presence of crystalline silica or asbestos cannot be detected. In such case, the *absence* of crystalline silica or asbestos is assumed to have been demonstrated.

Ballast bed:
The ballast bed is the layer of railway ballast from the top of the sleeper or bearer to the substructure (earth track or structure). The thickness of this ballast bed can vary depending on the requirements set out in the design prescription (OVS00056-5.1 Track and superstructure rail in ballast) and the location. The ballast bed allows for placement corrections both in height and laterally. This is usually done with heavy machinery such as the tamping machine. A ballast bed can also be corrected locally by hand or with a railway crane with a tamping device. When applying the tamping machine, it is important to maintain enough ballast under the bottom of the sleeper or switch girder. This will prevent contact with the substrate or geotextile, damage to the ballast due to compression, damage to the sleepers and accelerated degradation of the ballast bed. The ballast bed of a newly constructed track generally consists of the same type of rock. The rock is then replenished during maintenance in the years that follow. This may involve a different type of rock. As a result, it is almost certain for a ballast bed not to consist of one homogeneous type of rock.

Railway ballast size:
Railway ballast size (referred to in SPC0003 as “fraction”) is defined by one pair of sieves (#) in mm with “d” as the lower limit and “D” as the upper limit between which the majority (mass) of the total sieve distribution lies. Our ballast types 1 and 1a, for example, fall under ballast size 31.5/50. This means that

the mass percentage of the portion of this ballast that passes through the square 50 mm sieve but not the square 31.5 mm sieve must be at least 50% in accordance with NEN-EN 13450:2003+C1:2006.
Over time, the ballast will degrade due to wear and load (trains and maintenance) and increasingly fine particles will form (including pollution). As a result, the size distribution will shift. Very old ballast, for example, may pass through sieve # 21 mm at a rate of 50% while this rate cannot exceed 3 percent for new ballast from the quarry.

XRD:
X-ray Powder Diffraction - XRPD, usually abbreviated to *XRD*, is a powerful non-destructive testing method (NDT) for determining a range of physical and chemical properties of polycrystalline and amorphous materials such as rock. This testing method is now being used internationally with a wide range of materials.
XRD is a laboratory technique used to determine whether a rock contains crystalline silica or potential asbestiform minerals (such as amphiboles).
X-ray diffraction can be performed either *qualitatively* or *quantitatively* . The detection limit for crystalline silica is around 0.1 mass percent but varies depending on the type of rock. Though Qualitative XRD provides a good result, Quantitative X-ray diffraction includes modelling and is better suited for determining the presence of crystalline silica. Due to the types of rock that will be applied as railway ballast, a high rate of reflections from other minerals is expected to be found in the diffraction patterns. As such, the quantitative method with deconvulsion (“full pattern fitting” method such as Rietvelt refinement) is a better option. The result is more accurate because it takes into account overlapping reflections of other minerals. That is why ProRail requires a **quantitative XRD**.
NEN-EN 13925 is the X-ray diffraction standard. It consists of 3 parts. These standards are mostly *descriptive* and involve general aspects of XRPD technology. The primary aims of these standards are:

- practical guidance, offering uniform concepts and terminology for the use of XRPD technology in NDT with general information about the possibilities and limitations relevant to laboratories.
- offering a foundation for quality assurance in XRPD laboratories, i.a. through performance testing and instrument monitoring and by comparing results of different instruments;
- applying radiation protection.

SEM/EDX:
SEM-EDX is a combination of two techniques: “Scanning Electron Microscopy” (SEM) and “Energy-Dispersive X-ray Spectroscopy” (EDX or EDS, where the “X” stands for X-ray and the “S” for spectroscopy).

SEM:
SEM (Scanning Electron Microscopy) allows for the microscopic surface structures of the sample to be examined with high precision and more accurately than with a traditional light microscope. The resolution of a scanning electron microscope can be less than 1 nm, which is much higher than that of a light microscope. This is why SEM provides a much higher quality and more precise image of the sample's surface topography.

EDX:
In order to determine the elementary composition of the sample, an EDX detector is connected to the SEM device. An EDX detector identifies the elements in the sample with X-rays and determines their concentrations and distribution. This makes it possible to determine which elements and compounds (minerals), if any, are present in the rock.

XRD is the most accurate method to identify crystalline silica while SEM/EDX is the most accurate method for determining the presence of asbestos.

## 2.5 References

### 2.5.1 Standards and norms

The references refer to NEN-EN 13450:2003+C1:2006. NEN-EN 13450:2003+C1:2006 (nl) is the Dutch translation of EN 13450 of February 2002. The English version takes precedent over the Dutch translation because we always source our railway ballast abroad. EN 13450 (en) of December 2002 is up for revision which should be published in 2023. This means that NEN-EN 13450:2003+C1:2006 (nl) will have to be amended as well. ProRail's SPC00033 and SPC00353 refer to EN 13450 and will have to be checked for validity and potential amendments. The new NEN-EN 13450 will consist of 2 parts. Part 1 discusses the properties and characteristics of the railway ballast and part 2 provides complementary information).

Furthermore, NEN-EN 13450 (en) of December 2002 refers to various other EN standards (see paragraph 2.5.1 “Standards and norms” of SPC00353-1) which have now been partially updated. This SPC00353 always refers to the latest issue as included in paragraph 2.5.1 “standards and norms”.

NEN-EN 933-5 (en) February 1998 “Test methods for geometric properties of aggregates – Part 5: Determination of the percentage of broken surfaces in course aggregates”, which is included in SPC00033, does not apply to this SPC00353 because recycled quartzless railway ballast is not (yet) used or available.

### 2.5.2 Prescriptions and procedures

OVS00056-5.1 “Rail track and superstructure in ballast”: indicates, for each TSI-category (P1, P2, P3, P4, P5, F1 and F2) in combination with the track load according to UIC specification 714 (load classes 1 through 6) the thickness of the ballast bed beneath the sleeper when building a new ballast bed and when replacing the ballast bed in an existing situation. This depends on the rail profile, sleeper type straight or bent and the sleeper distance. This can be used to calculate the required amount of ballast per linear metre of track.
OVS00056-5.1 paragraph 3.2.6 “Ballast bed” only mentions SPC00033. Of course, “SPC00353-1” must be read as well for ballast free of crystalline silica and asbestos. In due course, the text from OVS00056-5.1 "Rail track and superstructure in ballast" will be amended accordingly and it will also be indicated under which conditions and where quartzless ballast is to be used.

The Dutch Soil Quality Decree and the associated Soil Quality Regulation: published in the Official Gazette on 21 December 2007 ensure that no harmful materials can be deposited in the environment. This concerns *leaching* of the building material in particular, in this case the rock that makes up the railway ballast. This does not exclude the possibility of risks in other aspects. For example, The Soil Quality Decree does not address the risks of e.g. respirable crystalline silica or other potentially harmful materials that can become airborne due to the use of railway ballast.

PBE00012-V2.1: document about railway-specific products that are to be purchased in the free market. Available on the Procurement page:
https://www.prorail.nl/siteassets/homepage/samenwerken/leveranciers/documenten/beleid-inkoop-railinfraproducten-19-02-2021.pdf
It contains links to i.a. the certified suppliers as well as ProRail-approved certifying bodies.

# 3 Technical requirements

The foundation for the technical requirements in this SPC00353-1 is NEN-EN 13450:2003+C1:2006 (nl) “Aggregates for railway ballast” of February 2003. This standard indicates how certain properties of aggregates can be determined in a standardised way. The standard uses categories.
The choice of category is up to the user. In some cases, the user can choose to skip a test (“no requirement”) or include a more stringent value in their terms of delivery. In the latter case, the user specifies this clearly in their terms of delivery.

In NEN-EN 13450, neither the quartz content of rocks nor the dangers of inhaling dust are mentioned (inhalable dust, respirable dust or respirable quartz dust). Nor is there mention of the risks involved if the rock contains asbestos or other harmful materials.
Chapter 8 “Harmful components” does state that *ballast shall not comprise any components or materials apart from those specified in this standard.”*. Article 6.5 “Fines” states that fines must be considered non-harmful if the total content of fines is lower than the specified relevant category *“in accordance with provisions applicable to the location where the aggregates are used”.* Because the material specified in the standard mostly concerns natural stone, each natural stone is considered non-harmful if the fines content (particles smaller than 0.063 mm) falls within a category **and** complies with the provisions applicable to the country of use. Because ProRail opts for the most stringent requirement, category A (maximum mass percentage to pass the 0.063 mm sieve is 0.5%), the statutory requirements of the Netherlands determine whether a problem exists or not. This is not the case if the stone remains intact (retains its solid form), but if fines (dust) spread in the air and become inhalable, the above applies. This is, however, inherent to the use of quarry stone, aggregates or crushed stone. When limit values are exceeded, the risk of inhalable dust, respirable dust, respirable quartz dust and respirable asbestos dust emerges. To that specific end, several requirements have been included into this SPC00353-1 to ensure that quartz and asbestos cannot occur in the rock. It has now been established that compliance with category A for very fine particles (Fines) cannot prevent exposure risks to respirable quartz dust. As such, work must be carried out in accordance with the Occupational Health and Safety Strategy (Dutch: AHS) and Article 4.17 of the Working Conditions Decree (see 2.2).

