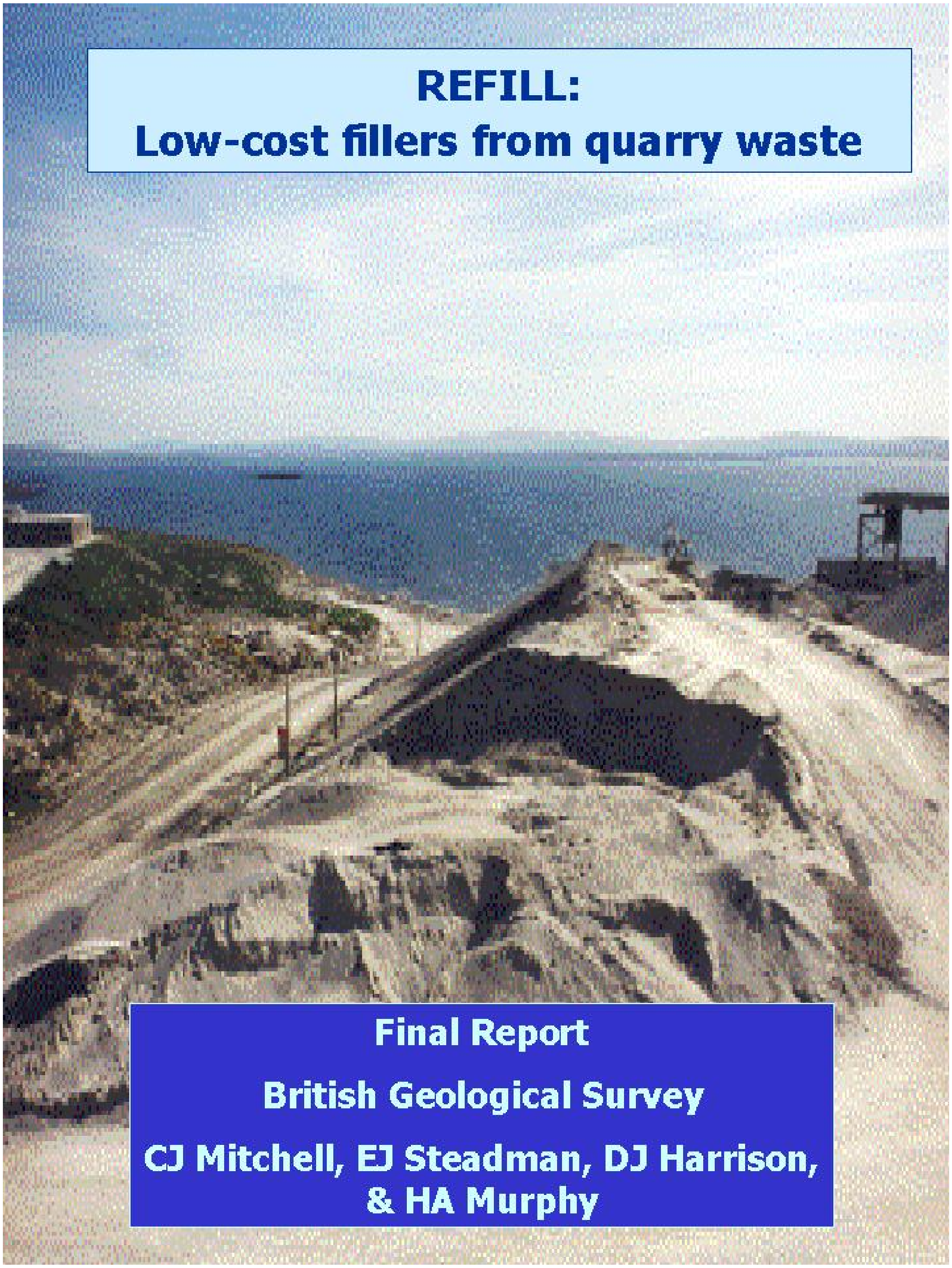
REFILL:
Low-cost fillers from quarry waste



Final Report

British Geological Survey

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SUMMARY

Aggregate quarrying produces substantial volumes of mineral residue material most of which remains in waste piles or tailings heaps, although some is used in back-filling of open pits and for landscaping and other uses within the quarry site. Fine-grained waste ('mud-slimes' or 'quarry dust') especially creates problems in its containment and disposal. This type of quarry waste has potential as a raw material for industrial mineral products and for use in the construction industry. Only a limited amount of research work has been done on the use of quarry waste as an industrial raw material and, in particular, little attention has been given to the use of the finer grained residues as mineral fillers. If beneficial use could be found for these wastes, which in aggregate quarries generally make up 20 – 30% of output, this would create added-value products and improve the profitability of the quarrying operation, as well as optimising resource use and reducing the environmental impact of waste disposal.

Stockpiles of fine grained residues at Leahill Quarry, Bantry Bay, Ireland

This research project (the REFILL Project) aims to develop low-cost, by-product fillers as a replacement for high-cost primary fillers, using the fine-grained mineral waste from aggregate quarrying. The Project is an EC-supported industrial research project (Brite-Euram BE97-5078) and was carried out by a consortium of partners from Britain (BGS,

Lodestone Technology Ltd.), Ireland (Tarmac Fleming Quarries Ltd.) and Greece (Doriki Construction and Industrial Corporation S.A., Yannidis Brothers S.A. and the Institute of Geology and Mineral Exploration) and co-ordinated by MIRO (Mineral Industry Research Organisation). This report provides the results of the BGS contribution to the Project.

The BGS objectives were to firstly collect samples of quarry fines from Leahill Quarry, Bantry Bay, County Cork, southwest Ireland (which was the main focus of interest for Tarmac Fleming Ltd, the Irish industrial partner in the Project), and also from many aggregate quarries in Britain. The quarry residues were then fully characterised by laboratory investigations of the mineralogical, physical and chemical properties of the fines. A third task followed, involving beneficiation testwork and the development of mineral processing methodologies to assess the potential for upgrading the fines. A final task was to contribute to the evaluation of the fines for use in different mineral products.

Sampling at Leahill Quarry, Bantry Bay and at numerous hard rock quarries and sand and gravel pits in Britain was carried out between July 1998 and September 1999. A total of 79 samples were collected from Leahill Quarry, including 10 rock samples, 20 samples of ‘historic’ fines, 10 samples of plant fines from the operational processing plant, 20 samples of ‘filler’ fines from the fluidised bed plant and an additional 2 bulk samples of fines for asphalt and concrete testing. Most samples were of 25 kg size and were taken using standard sampling procedures (BS EN 932-1:1997). A further 17 samples of fines were obtained from borehole cores, following the exploratory drilling at Leahill by Tarmac in 1998. 49 bulk samples of fines were collected from hard rock quarries and sand and gravel pits in Britain, including 6 samples from wharves processing marine sand and gravel.

The properties of the quarry residues were evaluated using a basic characterisation methodology involving mineralogical determination by X-ray diffraction (XRD), chemical analysis by X-ray fluorescence spectrophotometry (XRF) and particle-size analysis by a combination of wet sieving and X-ray Sedigraph analysis. Results are presented in a standardised factsheet format, giving the test data for each sample with a summary of results, and additional information on site data and sample type. 102 quarry residue Characterisation Factsheets have been produced and are enclosed in Appendix 2 of the report. A few samples from Leahill Quarry were selected for more detailed characterisation including determinations of mineral components, modal mineralogy and mineral liberation characteristics using methodologies such as petrographic analysis, XRD, Scanning Electron Microscopy (SEM) and Electron-Probe Microanalysis (EPMA). Part of this work was done in collaboration with the Institute of Geology and Mineral Exploration in Athens, Greece.

Leahill Quarry works a sequence of late-Carboniferous siltstones and sandstones to produce high quality roadstone aggregates. The quarry processing results in large amounts of fine-grained quarry residues (‘fines’ or ‘quarry dust’) which total about 20%

of the quarry output. The Characterisation Factsheets present data on the composition and likely properties of the quarry residue samples and provide an essential starting point for assessing their suitability for use in mineral-based products.

The Leahill Quarry fines consist essentially of feldspar (40%), quartz (35%), mica (20%) and chlorite (5%) with small amounts of calcite and rutile. The fines are remarkably consistent in mineralogy and chemistry regardless of sample type (plant fines, historic stockpile fines, filler fines, rock samples, borehole core). The fines contain between 20-25% filler grade material (material finer than 75 microns). This very fine-grained product is also of similar composition, but with slightly elevated mica and chlorite contents.

Mineral processing methodologies were used to investigate the potential for upgrading the fines to improve their quality. However, trials with both air classification and hydrocycloning techniques were unsuccessful in removing the mica and chlorite from the fines. The testwork has therefore shown that it is not possible to significantly reduce the iron and titanium contents of the quarry fines by mineral processing. Most mineral fillers, particularly those used in high-grade applications (paint, paper etc.), ideally have low iron and titanium contents, as these components tend to cause discolouration in manufactured products. The main potential end use for the Leahill Quarry fines, however, was thought to be as a low-grade filler in construction materials, specifically in asphalt and concrete.

Evaluation of the fines from Leahill Quarry for use in asphalt and concrete products, as well as in the formulation of synthetic soils (soil-less composts), has been carried out within the Project by Tarmac Ltd. BGS has supported this work by quantifying the amount of chlorite and mica present and by identifying the clay mineralogy of the filler grade material. The presence of clay minerals in the raw materials used in asphalt and concrete can have a detrimental effect on the properties of the bound material.

The clay mineral smectite has not been identified in any of the samples examined from Leahill Quarry. This ‘swelling clay mineral’ can have seriously detrimental effects on asphalt and may also affect the quality of concrete. The only clay minerals present are illite (mica – muscovite variety) and chlorite. The plant fines contain between 20% and 24% mica and chlorite (combined) and the filler-grade fines typically contain between 30% and 40% combined. These minerals form platy particles which can lead to drying shrinkage and cracking in concrete and asphalt products. The proportion of liberated discrete particles of mica and chlorite in the fines is an important factor in evaluating their likely in-service performance. The liberation analysis work has shown that only 40% of the mica and chlorite in the filler fines is liberated; most is interlocked with other minerals (mainly quartz) in rock fragments. Therefore, any deleterious effects of using this material in asphalt and concrete products are likely to be minimal.

Growing trials in synthetic soils made from Leahill fines and organic waste

The laboratory characterisation and mineral processing studies carried out by BGS on the Leahill Quarry fines and on residues from many British quarries have supported other project collaborators in meeting the objectives of the REFILL Project. Significant volumes of quarry residues from Leahill Quarry are now being used successfully in asphalt production in Britain, and the research has shown that satisfactory concrete products and artificial soils can also be manufactured using these fine-grained quarry residues.

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1. INTRODUCTION AND BACKGROUND

Aggregate extraction and processing operations generate considerable volumes of mineral residues, much of which is fine-grained (‘mud-slimes’ or ‘quarry dust’). In most aggregate quarries the residues amount to between 20% and 30% of total output and some quarries (such as certain sandstone and gritstone quarries) may produce as much as 40% residues. This potentially valuable resource is often substantially unused and the residues are mostly either stockpiled on site, disposed of in tailings ponds or transferred away from the quarry for disposal at waste sites. These residues are known as ‘permanent’ wastes. Some quarry wastes are, however, used at many sites in backfilling or in site restoration within the quarry or pit. These are known as ‘temporary’ wastes.