In the upcoming EN 13450 Part 1, Chapter 8 "Harmful components" has been removed and "*Fines content*" was made to include that "*Fines shall be considered non-harmful if the total fines content is less than the relevant category"*. In Part 2 of the upcoming EN 13450, “*Fines content*” has been made to state that “*Fines shall be considered non-harmful for the performance of railway ballast if the total fines content is less than the relevant category”* with the addition *“in accordance with the provisions applicable to the location of use of the aggregate”*. Fines do not contribute to the intended functions of the railway ballast and pose a risk of harmful inhalable and respirable dust. ProRail also argued for a stricter category for "fines" during the review of the draft of EN 13450, but this was denied.

In Chapter 2, “Normative references”, EN 13450 and NEN-EN 13450:2003+C1:2006 refer to a series of EN standards, some of which are outdated. SPC00353-1 uses the most recent versions of the standards. This means that in several cases where EN 13450 and NEN-EN 13450:2003+C1:2006 refer to an annex from that document, the reference is no longer accurate because the annex is included in the latest EN standard. For example, Annex C (normative) for determining the Los Angeles coefficient from EN 13450 is included in NEN-EN 1097-2 of 2010 as Annex A. This makes no difference for the result.

## 3.1 Functional requirements

1. Only ballast that meets both definitions of “3.2 railway ballast” and “3.3 natural railway ballast” from NEN-EN 13450:2003+C1:2006, Chapter 3 “Terms and definitions” is permitted for deliveries to ProRail.
   By requiring that the ballast meets both definitions, it is ensured that this is always a natural stone of mineral origin and that the surface is 100% broken. The 100% broken surface is important for hook resistance, which is important for the stability (transverse and longitudinal resistance) of the track. As such, round particles (such as gravel or broken gravel) with smoother surfaces and a lower hook resistance are excluded. In addition, any artificial (side) products from industrial processes such as blast furnace slags and steel slags are excluded. Prior experience with these products from industrial processes indicates that they are generally of lesser quality and do not meet all of the current SPC00353-1 requirements, including the Soil Quality Decree. Prior experience with natural broken aggregates of mineral origin as railway ballast is good.

2. For a clarification see Chapter 2 “Introduction”.

3. For a clarification see Chapter 2 “Introduction”.

### 3.1.1 Quartzless railway ballast

Requirements to demonstrate that the ballast is free of crystalline silica.

4. If both the analysis by the supplier/quarry and the counter expertise contain the result “crystalline silica not detectable”, it is assumed that the delivered railway ballast does not contain crystalline silica for the duration of the frequency period (i.e. until the next routine analysis).

5. Because the crystalline silica percentage in the rock is of vital importance for the health of all parties involved , the analysis must be performed on a representative sample in accordance with NEN-EN 932-1. The goal is to obtain a composite sample that is representative of the average properties of a batch. This norm is observed until further notice, despite the fact that these sampling techniques are primarily relevant in a civil engineering context and not for establishing the composition of rock. Over the course of the current year of 2022, it is being investigated whether sampling for environmental purposes (SIKB protocol 1002, version 9.0 of 1 February 2018; Sampling for batch analysis of unmoulded building materials (protocol 1002)) is a better alternative.

6. It is important to ascertain that the rock does not contain crystalline silica. This can only be done with Quantitative X-ray Diffraction (XRD). XRD gives a much more accurate result than the assessment on a few stone fragments that are turned into grinding plates for visual examination under the microscope. X-ray Diffraction (XRD) has a detection limit for crystalline silicates of approx. 0.1 mass percent. Quantitative X-ray Diffraction is the method of choice because it is more accurate (correction for reflection overlap). If quantitative XRD fails to detect crystalline silica, it is currently assumed that a rock does not contain crystalline silica.

7. The quantitative XRD analysis must be performed by experienced laboratories. A laboratory that is internationally recognised for the quality of its research methods must be selected. Annex 4 “Additional provisions for quantitative XRD analysis” describes the minimum conditions a lab must achieve in order to qualify on top of compliance with NEN-EN 13925-1, NEN-EN 13925-2 and NEN-EN 13925-3.

8. ProRail must be notified immediately if the presence of crystalline silica is detected in the rock. It may have repercussions for ongoing projects and the health of all those involved.

9. Quantitative XRD can detect a rare quartz crystal in the sample, a deposit from a quartz vein in the quarry's bedrock or contamination by a host rock with crystalline silica despite

geological analyses, petrographic reports, etc. classifying the mass of the rock (bedrock) from the quarry as free of crystalline silica. This is referred to as "*non-primary crystalline silica*". Rather than being formed together with the rock itself (primary), this crystalline silica ended up in pores and cracks due to subsequent processes or due to intrusions into the bedrock. Other potential causes include contamination by a host rock or an extraction area with a different type of rock. Rather than immediately rejecting the quarry, it needs to be investigated, in consultation with ProRail, whether or not the quarry may continue to supply Quartzless railway ballast. An extra quantitative XRD analysis to replace a negative result (crystalline silica present) can only be conducted after ProRail's written permission.

10. The 4 mandatory analyses per year may be supplemented with no more than 1 extra quantitative XRD analysis per year. If the crystalline silica test comes back positive for the second time in the same year, ProRail will consider this an indication that the rock is not free of crystalline silica.

11. ProRail requires that each extra quantitative XRD analysis (in accordance with requirement 9) contains the result "crystalline silica not detectable". The likelihood that "non-primary crystalline silica" or contamination will cause a bedrock devoid of crystalline silica to once again test positive is thought to be low (though not impossible, of course).

12. When the extra quantitative XRD analysis comes back positive (i.e. crystalline silica detectable), the certificate is withdrawn immediately. The need for additional inquiry can then be established in consultation with ProRail.

13. Because the percentage of crystalline silica in the rock is of essential importance to the health of all parties involved, ProRail may ask a third independent party to take a representative sample in accordance with NEN-EN 932-1 in order to determine the percentage of crystalline silica in the rock by means of quantitative XRD. This analysis can be performed by a certifying body in or outside the presence of ProRail. This is primarily intended for cases of doubt about the test results (e.g. when the quarry/supplier has to order an extra XRD) and for the initial certification of a quarry as validation. The producer/supplier/quarry declares in writing that this will be permitted and easy for the CB to check.

### 3.1.2 Asbestos-free railway ballast

Requirements to demonstrate that the ballast is free of asbestos.

14. If both the analysis by the supplier/quarry and the counter expertise contain the result "asbestos not detectable", it is assumed that the delivered railway ballast does not contain asbestos for the duration of the frequency period (i.e. until the next routine analysis).

15. Because the asbestos percentage in the rock is of vital importance for the health of all parties involved, the analysis must be performed on a representative sample in accordance with NEN-EN 932-1. The goal is to obtain a composite sample that is representative of the average properties of a batch. This norm is observed until further notice, despite the fact that these sampling techniques are primarily relevant in a civil engineering context and not for establishing the composition of rock. Over the course of the current year of 2022, it is being investigated whether sampling for environmental purposes (SIKB protocol 1002, version 9.0 of 1 February 2018; Sampling for batch analysis of unmoulded building materials (protocol 1002)) is a better alternative.

16. Natural stone of mineral origin that is processed into railway ballast must be demonstrably free of asbestos by means of an SEM/EDX analysis performed by the supplier/quarry (result: asbestos not detectable).
    Because the mineral composition of the rock changes due to the changes in the type of rock from quartz-bearing to quartzless rock, other risks are involved. One such risk is the potential presence of asbestos. ProRail, however, is committed to preventing any health issues. Rocks such as dunite or peridotite or other rocks with a high concentration of olivine may contain asbestos in the bedrock due to their geological history. In addition, such rocks may react with water and CO2 in the air under certain circumstances and transition into other

solid(s) (rock). One example is serpentine which occurs in various forms. Chrysotile (white asbestos), for example, is associated with a health risk. For this reason, each new quartzless rock is subjected to an asbestos analysis as well.

17. Demonstrating the absence of asbestos with SEM/EDX must be done in accordance with IFA-AM 7487 “Verfahren zur analytischen Bestimmung geringer Massengehalte von Asbestfasern in Pulvern, Pudern und Stäuben mit REM/EDX “. This German standard was selected due to its very low detection limit and the fact that it is used in deliveries to the DB, for example. A potential alternative is NEN-ISO 14966 (en) December 2019 Ambient air – Determination of numerical concentration of inorganic fibrous particles – Scanning electron microscopy method, but the latter is based on concentrations in the air rather than solid material. The same seems to apply to NEN-ISO 22262-2, the international counterpart of IFA-AM 7487. For now, it was decided to go with the German standard. As long as no asbestos occurs in the solid, it cannot become airborne as dust. SEM/EDX and REM/EDX are one and the same.

18. ProRail must be notified immediately if the presence of asbestos is detected in the rock. It may have repercussions for ongoing projects and the health of all those involved.

19. Due to contamination by asbestos-bearing rock from the same quarry, a sample may contain asbestos despite i.a. geological analyses and petrographic reports labelling the mass of the rock from the quarry asbestos-free. Asbestos presence in the quarries will, for example, have to be mapped and recorded on a map of the quarry to prevent it from being used for deliveries to ProRail. There are other ways of preventing the presence of asbestos in railway ballast (see clarification in 24) as well. Such measures must be recorded in the internal quality system of the quarry.