The main effects of ‘permanent’ waste are:

- Loss of usable land and/or sterilization of mineral resources at the quarry or pit
- Visual impact
- A source of dust
- A possible source of contamination to surface water courses
- Additional costs to the quarrying company of storage and long-term maintenance of the waste pile

If beneficial use could be found for these residues this would reduce quarry waste and optimise the use of resources, reduce the environmental impact of stockpiling and waste disposal, and improve the profitability of the quarrying operations. Some limited commercial use has been made of quarry waste but little attention has been given to the use of the fine-grained residues as mineral fillers.

The ‘REFILL’ Project aims to develop low-cost, by-product fillers as a replacement for high-cost primary fillers, using the fine-grained mineral waste from aggregate quarrying. The Project is an EC-supported industrial research project (Brite-Euram BE97-5078) involving a consortium of partners from Britain (including BGS), Ireland (Tarmac Fleming Quarries Ltd) and Greece (including Doriki Construction Corporation and the Institute of Geology and Mineral Exploration) and co-ordinated by MIRO (Mineral Industries Research Organisation).

This report presents the results of the BGS research work for the Project and focuses on the characterisation of the petrological, mineralogical, chemical and physical properties of the fine-grained residues from many aggregate quarries in Britain and also from one large coastal quarry in southwest Ireland (Leahill Quarry), which is the main interest of the Irish industrial partner (Tarmac Fleming Ltd). The potential for upgrading certain quarry residues by suitable low-cost beneficiation techniques has also been investigated and the results of the laboratory investigations have been used to assess the potential of the quarry residues for mineral fillers and other value-added products (such as asphalt, readymix concrete, concrete products, sub-base roadstone and synthetic soils). The Project's Final Report includes the research results of all partners, with a detailed techno-economic evaluation and exploitation plan.

Aggregate quarry waste may result from the extraction of overburden or interburden or from the quarrying of inferior-quality mineral which does not meet the specific requirements for the present markets for the aggregates. Residues can also be generated during aggregate processing, from the crushing and screening process or from the drying, coating or separation plant. The nature and particle size of the residues will vary widely in different types of extraction operation.

The principal materials studied by BGS in the REFILL project (from which marketable mineral fillers or construction materials may potentially be recovered) are:

- Waste from hard rock quarrying – mostly fine grained residues from sandstone (eg. Leahill Quarry), limestone and igneous rocks
- Waste from land-won sand and gravel pits of both fluvial and glacial origin
- Waste from marine sand and gravel processing operations

2. PROJECT OBJECTIVES

The overall objective of this industrial research project is to develop low-cost, by-product fillers as a replacement for high-cost primary fillers in a range of industrial products where neither the production specification, nor the end use, demands a high-grade filler product.

The source of the by-product fillers is quarry residues from aggregate quarrying and processing, specifically from limestone and siliceous rock types. The products under investigation are industrial paints, low-grade paper, asphalt, membranes and concrete products. The applications and market sectors are:

Applications	Sector
Paint	Marine
Membranes	Construction
Asphalt	Road construction
Concrete	Construction
Paper	Packaging

SUMMARY OF BGS OBJECTIVES (within the projects work programme)

Task 1. Field Study, drilling and sampling

To undertake literature surveys to identify suitable sampling procedures, product specifications and relevant research papers. To take samples of quarry fines from Leahill Quarry, Co. Cork, Ireland and from other quarries in Britain. Also to take representative samples of fines from borehole cores drilled at Leahill Quarry.

Task 2. Quarry residue evaluation

To carry out laboratory investigations of the mineralogical, physical and chemical properties of the residues from the Irish and British quarries.

Task 3. Laboratory scale beneficiation tests on residues

To carry out beneficiation testwork and to develop processing methodologies for the separation of a range of target minerals from the quarry residues (concentrating on the use of dry techniques).

Task 6. Evaluation of products

To assess the resource potential of quarry residues with regard to material quality and available volumes, and to assess the market potential for the different products that can be obtained from the processing of the residues.

3. RESEARCH METHODOLOGY

A range of laboratory methodologies were developed and utilised for analysis of the quarry residues. This section describes the methodologies used at each stage of the project's work programme (Tasks 2, 3 and 6).

3.1 Quarry residue evaluation (Task 2)

The characterisation work carried out can be sub-divided as follows:

i) Basic characterisation: Determination of *mineralogy* (by X-ray diffraction, XRD), *chemistry* (by X-ray fluorescence spectrophometry, XRF) and *particle-size distribution* (PSD, by particle-size analysis methods).

ii) Detailed characterisation: Determination of petrographic properties such as rock fabric and texture, size distribution of mineral components and modal mineralogy, including accessory minerals. This has been carried out using binocular microscopy and electron beam instruments (Scanning Electron Microscope, SEM and Electron Probe MicroAnalysis, EPMA using an Electron Microprobe.

3.1.1. Basic characterisation methodologies

Mineralogy: Bulk mineralogy was determined by X-ray diffraction (XRD), using a Phillips PW 1710 X-ray diffractometer operating at 45 kV and 40 mA. The samples were back loaded into aluminium holders and scanned over an angular range of 2 to $50^{o}2$□ using Co-K□ radiation. The X-ray diffraction peaks were interpreted with reference to the JCPDS database to identify the peaks observed.

Chemistry: Major element chemistry was determined using X-ray fluorescence (XRF) spectrophotometry.

Particle-size analysis: The samples of 'fines' were wet screened using the sieve series 10 mm, 2 mm, 1 mm, 500 µm, 250 µm, 125 µm and 75 µm. The sieve residues were dried and weighed. The particle-size distribution of the –75 µm material (the filler grade) was determined using an X-ray Sedigraph particle-size analyser.

3.1.2. Detailed characterisation methodologies

Binocular microscopy: Polished thin sections of the rock samples and polished resin-bound loose grain thin sections of the fines were produced. Petrographic analysis was carried out using a Zeiss binocular microscope, with camera attachment. Each rock sample was examined to determine its lithology, fabric, mineralogy and grain size distribution. The 'fines' samples were examined to determine the lithology of the individual particles.

Scanning Electron Microscope (SEM) analysis: The samples were examined as back scattered electron (BSE) images using a Cambridge Stereoscan 250 Mk II Scanning Electron Microscope. The semi-quantitative chemical composition of individual mineral components was determined using an integral energy dispersive system.

The modal mineralogy of selected rock samples was estimated by petrographic image analysis of BSE images and X-ray elemental maps generated by energy dispersive X-ray analysis (EDXA). The analysis was performed using a Kontron Elekronik image analysis system with a SEM processor interface to control the SEM and EDXA. The image analysis system identified and measured the modal proportions of the minerals present based on their unique BSE image and X-ray characteristics. This also enabled the measurement of the minimum and maximum particle diameters of all the mineral grains analysed. The mean particle diameter (also known as the mean 'intercept') was determined from this data. The cumulative frequency particle-size distribution of each mineral component was then determined by ratioing the mean intercept against the specific gravity of each respective mineral and plotting on semi-logarithmic charts.

Electron Probe Microanalysis (EPMA): The chemical composition of individual phases was determined by electron probe microanalysis (EPMA) using a Cambridge Instruments Microscan V electron microprobe with a Links Systems energy dispersive system (EDS).

3.1.3. Collaboration with the Institute of Geology & Mineral Exploration (IGME)

Further characterisation of the Leahill Quarry fines was carried out during collaboration between the BGS and the Institute of Geology & Mineral Resources (IGME), Athens, Greece. This involved a visit to the Mineralogy & Petrology Department, IGME (19-23 June 2000). The aim of the work was to provide information about the likely liberation characteristics of the quarry fines.

Petrographic analysis: The mineralogy of selected fines samples was determined by petrographic analysis. The samples were screened and subject to heavy media separation (using bromoform) to produce dense and less-dense fractions. Polished loose-grain thin sections were made from these products. Each was examined using a Leitz binocular microscope with a JVC video camera attachment. A direct video signal feed to a PC enabled 'real-time' examination, and capture of images, of the material. The mineral components were identified by an experienced IGME petrologist (Mrs Stavroula Karantassi). Also the 'degree of liberation' (i.e. the proportion of each mineral that is liberated) and the particle-size at which they are liberated was determined.

Mineralogy: Bulk mineralogy of selected fines samples was determined by XRD. The samples were processed using a Wilfley laboratory shaking table (a gravity separator) to produce dense and less-dense products. The bulk mineralogy of the products was determined using a Siemens X-ray diffractometer. The samples were front loaded into plastic holders and scanned over an angular range of 2 to 80°2θ using Cu-Kα radiation.

The X-ray diffraction peaks were interpreted, by an experienced IGME mineralogist (Dr. Vasssilis Perdikatsis), using the integrated Siemens PC software to identify the minerals present. The modal mineralogy was determined by modelling the raw XRD data using the Siroquant quantitative analysis software. This uses the Rietveld method to produce a theoretical X-ray diffraction trace that can be matched against the actual X-ray diffraction trace. The modal mineralogy of the sample corresponds to that which will produce the best ‘fit’ between the theoretical and the actual X-ray diffraction traces.

3.1.4. Mineral liberation studies

Mineral processing relies on an understanding of the mineral composition and the particle-size distribution and related textures of the mineral components of a rock. The ‘liberation size’ of a mineral is the particle-size at which it becomes free of the other minerals present. Total liberation could be achieved by crushing and/or grinding a rock to the liberation size, assuming preferential breakage along mineral grain boundaries.

However, crushing and/or grinding a rock to the liberation size may not be appropriate, as it may be too energy intensive (i.e. expensive) or the resulting particle-size distribution may be too fine for effective mineral processing. Also the particle-size distribution of the mineral components will dictate the mineral processing methods that could be brought to bear on the material as different methods operate effectively over different particle-size limits. Therefore it is important to determine the liberation size and the particle-size distribution of the mineral components in a rock prior to mineral processing.

Liberation analysis involved detailed petrographic examination of uncrushed rock samples, plant fines and filler fines from Leahill Quarry. Mineral size data from each rock sample has been used to determine the respective liberation sizes using two different modelling methods. Kings model allows the prediction of the ‘fractional liberation’ (1.000 being 100% and 0.000 being 0%) of a mineral from the ‘mean intercept length’ (i.e. the mean particle size). The mean size is equivalent to the mid-point on the cumulative frequency particle-size distribution chart for each mineral, known as the D_{50} (i.e. the size at which 50% of the mineral particles are finer).

Petruks model allows the prediction of the minimum, optimum and practical ‘grind’ required to liberate, plus it also allows an estimation of the ‘apparent liberation’ (i.e. proportion of particles liberated) likely to be attained for a certain grind ‘set-point’. The ‘minimum grind’ is equivalent to D_{80}, the ‘optimum grind’ is equivalent to D_{30} and the ‘practical grind’ is midway between these points, D_{55}. The apparent liberation achievable for a given grind size can be predicted by comparing the particle-size distribution of the ground material with the particle-size distribution of the minerals in the unbroken ore.

The mineral liberation size and modal mineralogy of rock samples was determined by SEM image analysis. Mineral size data from each rock sample was used to determine the respective liberation sizes using Kings and Petruks mineral liberation models respectively. The 'apparent liberation' of the minerals present was determined. The mineral size data was also combined with the modal mineralogy to determine the modal mineralogy of specific size intervals within the rock samples.