20. The 4 mandatory analyses per year may be supplemented with no more than 1 extra SEM/EDX analysis per year. If the asbestos test comes back positive for the second time in the same year, ProRail will consider this an indication that the rock is not free of asbestos.

21. ProRail requires that each extra SEM/EDX study (in accordance with requirement 19) contains the result “asbestos not detectable”. The likelihood that contamination will cause a bedrock devoid of asbestos to once again test positive is thought to be low (though not impossible, of course).

22. When the extra SEM/EDX analysis comes back positive (i.e. asbestos detectable), the certificate is withdrawn immediately. The need for additional inquiry can then be established in consultation with ProRail.

23. Because the percentage of asbestos in the rock is of essential importance to the health of all parties involved, ProRail may ask a third independent party to take a representative sample in accordance with NEN-EN 932-1 in order to determine the percentage of asbestos in the rock (counter expertise). This analysis can be performed by a certifying body in or outside the presence of ProRail. This is primarily intended for cases of doubt about the test results (e.g. when the quarry/supplier has to order an extra SEM/EDX) and for the initial certification of a quarry as validation. The producer/supplier/quarry declares in writing that this will be permitted and easy for the CB to check.

24. Asbestos may be present in certain extraction areas of a quarry. Delivery from that extraction area to ProRail must be prevented. The quarry's quality management system must assure that no asbestos is present in the rock used to produce railway ballast for ProRail. The QMS of the quarry must include this procedure. This can be done with internal inspections, geological research data, mapping of the locations with asbestos veins, etc. An expert should be able to recognise and mark asbestos veins with a visual inspection.

25. It does not suffice to merely include in the quarry's quality management system that measures are implemented to assure that no asbestos is present or can end up in the railway

ballast product. This must be assessed by an expert appointed by ProRail who will draft a statement to be signed by ProRail.

### 3.1.3 Conversion reactions of rocks

26. The “during their lifetime” requirement forces the supplier to demonstrate that any converted product is free of crystalline silica. Rocks such as dunite or peridotite or rocks with a high concentration of olivine can react with water and $CO_2$ in the air under certain circumstances and thereby convert into another solid. Silica formation is one potential result of such a reaction. The CB must verify that the supplier/producer is in possession of test results/reports where worn rock from the quarry or from the track has been analysed with XRD.

27. The “during their lifetime” requirement forces the supplier to demonstrate thtat any converted product is free of asbestos. Rocks such as dunite or peridotite or rocks with a high concentration of olivine can react with water and CO2 in the air under certain circumstances and thereby convert into another solid. One example is serpentine which occurs in various forms. Chrysotile (white asbestos), for example, is associated with a health risk. The CB must verify that the supplier/producer is in possession of test results/reports where worn rock from the quarry or from the track has been analysed with SEM/ EDX.

28. Almost all quarries have undeveloped areas by the edge. The conversion products can be determined by sampling those areas. By analysing these samples with quantitative XRD and SEM/EDX, the conversion product composition can be determined as well as any other future risks with crystalline silica and asbestos.

29. If another sample can be taken from the track, the conversion speed can be determined in addition to the conversion product analysis.

30. Through modelling or a numerical calculation model, the supplier must demonstrate that if the rock reacts with the environment, no more than 8% of the original material is converted in the space of 30 years. At a rate of 8% conversion into softer material over the course of 30 years, settlements and “technical contamination” will be very limited. Water drainage is barely affected and these settlements are barely noticeable in the regular maintenance regimen (0.3% per year or approx. 0.8 mm). These settlements will generally be distributed very evenly. But if this amounts to 30% over the course of 20 or 30 years, there are consequences: larger settlements, more maintenance and a potentially accelerated reduction of water permeability.

### 3.1.4 Environmental requirements: Dutch Soil Quality Decree

31. Compliance with the Soil Quality Decree/Regulation is a statutory requirement. This decree can be found on the website Overheid.nl. It serves to protect our soil and the environment. Railway ballast is covered by the term “Bouwstof” [building material].

32. New products formed in conversion reactions must comply with the Soil Quality Decree as well. This means that the supplier/producer must also test the “weathering products” against the Soil Quality Decree/Regulation.

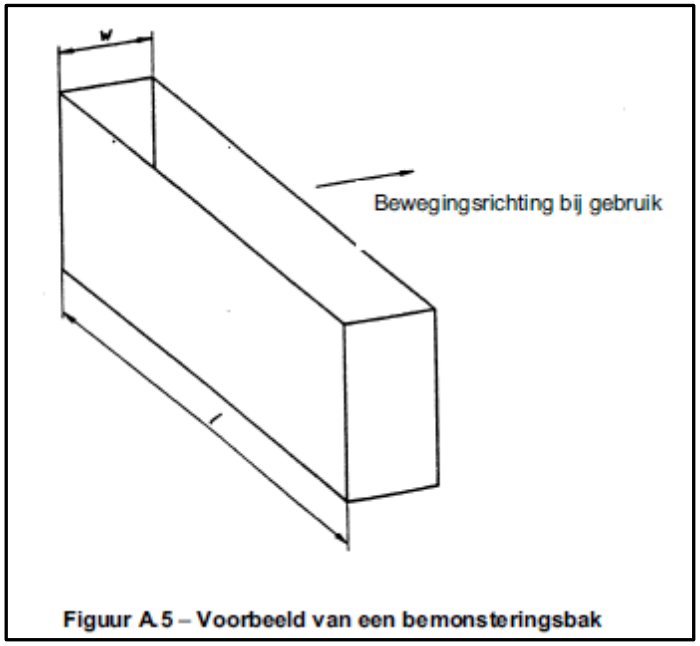
33. The “Fabrikant-eigenverklaring” [Manufacturer’s Statement] is a written statement issued by the manufacturer of a building material, soil or water bed material, declaring that the party in question meets the requirements set out in or under the Soil Quality Decree/Regulations with regards to environment hygiene quality. The statement conveys how it was determined that the party meets the requirements set out in or under this decree.
The NL BSB certificate indicates that the requirements of the Soil Quality Decree, formerly known as the Building Materials Decree, are being met. The NL BSB certificate does not address any additional quality requirements set by market parties.

### 3.1.5 Sampling

34. NEN-EN 932-1:1996 describes several procedures for the sampling of aggregates, which includes railway ballast, from deliveries, preparation and processing installations including stock. A sampling plan must be drafted *in advance*. The purpose is to obtain a representative sample with (average) properties of the product. The methods are based on manual procedures. It is advised to set a minimum mass for a composite sample at all times. The nature and number of tests for which the sample is taken, particle size and density are important factors in this regard. When it comes to railway ballast, sampling from a conveyor belt, a depot (flat and cone-shaped depots), from lorries and ships is important. Generally speaking, the ballast is dumped into depots from lorries and ships and the procedure for depots is then followed.

#### 3.1.5.1 Other samples (carriage, track):

Sampling from a carriage or track must take place in accordance with NEN-EN 13450, Annex A and B.
When sampling from a railway carriage, a sampling container (see EN 932-1, Figure A 5) is required for the fully loaded carriage, one sampling container (l=700 mm, w=450 mm, h=250 mm) being a subsample of a number of 4 on 1 carriage. At least 4 subsamples (containers) should be filled at the chute while unloading (moving carriage) or when sampling from a conveyor belt, if applicable.




Figuur A.5 – Voorbeeld van een bemonsteringsbak

A sample from the track consists of the railway ballast between the sleepers. The ballast must be dug out entirely without including any subgrade. A steel frame can be used if necessary (see Figure A.1, Annex A EN 13450).

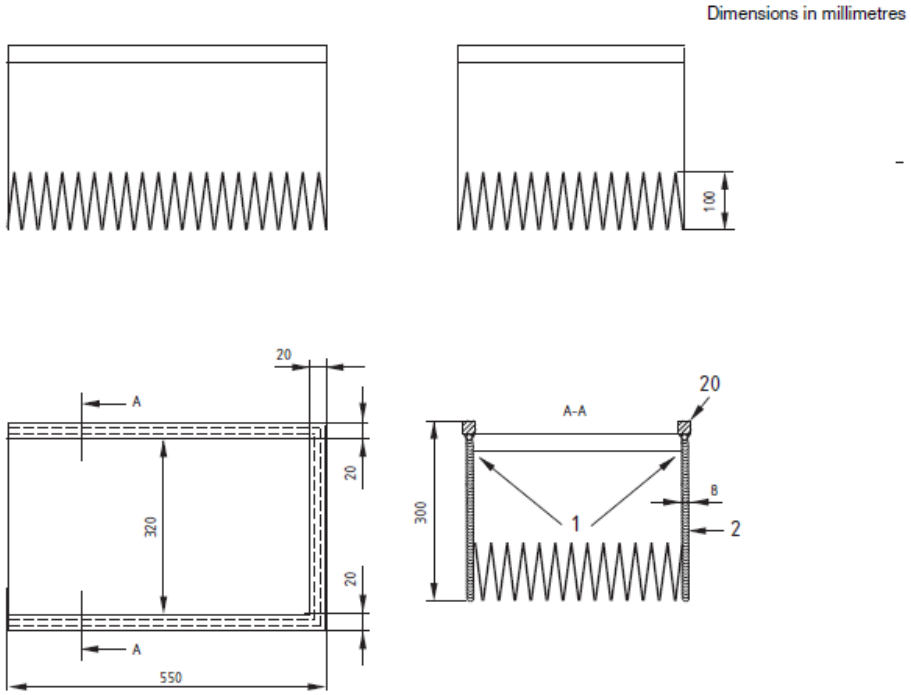



Figure A.1 - Frame for sampling railway ballast

The ballast is removed via an opening on one side of the frame. As the ballast is removed, the frame can be driven deeper and deeper into the ballast. The drawback is that this is very laborious and may damage the geotextile.

A better method for obtaining samples from the track is described in RLN00243 “Reuse and processing of released railway ballast”, Annex 1, 3.2 Step 4: Ballast bed sampling (*cylinder drilling*).

Samples collected after transport or processing in the track are unsuitable for determining compliance with the delivery conditions (sieve curve, fines and dust content, Shape index, Flakiness, maximum length, etc.) because these properties have changed in part due to the transport and the number of operations, stopping and profiling, and the trains that have already passed. These methods might be suitable for a dispute, to determine degradation during transport or for specific railway issues. NEN-EN 13450 Annex B only gives informative values for the maximum percentage that may pass the 22.4 mm sieve (this will always be somewhat higher than the specific sieve curve from the supplier). Softer rock in particular will reach these limit values more quickly.

{Sampling from the track must be carried out *before* tamping the railway ballast, as this involves the ballast being stirred up by the tamping hammers with great force which damages part of the ballast (ballast particles break off). This means more fine material and a shifting sieve curve.

These samples from the carriage or track do not fall under the responsibility of the supplier/producer but are still included in the document for information purposes.

### 3.1.6 Production

35. Mixing materials of different geological origin means that the average properties of the mixture differ from those of the individual rocks. In quarries with multiple excavation areas

and with rocks of varying hardness, this may cause practical issues. For example, a softer, unsuitable rock could be delivered by mixing it with a harder rock to bring the average LA value up to the required level. The softer rock will degrade more quickly and cause settlements. And the mixture does not come with a certificate, of course.
The fact that different rocks do end up in the railway ballast bed in practice is unavoidable due to logistics. It must therefore be ensured that the deliveries are always from 1 certified geological origin (quarry), meaning they meet all requirements from the SPC.

## 3.2 Geometrical requirements

### 3.2.1 Railway ballast size

A railway ballast type must always be characterised by two main sieve sizes in accordance with NEN-EN 933-2 "Inspection sieves, nominal opening sizes". NEN-EN 933-2 is not mentioned in NEN-EN 13450. NEN-EN 13450 refers to the version of NEN-EN 933-1 (sieving method) of 1997 that does include NEN-EN 933-2. When it comes to the sieves used for the railway ballast size, it makes a difference whether round or square sieve holes are used. Round holes were often used in the past. This would occasionally lead to minor differences in the sieve curve. Nowadays, only square sieve holes are applied for the sieve sizes of 125 mm through 3.55 mm. Metal wire sieves are used between 3.15 mm and 0.063 mm (vulnerable).
The sieves used to determine the railway ballast size in accordance with NEN-EN 13450 are 80 mm, 63mm, 50mm, 40mm, 31.5mm, and 22.4 mm. The possible sizes are A through F where A through C are characterised by the sieves d=31.5 and D=50 mm and the categories D through F by the sieves d=31.5 and D=63 mm. The latter categories are coarser and more common in countries with a wide track. ProRail applies a Category A size distribution. An additional requirement for categories A through E is that least fifty percent of the mass must fall between the two particular sieves.

Based on NEN-EN 13450, only type 1a (31.5/50) is relevant for Category A from the standard. For type 2a, the particle (size) distribution is not included in NEN-EN 13450. In the 2023 edition of NEN-EN 13450, however, type 2a (22/40) will also be included and the number of categories will be expanded to eight (A through H), with the final category providing for reasonable interpretive flexibility. The following extra sieves are included in the new standard: 16mm, 11,2mm, 8mm en 4 mm.

36. No clarification necessary.
37. No clarification necessary.

### 3.2.2 Grading

38. Determining the grading (sieve curve) of railway ballast in accordance with NEN-EN 933-1 must be carried out with a sufficient sample size (weight). The fact that sieve D=50 mm is not included in table 1 of NEN-EN 933-1 allows for interpolation between the 32mm and 90 mm sieves. This means that the minimum sample size for type 1a is 25 kg. A minimum of 16 kg applies to type 2a. The accuracy of the sieve curve will increase, however, if the samples carry more weight. This is always allowed. Rocks with a higher density, such as basalt, (approaching 3.0 $Mg/m^3$) have less volume and therefore less particles in a certain weight. This allows for larger deviations in the grading. It is recommended to take at least 40 kg for each ballast type

39. In principle, no over- or undercutting of the grading bandwidth is allowed. For ProRail, this is mostly based on past gneiss, basalt, and porphyry deliveries where it was known that these sieve limitations were virtually never exceeded. The sieve curves of various railway companies were analysed in the drafting of NEN-EN 13450, which led to categories A through F to include the (main)sieve curves of nearly every European country. The Netherlands does not possess its own quarries, so the railway ballast is always sourced abroad. Production processes are mostly geared towards the specifications of that country's railway company. Mutual deviations on the bandwidth are between 5 and 10% mass. Theoretically, this may bear consequences for the behaviour (settlements over time, densification sensitivity, processability, water permeability, dust emission, volume, etc.) but practically this will be of very little significance between categories A and E. Still, it is

important that the sieve curve of Cat A is met. This also means that the production process is aligned with demand and that the quality of each batch is nearly identical. The new European standard EN 13450 of 2023, part 1 states that at least 90% of the sieve curve results (test frequency 1x/week) must be within the sieve curve over a period of 6 months. This means that an excess is allowed in 10% of the cases.

40. For railway ballast type 2a (22/40), the particle (size) distribution is not included in NEN-EN 13450 but is likely to appear in the update of 2023. The clarification to requirements 38 and 39 applies here as well. Type 2(a) was used in the past as a vertically draining cover layer on a sand body with a vertical thickness of 10 cm, but as of 2015 it is no longer included in OVS00056-5.1 and has been replaced by a geotextile (geogrid, combination cloth, filter fabric). It is still being used as a walkable 5-cm top layer for yards and sidings. In addition, it can be deployed in specific cases for heavy loads, e.g. in order to reduce initial settlement.

### 3.2.3 Fine particles

41. The fine particle content (i.e. the mass percentage that should pass the 0.5 mm sieve ) must be determined in accordance with EN-933-1. It is particularly important to take a sufficiently large sample because this involves relatively low mass percentages.

42. No clarification necessary.

### 3.2.4 Fines

43. Determining the fines content, also referred to as dust content (i.e. the mass percentage that passes the 0.063 mm sieve) has become an important requirement in view of occupational safety. For Quartzless railway ballast, the combined washing and dry-sieving procedure must always be used on a sufficiently large sample in accordance with EN-933-1. The results of the washing and dry sieving (mass percentage passing the 0.063 mm sieve) are added up.

44. Stricter requirements for fines than category A in accordance with EN 13450 Article 6.5 “Fines” have a positive effect on the reduction of dust formation in the rest of the chain. This means that the amount of inhalable dust (particles that can be inhaled) and respirable dust (smaller particles that can reach the lungs) is lower at 0.2 mass% than e.g. at a limit value of 0.5 mass% (category A). However, German quarries that produce crystalline silica-free ballast do not wash the material since the DB requires category B instead of A. In this instance, washing is not required at all. The quarries may meet the requirement for category A (0.4 to 0.5 mass%) which means that a stricter requirement of e.g. 0.2 mass% would exclude the quarries and prevent ProRail from receiving “quartzless ballast”.
For type 2a, ProRail requires in accordance with NEN-EN 13450 Article 6.5 category A, once again a stricter requirement will render quarries with the rock free of crystalline silica unable to get certified. These quarries may not even be able to meet category A with the 22/40 because the specific surface area of this size is larger and more dust is thus expected to form.
ProRail will review its requirements for fines once multiple quarries are able to deliver quartzless ballast with sufficient capacity while using a washing installation, for example, to reduce the dust content.

#### 3.2.4.1 Dust simulation test

In the dust simulation test performed in accordance with paragraph 3.2 of TNO report R11703 of 31 August 2021, each type 1a (31.5/50) sample is subjected to measurements of inhalable and respirable dust emission under identical conditions. This is not related to the publicly established limit values, but it does make it possible to compare different rocks in terms of the amount of inhalable and respirable dust released during the test. Some types of stone produce more dust than others. What ProRail aims to prevent in the long term is that a quartzless and asbestos-free rock is approved (bearing no risk of respirable quartz dust or respirable asbestos) thereby introducing a much higher risk of inhalable and respirable dust itself.
The concentration of inhalable dust must be recorded during the simulation measurements in accordance with paragraph 3.2 of TNO report R11703 of 13 August 2021. The target value

was set to 320 mg/m3 but is not being used as a rejection criterion.
The target value of 320 mg/m3 for inhalable dust should be considered a benchmark for the time being. A higher value does not lead to rejection.
The concentration of respirable dust must be recorded during the simulation measurements in accordance with paragraph 3.2 of TNO report R11703 of 13 August 2021. The target value was set to 18 mg/m3 but is not being used as a rejection criterion.
The target value of 18 mg/m3 for respirable dust should be considered a benchmark for the time being. A higher value does not lead to rejection.