3.2. Laboratory scale beneficiation tests on quarry residues (Task 3)

3.2.1. Dry size classification

Approximately 1 kg from each sample was processed using air classifiers.

- A Hosokawa Micron zig-zag air classifier was used to remove material coarser than 150 μm. This separator uses a vertical zig-zag shaped column, with an upward moving air current to remove fine-grained, less-dense and flakier material from coarse-grained, heavier and more granular particles. The cut-point of the separation is controlled by adjusting the velocity of the air flow. The products are referred to as A/C +150 μm and A/C –150 μm.

- A Hosokawa Micron centrifugal air classifier was used to split the A/C –150 μm material into successively finer products, with cut points of 75 μm, 10 μm and 2 μm. This separator uses a rotating plate with outward radiating zig-zag channels and air flowing through the channels. The cut point of the separation is controlled by adjusting the rotational speed of the plate and the velocity of the air flow. The products are referred to as A/C +75 μm, A/C +10 μm, A/C +2 μm and A/C –2 μm.

3.2.2. Wet size classification

This was carried out to provide comparative data for the dry size classification trials. Approximately 1 kg from each sample was processed using wet screening and hydrocyclones.

- Wet screening was used to remove material coarser than 75 μm. Stainless steel sieves with 150 μm and 75 μm diameter apertures were used. The products retained on the sieves, +150 μm and +75 μm, are equivalent to A/C +150 μm and A/C +75 μm respectively.

- A Mozley C155 25mm hydrocyclone, attached to a Mozley test rig, was used to remove coarse silt grade (>10 μm) material from the –75 μm material. The material was processed as a suspension. Fine and coarse particles were separated, under pressure, into overflow and underflow products respectively. The underflow (equivalent to the A/C +10 μm product) is referred to as H/C +10 μm.

- A Mozley C1010 hydrocyclone assembly (fitted with six Mozley 10mm hydrocyclone units), attached to a Mozley test rig, was used to remove fine silt grade (>2 μm) material from the 25mm hydrocyclone overflow. Overflow and underflow products were produced. The underflow (equivalent to the A/C +2 μm product) is referred to as H/C +2 μm. The overflow (equivalent to the A/C –2 μm product) is referred to as H/C –2 μm.

3.3. Evaluation of products (Task 6)

Clay mineralogy: The clay mineralogy was determined by X-ray diffraction analysis. A portion of the clay fraction (<2 μm) was extracted by sedimentation. A small sub-sample of the clay fraction (80 mg) was dispersed in deionised water, deposited onto a porous ceramic disc by vacuum filtration and allowed to dry in air. This is known as an oriented clay mount. The sample was analysed using a Phillips PW 1710 X-ray diffractometer operating at 45 kV and 40 mA. The sample was scanned over an angular range of 2 to $32^o 2\theta$ using Co-Kα radiation. The analysis was repeated after glycolation (using ethylene glycol) and again after heat treatment (2 hours at 550^oC) of the sample. The clay mineralogy was determined by interpretation of the X-ray diffraction peaks with reference to the JCPDS database to identify the peaks observed.

Mica-chlorite quantification: The mica and chlorite content was determined by X-ray diffraction analysis. The samples were prepared and analysed as for the determination of bulk mineralogy by XRD. The angular scan range was limited to 7 to $17^o 2\theta$ to encompass the clay mineral basal spacings that produce the most intense diffraction responses. These occur at 10.33 $^o2\theta$ (the mica (001) basal spacing) and at 14.61 $^o2\theta$ (the chlorite (002) basal spacing). The scans were repeated twice. The intensities (counts per second, cps) and areas ($^o2\theta$ /cps) of the diffraction peaks were measured and an average value for each calculated. Calibration standards (with a range of known mica and chlorite contents) were also analysed and used to produce calibration charts for both mica and chlorite. The mica and chlorite content of each sample was then determined. The modal mineralogy of each sample was also determined by subtracting the major element contribution of the mica and chlorite from the XRF data and apportioning the remainder to quartz and feldspar

4. WORK UNDERTAKEN

4.1. Field study, drilling and sampling (Task 1)

Two visits to Leahill Quarry, Bantry Bay, Ireland were undertaken by BGS in 1998, in August and November. The initial visit was for general geological and site studies, for collection of lump samples from the quarry face and for the collection of historic fines from dumps and stockpiles and fines from the operational mobile processing plant. Ten rock samples and ten fines samples were collected and returned to BGS laboratories for initial characterisation. The main sampling work was undertaken during the second visit. Twenty samples (each 25kg) of fines (0-3 mm sized material) were taken from the new fixed processing plant and also from stockpiles/dumps. Samples of fines were taken according to the relevant British Standard for sampling (BS EN 932-1:1997).

Quarrying siltstone and fine sandstone at Leahill Quarry

In early June 1999 samples of ‘filler’ fines (material mostly finer than 75 microns) from the fluidised bed at Leahill Quarry were received at BGS. The fluidised bed was intended to remove most of the filler grade material from the aggregate processing stream. These samples (sixteen samples of ‘unconditioned’ filler) represented weekly production of filler between February and April 1999. Additionally, four samples of damp ‘conditioned’ filler were included in the batch. Additional samples of Leahill Quarry fines were also obtained over the next year for collaborative studies with Tarmac. The first was a bulk sample of filler (LHF 51) from the fluidised bed which Tarmac investigated for its performance in asphalt applications. The second was a bulk sample of plant fines (LHF 52) which Tarmac tested for its performance in concrete applications.