45. The supplier/producer must declare in writing their cooperation with dust simulation measurements taken on ProRail's behalf, allowing ProRail to collect samples for analysis directly from the production process of the supplier/quarry.

### 3.2.5 Flakiness Index

46. The Flakiness Index is a measure for the content of flat stones and applies to pieces of rock with a particle size between 4 and 100 mm. A representative sample is divided into fractions. The “flat stone” content is determined for each fraction and then the average across all sizes (fractions). An example of a fraction is 40/50 (the portion of the sample that passes through the 50 mm sieve but not the 40 mm sieve). This quantity is sieved on a bar sieve with half the distance between bars relative to the pass-through sieve, in this case 25 mm. Everything that falls through that sieve is considered “flat”. Depending on the type of rock, more or less flat stone fragments can form during the breaking process. The type of breakers may affect this as well. Due to their greater tendency to break (settlements), the mass percentage of flat pieces must be limited. The percentage of flat pieces also affects the result of various testing methods (LA, Deval, AIV).

47. No clarification necessary.

### 3.2.6 Shape index

48. The Shape Index is a measure for the content of “non-cubic” stones and applies to pieces of rock with a particle size between 4 and 100 mm. A special “particle calliper” is used to determine the particle length L (the greatest distance between two parallel surfaces) and the particle thickness E (the smallest distance between two parallel surfaces) of several pieces of rock. The Shape Index is now determined as the total mass of particles where the L/E exceeds 3 expressed as a percentage of the total mass of the sample. This is another way of determining “other” flat pieces. The Shape Index, however, also indicates what percentage of the stones is cubic (namely 100-SI). The percentage of flat pieces affects the result of various testing methods (LA, Deval, AIV).

49. No clarification necessary.

### 3.2.7 Particle length

50. Particles with a length exceeding 100 mm break more easily and their quantity should be limited to prevent settlements. Particles with a length exceeding 100 mm are not separately determined by the tests with the Flakiness Index and Shape Index.

## 3.3 Physical requirements

The physical requirements outlined in this paragraph 3.3 pertain primarily to the load-bearing durability of the ballast. This involves the impact loads of passing trains and the maintenance loads of compactors such as the vibratory plate and the tamping machine in particular. Furthermore, the lifespan of the ballast depends on environmental conditions, especially resistance to frost-thaw transitions in the case of ProRail. The associated requirements are set out in paragraph 3.4 “Durability”. This is organised in accordance with NEN-EN 13450 although both paragraphs 3.3 and 3.4 pertain to the durability of the ballast. In certain types of rock, quartzless railway ballast has a slightly higher water absorption rate than typical, and we want to maintain a certain degree of durability. Therefore, greater water absorption can only be tolerated if compensated by another property, such as the hardness of the rock. Experience with existing rocks with a water absorption rate of <0.5%, a hardness

requirement of $LA_{RB}$ 16, and a magnesium sulphate test limit value of 1.0 mass percent serves as the reference. We know this combination provides for ballast with sufficient durability for application at ProRail. An increase in the water absorption rate would theoretically reduce resistance to freeze which could translate into reduced durability. By requiring a higher hardness level of the rock, degradation due to impact loads is reduced and the durability is extended as a result. Higher water absorption is compensated by higher hardness of the rock to maintain sufficient durability. It should be noted that this is a theoretical statement based on literature. What is known, however, is that rocks with a water absorption of <1.5 mass% and a value for the Magnesium sulphate test of max. 3.0 mass% with an $LA_{RB}$ of around 12 have more than enough durability for the application abroad. This was accounted for when determining the requirements for water absorption, the magnesium sulphate test and the hardness.

### 3.3.1 Resistance to fragmentation

51. The $LA_{RB}$ (Los Angeles Railway Ballast) determines the rock's resistance to fragmentation. NEN-EN 1097-2 includes two tests: the Los Angeles testing method and the Impact testing method. In the Los Angeles method, a value is always accompanied by the LA abbreviation. This does not apply to the Impact testing method. According to the NEN-EN 1097-2 standard, this is the “SZ” abbreviation which stands for “Schlagzertrümmerung”. AIV (Aggregate Impact Value) tends to be used in the UK and other English-speaking countries. In NEN-EN 13450, the term “impact value” is added to the “SZ” abbreviation. Correlations between the LA, SZ and $M_{DE}$ (Micro-Deval) have been studied in the past (ERRI D-182). LA and SZ correlated well, so one of the two can be selected as desired. ProRail requires a value for the $LA_{RB}$.
    The LA test must be executed in accordance with Annex A (normative) for railway ballast.

52. The same LA value is required for both ballast types. This is, after all, always the same rock from the quarry. The determined $LA_{RB}$ is stricter ($LA_{RB}$ 12 instead of $LA_{RB}$ 14) than the requirement in SPC00033 to serve as compensation for the less stringent requirement for water absorption. In theory, this should extend the lifespan and make the ballast more durable.

53. When certifying or renewing the certificate after 1 year, the assessment of the $LA_{RB}$ should be based on the latest available test data. Since the $LA_{RB}$ is tested twice a year, a value is available every 6 months.

### 3.3.2 Resistance to wear

54. Despite the fact that no correlation was found between the LA and the $M_{DE}$ or between the SZ and the $M_{DE}$, it is still required to determine the $M_{DE}$ value. On the one hand, this is to track the progress in values for the resistance to wear (just like with resistance to fragmentation). Because it results in statistical information about the composition of the rock. If this value remains fairly constant, so does the composition of the rock. On the other hand, there is a slight indication (TNO report R11703 of 31 August 2021) that the $M_{DE}$ correlates with the dust-generating capacity of the rock (contrary to the LA or SZ). By gathering more information about this in relation with dust simulation testing, it may be possible to create a requirement for this in the future.

55. Although no requirement has currently been set for the $M_{DE}$, the value does need to be determined. The $M_{DE}$ test must be executed in accordance with Annex A (normative) for railway ballast.

## 3.4 Durability

The term durability refers to the lifespan of the ballast in terms of weathering and resistance to freeze transitions. Of course, this depends greatly on the climate in which the railway ballast is utilised. See the clarification under 3.3.

At the time of conception of NEN-EN 13450, experience with the Magnesium sulphate test was limited and the freeze-thaw test with water was usually applied with an expanded cycle count from 10 to 20. Annex H (informative) of NEN-EN 13450 provides a guideline. ProRail decided at the time to include

both tests in the terms of delivery and allow a supplier to choose a test. The rock would have to pass one of the two tests. The limit values were obtained from the basalt, gneiss, and porphyry used at the time. Contrary to SPC00033, the freeze-thaw test with water has been removed from this SPC00353. Most (international) terms of delivery have adopted the magnesium sulphate test because it determines the freeze resistance more effectively and enough experience has been gained with the test.

### 3.4.1 Resistance to freezing and thawing

56. For quartzless railway ballast types 1a and 2a, resistance to freezing and thawing must be determined with the magnesium sulphate test. Enough international experience has been gained with the test and it paints a much clearer picture than the freeze-thaw test with water. Many European countries have adopted this test.

57. Determining resistance to freezing and thawing in accordance with Annex G must be done in accordance with NEN-EN 1367-2 of 1998 with the amendments described in Annex G. A more recent standard NEN-EN 1367-2 of 2007 exists but it does not include Annex G from NEN-EN 13450 of 2002. The new 2007 standard can be used in combination with Annex G. It will produce identical results.

58. The first limit value for the magnesium sulphate test was established based on the 3 most popular rocks at the time; gneiss, porphyry and basalt. These rocks have proven themselves in ProRail's tracks for decades. However, other railway companies with their own quarries use a less rigorous limit value, and there are no documented issues with the rock over its lifespan for use in foreign applications. ProRail has expanded the criterion to a maximum of 2.0 mass percent in order to allow for more quartzless rocks to be approved.

59. When certifying or renewing the certificate after 1 year (audit), the assessment of the magnesium sulphate test should be based on the latest available test data. Since the magnesium sulphate test is conducted twice a year, a value is available every 6 months.

### 3.4.2 Water absorption

The sensitivity of a rock to damage due to freeze-thaw transitions depends on the climate, the application, the composition of the rock and the associated pores and micro-cracks. Depending on the climate, the rock is exposed to freeze-thaw cycles where the degree of water absorption and varying temperatures cause damage. The more liquid a rock is able to hold, the greater the damage can be. The damage is exacerbated in the case of salt water (sea regions) and de-icing salt (e.g. on platforms and crossings). Resistance to freezing and thawing also depends on the strength of the rock.
Annex H (informative) of NEN-EN 13450 indicates climate categories where ProRail has opted for category A at the time. This means that when water absorption remains below 0.5% mass, the rock can be considered resistant to freezing and thawing. But it also includes a warning that this is no guarantee. Some rocks have a higher water absorption rate but are still resistant to freezing and thawing as demonstrated with tests, but the opposite occurs as well: rocks with low water absorption that are not resistant to freezing and thawing. This is why ProRail decided that the water absorption rate must be determined while also conducting a magnesium sulphate test irrespective of the result. Both tests are subject to requirements.
Water absorption is also an indicator of the porousness of the rock, which affects its strength and as such also the tendency to break under freezing temperatures.

60. NEN-EN 1097-6 is a standard that describes both the water absorption test and how to determine the specific weight of the rock. For the water absorption rate, the test must be performed in accordance with Annex B (normative). Water absorption is rounded to the nearest 0.1%.

61. The value in accordance with NEN-EN 1097-6 Annex B smaller than or equal (≤) to 1.0% allows for more volcanic rock, known for the possibility of slightly higher water absorption.

This is necessary for quartzless volcanic rocks to be permitted, though subject to a stricter requirement for the LA value in order to maintain the expected durability.

62. When certifying or renewing the certificate after 1 year (audit), the water absorption analysis should be based on the latest available test data. Since the water absorption rate is tested twice a year, a value is available every 6 months.

### 3.4.3 Particle density

63. NEN-EN 1097 speaks of 4 types of density. The density of the rock must be determined as saturated to constant mass ($\rho_{cm}$), which means that the accessible pores and micro-cracks are filled with water. This is expressed in megagram per cubic metre ($Mg/m^3$), which is equal to gram per cubic centimetre. The specific weight $\rho_{cm}$ is rounded to the nearest $0.01 Mg/m^3$. The test must be performed on a minimum of 10 stone fragments in the 40/50 size category with each piece weighing between 150 and 350 grams. The same test can be used to determine water absorption as well.

64. For reasons of stability, railway ballast requires a certain minimum specific weight. The minimum value was set to 2.6 $Mg/m^3$ based on past experience with railways ballast. A rock with a lighter specific weight is desirable for the “long haul” since the cost is calculated per tonne. A tonne of light material has a larger volume than a tonne of heavy material. On the other hand, a heavier rock generates more transverse resistance and thus a more stable position. With the softer subsoil in the Netherlands, however, this can also accelerate the settling of the track due to the extra weight.

### 3.4.4 Sonnenbrand

65. “Sonnenbrand” is a specific degradation process that can occur in basalt or basalt-related rocks under the influence of atmospheric circumstances. Sonnenbrand can be recognised by the appearance of grey/white “stars” or spots on the rock. This is where hairline cracks will eventually originate and move radially to form a network. This reduces the strength of the rock which will disintegrate over time, significantly shortening its lifespan. We know from the past (literature) that this can happen within several months in the worst case scenario. The boiling test in accordance with EN 1367-3 is intended to identify the grey/white “stars” or spots (a form of accelerated ageing). NEN-EN 13450 states that testing in accordance with NEN-EN 1367-3 is only necessary if signs of Sonnenbrand have been found. ProRail requires the boiling test to be performed without exception for basalt or basalt-like rock in accordance with NEN-EN 1367-3.

66. Contrary to and in deviation from NEN-EN 1367-3, ProRail requires that no grey/white “stars” or spots or radial hairline cracks occur on the rock before and after the boiling test, i.e. the rock must be free of Sonnenbrand signs. Only then is the rock considered “free of Sonnenbrand”.
The new NEN-EN 13450 states that the rock is free of Sonnenbrand if the loss of mass percent after boiling is less than or equal to 1% and the increase in the LA value after boiling does not exceed 8% (or 5% for the Impact Value). So, grey/white “stars” or spots before or after boiling are potentially allowed. This means that in this case, accelerated degradation and the associated hardness reduction are allowed as well. No data is available about the reduced lifespan. ProRail requires visual inspection only, before and after the boiling test to identify Sonnenbrand. If Sonnenbrand is found, the rock is rejected even with a higher $LA_{RB}$.

### 3.4.5 Harmful components

67. The term “harmful components” (chapter 8 in NEN-EN 13450 of 2002) is somewhat misleading. It does not refer to health, safety or environmental aspects but rather the performance of the railway ballast. It is determined that railway ballast may only consist of a material specified in this standard. According to the definition of “railway ballast” in the standard, it must consist of aggregates consisting of particles the surface of which can be described as 100% broken and the aggregate may consist of natural (rock), artificial (mineral origin) or recycled material. Only *natural rock of mineral origin* is allowed in our SPC due to

the specific reference to the definitions of “3.2 railway ballast” and “3.3 Natural railway ballast” from NEN-EN 13450. The presence or application of other materials or components is not permitted.

68. With regards to “other components or material”, contaminations (e.g. sand, other rocks such as host rocks, wood, organic contaminations, marly and clay-like components may occur. Only traces of ignition wires and detonators are permitted. Therefore, quarries with multiple extraction zones and rock types must ensure that the certified rock is of uniform quality. Any other contamination is not allowed (0%).

### 3.4.6 Magnetism

Some quartzless rocks may contain magnetite or other magnetic minerals. These minerals occur in rocks suitable for railway ballast in such small quantities that the magnetism does not damage any of the railway systems. It is mentioned here because some geological reports of quarries report this specifically and may lead to questions.

### 3.4.7 Evaluation of conformity

69. Chapter 9 of NEN-EN 13450 describes how to to demonstrate that the product meets the standard and the values applied. In addition, it refers to “Factory Production Control” (FPC) which is attached as Annex I and contains requirements for inspection of the manufactured product, in this case railway ballast. In the upcoming version of the standard, chapter 9 is replaced with the AVPC (Assessment and Verification of Constancy of Performance) and Annex I has been removed. Annex I contains the table with the necessary test frequencies, for example. In the upcoming version of the standard, this will be the AVPC.
For purposes of clarity, SPC00353-1 Annex 2 contains the table with minimum test frequencies. It is identical to Annex I from the FPC supplemented with frequencies for the additional requirements pertaining to ballast free of crystalline silica and asbestos.

### 3.4.8 Designation and description

70. It is important to note at this point that reference is made to EN-932-3. This standard offers a simplified procedure for the petrographic analysis of aggregates for a general classification. Its availability is a minimum requirement and allows ProRail to obtain the *correct name and composition* of the rock. Note that reference is also made to grinding plates, so it cannot be assumed that this is sufficiently accurate, especially for determining the quartz content and the presence of asbestos. The correct name of the rock must be stated on the certificate. Due to the semi-annual quantitative XRD analysis, the mineral composition of the rock is largely understood but not in detail. Quantitative XRD and the petrographic analysis can supplement each other.

### 3.4.9 Marking and labelling

71. This chapter indicates that a receipt is provided upon delivery stating at least the following information: identification of the ballast, shipment date, serial number of the receipt and a reference to NEN-EN 13450.

72. The user may request additional information. ProRail also requires the delivery receipt to be accompanied by the certificate (copy) of the rock in accordance with SPC00353 for every batch delivered.

### 3.4.10 Transport

Requirements 73 through 76 only apply to the portion for which the manufacturer/supplier is responsible. Delivery logistics may be completely outside of the supplier’s/producer's responsibility if loading takes place at the quarry in transport provided by third parties (ship, carriage, lorry) only. The supplier/producer may arrange part of the transport themselves, e.g. by ship (sea or inland) to a location within the Netherlands.

73. Loading, transshipment and unloading take place several times in the case of transport by (dumping) lorry, ship, train or a combination. Occasionally, intermediate railway ballast depots are established as well. All of these activities stress the railway ballast with cranes, shovels, falling heights from a conveyor belt etc. and a very small fraction of stones will break into smaller pieces. This requirement is meant to prevent this from getting out of hand. In the case of a sample from the track or a side unloader or hopper, a sieve analysis can be made to determine whether the percentage passing through the 22.4 mm sieve has risen above 5 mass percent. In practice, these random tests are never performed because railway ballast delivered to ProRail is always certified. This means that the number of operations performed with the ballast can be large as demonstrated by the TNO study in 2020 (9 actions). The aim should therefore be to limit the number of operations as much as possible as this will improve the quality of the ballast and, from an occupational health and safety point of view, much less dust will be released when handling the ballast.

74. Although no requirements apply to type 2a, the clarification under requirement 73 applies nonetheless. The aim should once again be to limit the number of operations as much as possible as this will improve the quality of the ballast and, from an occupational health and safety point of view, much less dust will be released when handling the ballast. Especially since finer railway ballast sizes have a larger specific surface area and will therefore be able to release more dust during their processing.

75. No limitations apply to the methods of transportation. A lot depends on logistics, both on the supplier's and the receiver's end. However, it is recommended to minimise the transshipment of railway ballast (see also the explanatory notes to requirements 73 and 74). The method of transportation also affects durability.

76. Sea water (salt water or brackish water) conducts electricity and may leave salt residue on and inside the pores and in the micro-cracks in the rock. If salt water is present, this could reduce the "ballast resistance" causing the track circuits (if present) to detect an occupied track without the presence of a train. This does require the insulated rail to make contact with the ballast, e.g. because the rail insulation is defective or because the ballast makes contact with the bottom of the rail.
    In addition, any salt present in the pores or micro-cracks of the rock may cause accelerated degradation of the rock due to crystallisation. However, rock supplied by ship over sea or that has been in contact with sea water is not inspected. Generally speaking, railway ballast is shipped in closed spaces to prevent (sea) water from entering from the outside.