Cores from exploratory drilling work carried out at Leahill Quarry (late 1998) were examined and tested for their aggregate properties at the central Tarmac laboratories in Wolverhampton. Seventeen samples of fines from the cores following aggregate testing were dispatched to BGS in July 1999 for characterisation and mineral processing studies.


Coarse aggregate from the primary crusher, Leahill Quarry

An additional 43 bulk samples of fines were collected between November 1998 and September 1999 from a further 24 quarries mostly operated by Tarmac in Britain. These quarries work a range of siliceous and igneous rock types or alluvial sand and gravel. Several quarries working limestone and dolomite were also sampled. Also, six samples of fines from the processing of marine dredged sand and gravel (siliceous material) were obtained from United Marine Dredging in the UK.

A full sample list is given in Appendix 1 (Table A).

A literature survey was conducted to identify relevant research papers, reports and information. The limited amount of literature obtained is archived as a reference 'library' and has been catalogued using PC-based bibliographic software (EndNote ®).

4.2. Residue evaluation (Task 2)

Of the 128 samples collected (79 from Leahill Quarry and 49 from various UK quarries) 102 have been characterised (basic characterisation); (the work carried out is summarised in Appendix 1: Table B). A factsheet has been produced for each sample characterised (see Appendix 2) and present data showing the mineralogy, chemistry and particle-size distribution as well as information on the locality, geology and sampling methodology.

A few samples (representing the range of lithologies found at Leahill Quarry) were chosen for detailed characterisation using electron beam instruments based on an initial petrographic examination. The four samples were:

- LHR 3	Medium siltstone	- LHR 1	Coarse siltstone
- LHR 7	Very fine to fine sandstone	- LHR 4	Fine sandstone

Liberation analysis, involving detailed petrographic examination, was carried out on the following samples from Leahill Quarry:

Rock samples: The mineral liberation size and modal mineralogy of two rock samples, LHR 7 and LHR 4 were determined. The 'apparent liberation' of the minerals present in a fines sample (LHF 11) and a filler fines sample (LHF 40) were also determined.

Plant / filler fines samples: The 'degree of liberation' (i.e. the proportion of liberated grains) of the mineral components of the plant and filler fines samples, LHF 11 (plant fines) and LHF 40 (filler fines) was determined.

4.3. Laboratory scale beneficiation tests on residues (Task 3)

Laboratory scale mineral processing testwork was carried out on fines from Leahill Quarry. As the fines contain a small proportion of chlorite and rutile (which are rich in iron and titanium) removal of these minerals should help to reduce the levels of impurities. Mineral fillers ideally have low iron and titanium contents, as these components are usually the cause of discolouration in manufactured products.

Initial characterisation of the fines indicated that the rutile, chlorite and mica are concentrated in the finest size fractions. Therefore, removal of these fractions should, in theory, reduce the iron and titanium contents. To achieve this, size classification trials (using air classification and hydrocycloning) were carried out on five samples of the production fines (LHF11, 13, 15, 17 and 19). The mineral processing test work is summarised as flowsheets (Appendix 1: Figures 1 and 2). One of these samples (LHF 11) was chosen for detailed product evaluation, involving chemical and mineralogical analysis, to determine the 'metallurgical mass balance' (i.e. the distribution of components across the classification products). The yield, grade and recovery of mica, chlorite, quartz and feldspar were determined for each of the products. The **yield** is the weight proportion of a product, the **grade** is the weight proportion of a given component (e.g. feldspar) and the **recovery** is the proportion of a given component recovered in a product. Grade-recovery charts for the mica and chlorite were also produced.

4.4. Evaluation of products (Task 6)

The suitability of the 'filler' fines (produced by the fluidised bed) from Leahill Quarry for use in asphalt and concrete was investigated in collaboration with Tarmac. BGS's role in this task was to identify the clay mineralogy of the filler grade material and to quantify the amount of chlorite and mica present.

The presence of clay minerals in aggregate or filler used in asphalt (and concrete) can have a detrimental effect on the subsequent technical properties of the bound material. Chlorite and mica are both present in the filler grade material from Leahill Quarry. The main problem associated with these minerals is their tendency to split along their basal cleavage forming platy particles. This can lead to a poor bond, increased water demand and likelihood of drying shrinkage and cracking. The critical factor in assessing their likely impact upon bound material is the proportion of chlorite and mica occurring as discrete particles. Mica and chlorite bound up in aggregate particles (with quartz mainly in this case) will pose less of a potential problem. The proportion of discrete particles of mica and chlorite occurring in the filler fines was determined by the liberation analysis work (as described in Task 2).

The chlorite and mica content of a range of rock, borehole core fines, filler fines and mineral processing products (sample list given in Appendix 1: Table C) was determined by XRD. The modal mineralogy of the samples was also determined.

5. RESULTS

This section presents the results obtained from the laboratory investigations of quarry residues from Leahill Quarry in Ireland (which was the focus of this research project) and from certain quarries in the UK. Detailed test data are included in the appendices. The results are described for each stage of the project's work programme (Tasks 2, 3 and 6).

5.1. Residue evaluation (Task 2)

5.1.1. Leahill Quarry: Rock samples (LHR 1 – 10)

The rock samples consist of dominant quartz (>50 wt%), with minor to major amounts (7 – 50 wt%) of chlorite, alkali (Na- and K-) feldspar and mica and trace amounts of calcite (<7 wt%).