# 4 Inspection

All inspections and tests necessary to meet NEN-EN 13450 and the requirements from this SPC00353 are entirely at the expense of the supplier/producer. This also applies to any additional tests necessary to determine the quartz content or the presence of asbestos. This does not apply to the counter expertise performed by an independent party on behalf of ProRail to determine the quartz content in the rock or the presence of asbestos. The costs of the dust simulation measurements are borne by ProRail as well. The supplier is allowed to attend the simulation measurements if so desired.

## 4.1 Minimum test frequencies

77. Railway ballast is subject to minimum test frequencies in accordance with NEN-EN 13450, Annex I table I.1 “Minimum test frequencies for general properties”. This Annex I.1 is attached to this document as Annex 2 and supplemented with the required minimum test frequencies for quantitative XRD and asbestos. For tests 1 through 12, this table is identical to table I.1 from Annex I from NEN-EN 13450. “Properties” 13 through 16 (XRD and SEM/EDX) have been added.

78. If a test frequency is e.g. 4x per year, this means that a sample must be taken and the test performed every 3 months. It is not permitted to take a sample and perform the test e.g. 4 times in the 1st quarter.

79. See the clarification to requirement 78.

## 4.2 Declaration of quality

80. The ProRail-approved Certifying Bodies can be found on the website of ProRail https://www.prorail.nl/siteassets/homepage/samenwerken/leveranciers/documenten/overzicht_certificerende_instellingen_nov_2019_0.pdf en via de PBE00012.

81. If one of the requirements cannot be met due to circumstances, e.g. because a test result is not available yet or older than required, ProRail must be informed. ProRail will often be able to assess the tests from the past to see whether or not certification can proceed.

82. ProRail's site “Overview of product certificates and specifications” will be updated accordingly. A certificate is valid for a maximum period of 3 years but only if all requirements from this SPC are being met during the CB's annual audit. This site states the validity of the certificate, among other things.

83. As such, the quality of the railway ballast is determined upon continuation. In principle, there is no difference between certifying a new quarry and the annual assessment of whether or not the quarry continues to meet all requirements from this SPC00353.

84. This gives the CB a time frame of 3 months to visit and assess the product location. This does justice to the “annual assessment” and the current data of the various tests.

85. A certificate thus states a maximum of two railways ballast types 1a and 2a.

86. It must be clear where the rock was sourced, the specific quarry and the country.

87. Based on the classification or the simplified petrographic description, it is clear what type of rock is delivered.

88. Some suppliers or quarries give their rocks a brand name.

89. This also records the validity period of the certificate and the legal validity of the certificate can be assessed upon delivery. These dates are also included on ProRail's site “Overview of product certificates and specifications".

### 4.3 Documentation certification

90. Should the ballast perform poorly or in the case of disputes with the receivers, 10 years of information can be analysed to find a potential cause. This may also help formulate better requirements in the current SPC00353.

91. ProRail wants to understand the data that led to the certificate being issued. On the one hand, ProRail wants to know what assets are applied in the track, on the other hand this information helps gain a better understanding of the lifespan and durability of the ballast combined with the necessary maintenance. This can lead to an improvement of this SPC.

92. The exact values from the various tests are recorded in this table. This means, for example, that in the case of a rock that in the past was only stated to be $LA_{RB}14$ compliant for crush resistance according to NEN-EN 13450, ProRail had no information about the exact value other than it being 14 or lower.

93. If a supplier/producer/quarry wants to get certified for the very first time, the (audit) documentation must be approved by ProRail. This is not necessary for annual assessment and recertification after 3 years.

### 4.4 Validity

94. In the past, it was possible for a certificate to have a 5-year validity period or no expiration date at all, due to the use of branch standards for aggregates, for example. A maximum validity of 3 years is now explicitly stated.

95. If the certificate states a validity period that exceeds 3 years, this certificate is not valid.

# 5 Quality Assurance

## 5.1 Producer recognition

The SPC00353 prevails over the underlying standards.

## 5.2 Certified quality system

This means that a third party, in this case the CB, is necessary to demonstrate the all requirements are met. It also means that the characteristics of the railway ballast shall be defined according to table ZA.1 "Scope and Paragraphs with Relevant Requirements" and the supplier may use the CE quality mark after proving compliance. System 2+ also means that the CB may use the initial type testing (the tests performed and the associated values) by the producer.

## 5.3 Authorised producers

No clarification necessary.

## 5.4 CE quality mark

In accordance with NEN-EN 13450 Annex ZA “Clauses of this European Standard addressing essential requirements or other provisions of EU Directives”, ZA 2.2 and ZA.3. A CE quality mark does not mean that the requirements from the SPC00353 are being met.

## 5.5 Lifecycle analysis (LCA)

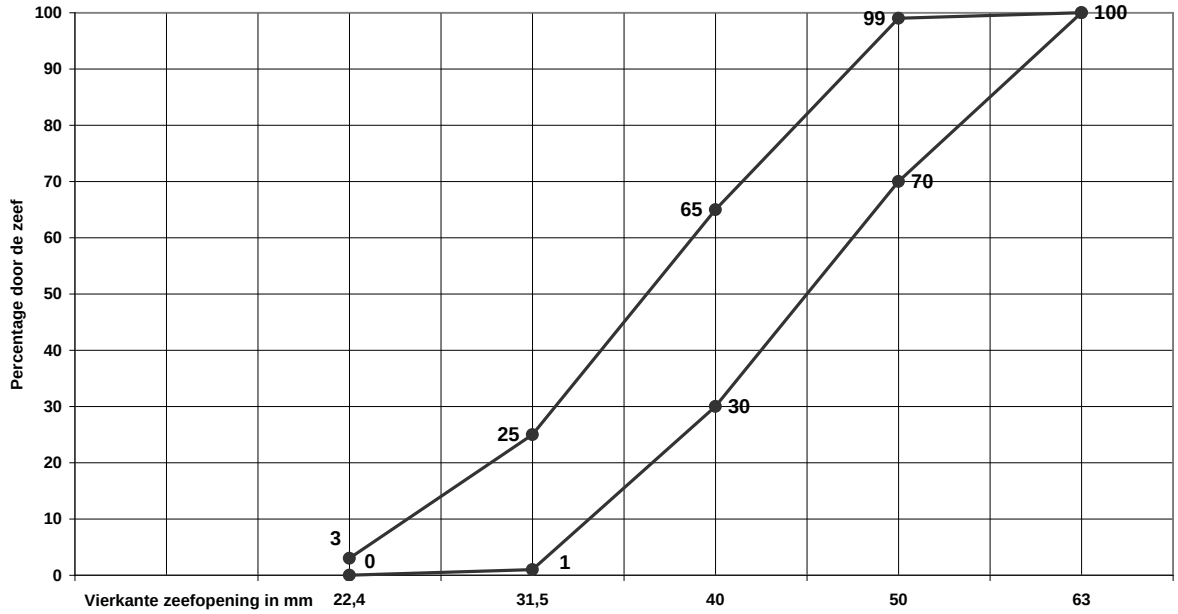
96. No clarification necessary.

97. No clarification necessary.

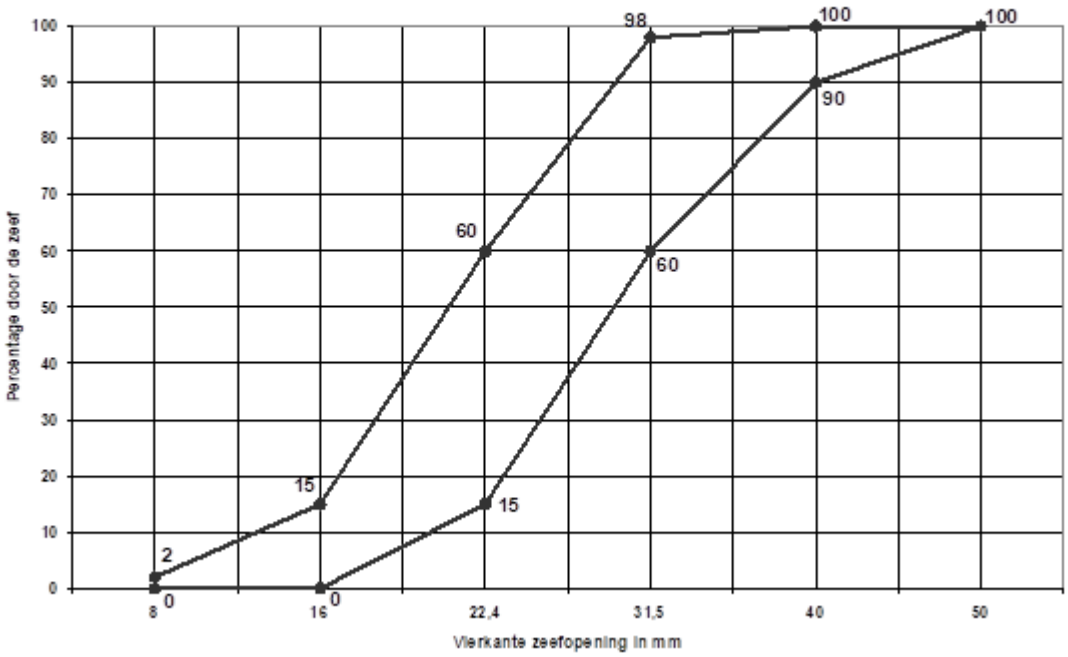
# Annex 1 Sieve curves

**Railway ballast 31.5/50**

**Zeefkromme 31,5/50 Categorie A (NEN-EN 13450 artikel 6.3)**




**Spoorwegballast 22/40**



Based on the specification, the ballast delivered must be within the sieve curve. A lot of variations are possible, of course. In general, if the sieve curve within the limits is close to the right line the ballast is coarser and if the sieve curve is close to the left line the ballast is finer. This is also why a difference is noticed between sieve curve-compliant finer and coarser ballast when delivered to the works.
If the upcoming EN 13450 indicates that at least 90% of the sieve curves must meet the requirement, the difference could be a little greater. When in doubt about the railway ballast, sieve curves can always be requested from the supplier/producer at the time of railway ballast delivery.

## Annex 2 Minimum test frequencies

Table I.1 — Minimum test frequencies for general properties

| Property | | Initials | Test method | Minimum-test-frequency |
|---|---|---|---|---|
| 1. | Grain (size) distribution | 6.3. | EN 933-1 | 1 per week |
| 2. | Fine particles | 6.4. | EN 933-1 | 1 per week |
| 3. | Very fine particles | 6.5. | EN 933-1 | 1 per week |
| 4. | Shape | 6.6. | EN 933-3<br>EN 933-4 | 1 per month |
| 5. | Particle length | 6.7. | - | 1 per month |
| 6. | Resistance to fragmentation<br>- Los Angeles<br>- Impact value | 7.2. | EN 1097-2 | 2 per year |
| 7. | Resistance to wear (micro-Deval) | 7.3. | EN 1097-1 | 2 per year |
| 8. | Freeze and thaw resistance | 7.4.1 | EN 1367-1<br>EN 1367-2 | 2 per year |
| 9. | Density | 7.4.2 | EN 1097-6:2000, Annex B | 2 per year |
| 10. | Water absorption | 7.4.3 | EN 1097-6:2000, Annex B | 2 per year |
| 11. | Sonnenbrand | 7.5. | EN 1367-3 | 2 per year |
| 12. | Harmful components [a] | I.3.3<br>I.4 | [a] | If required and when in doubt |
| 13. | Crystalline silica (QXRD) | SPC00353 3.1.1 | NEN-EN 13925-1, NEN-EN 13925-2, NEN-EN 13925-3, Annex 4 | 4 per year |
| 14. | Crystalline silica (Extra QXRD) | SPC00353 3.1.1 | NEN-EN 13925-1, NEN-EN 13925-2, NEN-EN 13925-3, Annex 4 | Maximum 1 per year |
| 15. | Asbestos content (SEM/EDX) | SPC00353 3.1.2 | IFA-AM 7487 Annex 5 | 4 per year |
| 16. | Asbestos content (extra SEM/EDX) | SPC00353 3.1.2 | IFA-AM 7487 Annex 5 | Maximum 1 per year |
| | | | | |
| [a] Unless prescribed otherwise, only necessary for the CE quality mark (see Annex ZA) | | | | |

For the determination of crystalline silica content and asbestos content, it is proposed to have this tested ~~2~~ 4 times a year. If, for example, the test results are always positive after the first three years, a reduction of the frequency to once or twice a year could be considered. ProRail reserves the right to order a counter expertise.

## Annex 3 Data and values of performed tests

Table annex 3 Data and values of performed tests

| Property | | SPC00353 Par nr. | Test method | To be submitted[1)] |
|---|---|---|---|---|
| 1. | Grain (size) distribution | 3.2.2 | NEN-EN 933-1 | Progressive annual average and 4 most recent sieve curves |
| 2. | Fine particles | 3.2.3 | NEN-EN 933-1 | Progressive annual average and 4 most recent test results |
| 3. | Very fine particles | 3.2.4 | NEN-EN 933-1 | Progressive annual average and 4 most recent test results |
| 4. | Flakiness index | 3.2.5 | NEN-EN 933-3 | 12 most recent test results |
| 5. | Shape index | 3.2.6 | NEN-EN 933-4 | 12 most recent test results |
| 6. | Particle length | 3.2.7 | NEN-EN 13450 par. 6.7. | 12 most recent test results |
| 7. | Resistance to fragmentation<br>- Los Angeles | 3.3.1 | NEN-EN 1097-2 | Progressive 3-year average and 2 most recent test results |
| 8. | Wear resistance<br>- micro–Deval | 3.3.2 | NEN-EN 1097-1 | Progressive 3-year average and 2 most recent test results |
| 9. | Freeze and thaw resistance (magnesium sulphate test) | 3.4.1 | NEN-EN 1367-2 | Progressive 3-year average and 2 most recent test results |
| 10. | Water absorption | 3.4.2 | NEN-EN 1097-6 Annex B | 6 most recent test results |
| 11. | Density | 3.4.3 | EN 1097-6:2000, Annex B | 6 most recent test results |
| 12. | Sonnenbrand | 3.4.4 | NEN-EN 1367-3 | 6 most recent test results |
| 13. | Harmful components | 3.4.5 | NEN-EN 13450 chapter 8 | Clarification |
| 14. | Crystalline silica (QXRD) | 3.1.1 | NEN-EN 13925-1, NEN-EN 13925-2, NEN-EN 13925-3, Annex 4 | 6 most recent test results |
| 15. | Asbestos | 3.1.2 | IFA-AM 7487, Annex 5 | 6 most recent test results |
| 1) Insofar as data is available to ProRail from the start of the certification process | | | | |

This data must be supplied for every certification and annual assessment or audit. It allows ProRail to perform its own analyses, alert the producer/manufacturer of shifting values if necessary and use this data to improve this SPC00353.

# Annex 4 Additional provisions quantitative XRD analysis

**1. Sample preparation**

The sample for XRD analysis should be split into a representative sub-sample using quarters, a *riffle type* sample divider or another method of choice. After initial crushing of the larger stones, the representative sub-sample should be mechanically ground in a liquid (usually alcohol) until a powder with a d50 of no more than 15µm is obtained. Optionally, the sample may be treated in a manner that prevents/reduces preferred orientation (e.g. via *side loading* of the powder in the XRD holder).

**2. The measurement**

For the measurement, the X-ray diffraction device must be configured as follows:

- with a Cu or Co X-ray tube,
- with an angle range of 5 to 65°2thèta (the X-ray diffraction analysis must have this angle range at a minimum),
- With a step size of max. 0.02°2thèta,
- And a measurement time per step of no less than 50s.

**3. Data processing**

After identification of the minerals present, data processing must be carried out using a *pattern decomposition* method (see EN 13925-2:2003).

**4. Analysis report**

The analysis report shall contain the following information at a minimum:

1. The type of device used to grind the material,
2. Whether preferential orientation was avoided or limited,
3. A description of the method/way in which preferential orientation was avoided or limited,
4. The name and type of device used to perform the X-ray diffraction analysis,
5. The type of radiation used,
6. The angle range of the measurement,
7. The detector type (point detector, Position Sensitive Detector (PSD), Area detector),
8. The measurement time per step,
9. The step size
10. The way in which the assessment/quantification was performed: software used + type full pattern fitting method,
11. A figure with the measured diffraction pattern, the modelled diffraction pattern as well as an enlargement of the zone where the most important reflection of quartz occurs (and potentially other forms of crystalline silica) with an indication of the exact position of that reflection/those reflections).

These additional provisions are intended to ensure that every lab able to perform XRD adopts certain conditions that allow for better comparison between test values. This data will also ensure that the present Annex can be improved in the next SPC00353 update.

## Annex 5 Additional criteria for SEM/EDX analysis

The SEM/EDX analyses performed by the supplier/quarry and the counter expertises must always contain the result ”asbestos not detectable” (see paragraph 3.1.2).

The SEM/EDX analysis must observe a demonstrable determination limit of smaller than or equal to 0.001% (10mg/kg). This means that a minimum of 10µg of powder on the filter must be analysed. Calculation of the quantity of powder on the filter searched is as follows:

$$inweeg\ (mg) \times \frac{deelvolume\ op\ filter\ (mL)}{totaal\ volume\ (500\ mL)} \times \frac{getelde\ beelvelden\ \times beelveldgrootte\ (mm^2)}{totaal\ filteroppervlak\ (mm^2)}$$

The determination limit can only be lowered by increasing the weighted sample, part volume and/or number of image fields counted.

Substantiation:

The Soil Quality Regulation sets out so-called maximum (composition) values for applications of building materials on the soil. A newly standardised substance for building materials is asbestos. Most building materials will not contain any asbestos. These building materials are subject to a zero-requirement for the composition value according to the “Productenbesluit Asbest” [Asbestos Product Decree]. This decree states that a zero-requirement applies except to products where no asbestos has been deliberately added and where the weighted concentration (serpentine asbestos, multiplied with ten times the concentration of amphibole asbestos) does not exceed 100 mg/kg d.s. This means that a more stringent requirement of 10 mg/kg d.s. Applies to amphibole asbestos.

IFA-AM 7487 prescribes a weighted sample of 10 – 50 mg where a sub-volume of 10 – 50 ml out of a total volume of 500 ml is applied to a gold-coated polycarbonate filter. If no asbestos fibres are found, the determination limit is estimated to be 0.008% (80 mg/kg). In reality, the determination limit varies depending on the weighted sample and the sub-volume and lies between 0.001 and 0.03% (10 – 300 mg/kg).