In hand specimen the rock samples range from **medium grained siltstones** to **fine grained sandstones**, that are pale to dark grey through to greenish- and purplish-grey in colour (with no apparent correlation between grain size and colour). In thin section (see plates 1 to 4) they consist of quartz (and occasional feldspar) grains in a fine matrix of chlorite, mica and quartz, with sparsely disseminated opaque mineral grains (Fe/Ti oxides and carbon ?) and calcite. There is an apparent increase in quartz content with increasing grain size, from siltstone to sandstone, and a corresponding decrease in the amount of matrix present. Quartz grains range in size from 15 – 30 µm (medium siltstone) to 120 – 180 µm (fine sandstone). Opaque mineral grains range in size from 10 – 20 µm (siltstone) to 30 – 100 µm (fine sandstone), occasionally up to 150 µm. Lineations, and structures in general, are generally weak or absent. Chlorite and mica often define marked lineations. Irregular banding of paler and darker grey material occasionally occurs, resulting from concentrations of quartz and mica respectively.

The chemical composition of the rock samples is summarised in Table 1.

Table 1. Chemistry of rock samples, Leahill Quarry, Co Cork, Ireland

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O
Mean	69.97	0.88	15.76	4.13	1.41	2.97
Minimum	59.16	0.51	7.19	1.91	0.96	0.64
Maximum	85.72	1.08	22.1	5.18	2.31	4.45

Data from 4 samples.

Petrographic examination by SEM confirmed the presence of a variety of accessory minerals including rutile, leucoxene, zircon, rare earth phosphates, apatite, magnetite, pyrite, chalcopyrite and galena. The main accessory mineral was found to be rutile (variety of TiO_2) and EPMA determined that it contained 92-94% TiO_2, with the remainder consisting mainly of silica, alumina and manganese.

5.1.2. Leahill Quarry: Historic and current fines samples (LHF 1 – 30)

The **historic** and **current** production fines samples consist of dominant quartz (>50 wt%), with major to trace amounts of chlorite (<50 wt%), minor amounts of alkali (Na- and K-) feldspar (7 – 20 wt%), minor to trace amounts of mica (<20 wt%) and trace amounts of calcite and rutile (<7 wt%).

The chemistry of the historic and current production fines (3mm –0mm) samples is summarised in Table 2. There is little difference in chemical composition between the historic production fines and the current production fines samples. The ‘filler’ (<75 µm) grade material from the current production fines samples was also analysed. Compared to the coarser ungraded fines the silica content is depressed and the titanium, alumina, iron and alkali contents are elevated. This indicates that the filler grade material has a higher proportion of rutile, chlorite and mica.

Table 2. Chemistry of historic and current production fines samples, Leahill Quarry, Co Cork, Ireland

	SiO_2 wt%	**TiO_2 wt%**	**Al_2O_3 wt%**	**$Fe_2O_3^t$ wt%**	**Na_2O wt%**	**K_2O wt%**
Historic fines samples Mean	70.21	0.89	14.26	4.72	1.25	2.66
Min	67.41	0.85	13.04	4.09	1.09	2.47
Max	73.72	0.99	15.78	5.13	1.42	3.06
Current fines samples Mean	69.80	0.85	14.08	4.88	1.44	2.51
Min	69.00	0.83	13.56	4.52	1.32	2.50
Max	70.70	0.87	14.56	5.15	1.59	2.52
Current fines samples <75 µm filler grade’ Mean	65.50	1.01	16.34	5.49	1.45	3.08
Minimum	64.80	0.99	15.90	5.06	1.33	3.00
Maximum	66.20	1.04	16.89	5.72	1.60	3.13

Data based on 5 historic production fines samples, 5 current production fines samples and 5 sub-samples of ‘filler’ grade material.

The historic production fines samples contain rock fragments with the following range of lithologies:

Fine sandstone (grains >150 µm)	7 – 31 %, av. 18 %
Coarse siltstone - very fine sandstone (grains 30 – 150 µm)	32 – 48 %, av. 40 %
Medium siltstone (grains <30 µm)	25 – 61 %, av. 42 %

The particle-size distribution of the historic and current production fines samples is summarised in Table 3. The fines samples have a ‘filler’ (material <75 μm) content of 19 to 23 wt%. The current production fines samples contain a higher proportion of fine-grained particles than the historic fines samples. This is most pronounced in the coarsest size fractions, for example the historic production fines samples contain 25% coarser than 2 mm whereas the current production fines contain less than 3%. This is thought to be partly due to differences in quarry processing and also the result of weathering loss of fines in the historic material.

Table 3. Cumulative frequency size data, historic and current production fines samples, Leahill Quarry, Co Cork, Ireland

	-10 mm	**-2 mm**	**-1 mm**	**-500 µm**	**-250 µm**	**-125 µm**	**-75 µm**	**-10 µm**	**-2 µm**
Historic fines samples Mean	100.0	75.0	53.7	41.2	32.3	23.9	**19.3**	11.7	5.5
Minimum	100.0	62.5	42.3	31.7	24.9	19.1	15.7	8.9	4.3
Maximum	100.0	92.0	78.1	66.5	52.7	31.8	26.3	15.8	7.0
Current fines samples Mean	100.0	97.3	71.1	50.1	37.3	27.9	**23.4**	12.2	6.1
Minimum	100.0	96.7	65.8	46.2	32.9	22.9	18.3	9.7	4.8
Maximum	100.0	98.3	74.9	54.1	41.6	31.0	26.3	13.9	7.4

Data based on 10 historic production fines samples and 5 current production fines samples.

5.1.3. Leahill Quarry: Fluidised bed ‘filler’ fines (LHF 31 – 50)

The fluidised bed ‘filler’ fines samples consist of dominant quartz (>50 wt%), with major to minor amounts of chlorite (7 – 50 wt%), minor amounts of alkali (Na- & K-) feldspar and mica (7 – 20 wt%) and trace amounts of calcite and rutile (<7 wt%).

The chemistry of the fluidised bed ‘filler’ fines samples is summarised in Table 4. The chemical composition of the ‘filler’ fines shows remarkable consistency over the period that the samples were collected from the fluidised bed separation plant (beginning of February to mid May 1999). Compared to the previous fines samples (historic and current production) the ‘filler’ fines are a little lower in silica content and a little higher in titanium, alumina, iron and alkali contents. The ‘filler’ fines are similar in composition to the <75 μm ‘filler grade’ material produced by screening previous fines samples (see Table 2).

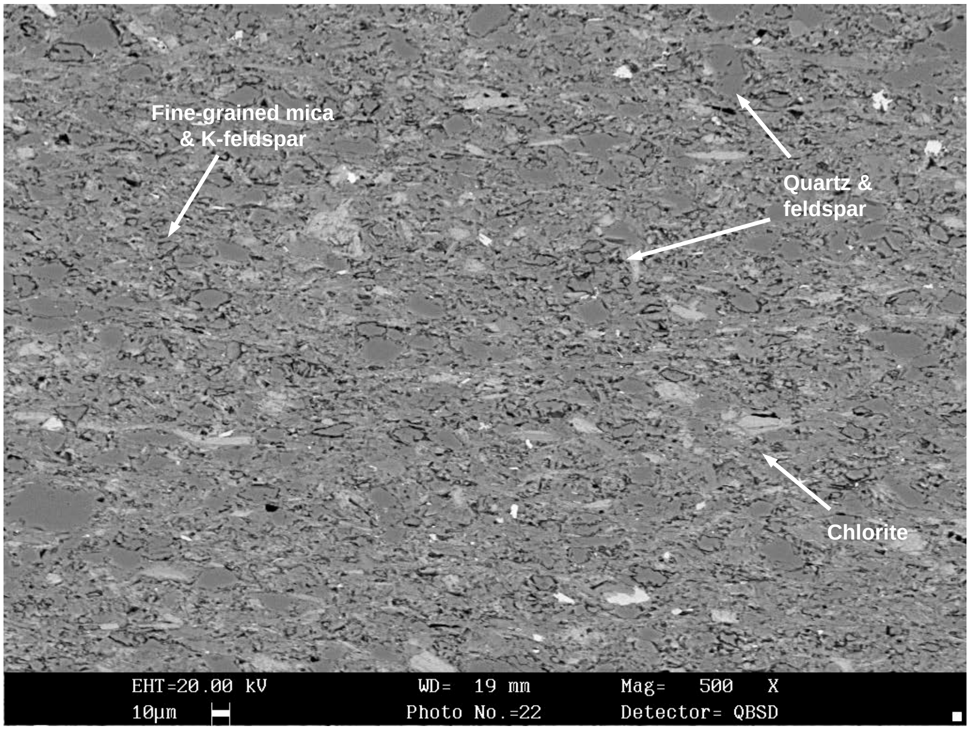


Plate 1. SEM (scanning electron microscope) photomicrograph of medium-grained siltstone (LHR 3), Leahill Quarry, Co. Cork, Ireland Larger grains (<20µm) are mainly quartz with occasional plagioclase feldspar. Paler, large grains are chlorite. The remainder is made up of fine grained mica and K-feldspar.

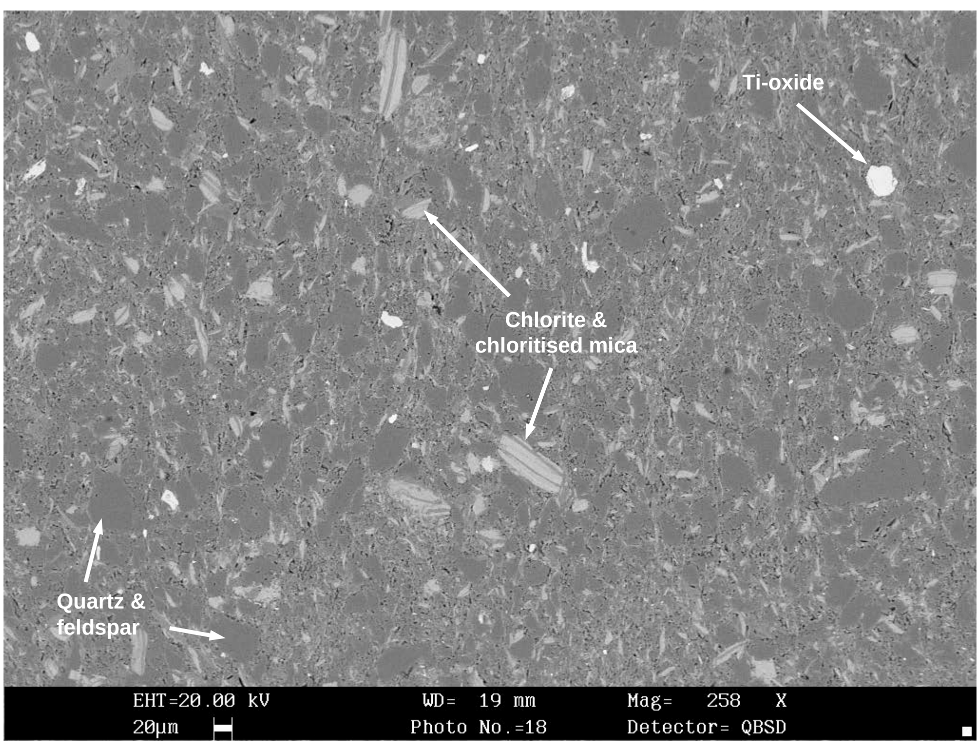


Plate 2. SEM (scanning electron microscope) photomicrograph of coarse-grained siltstone (LHR 1), Leahill Quarry, Co. Cork, Ireland Larger grains (<50µm) are mainly quartz with occasional plagioclase feldspar. Chlorite / chloritised micas are pale grey tones. Large bright phases (~20µm) are Ti oxide with fine grained rare-earth element (REE) phosphate, zircon and apatite.

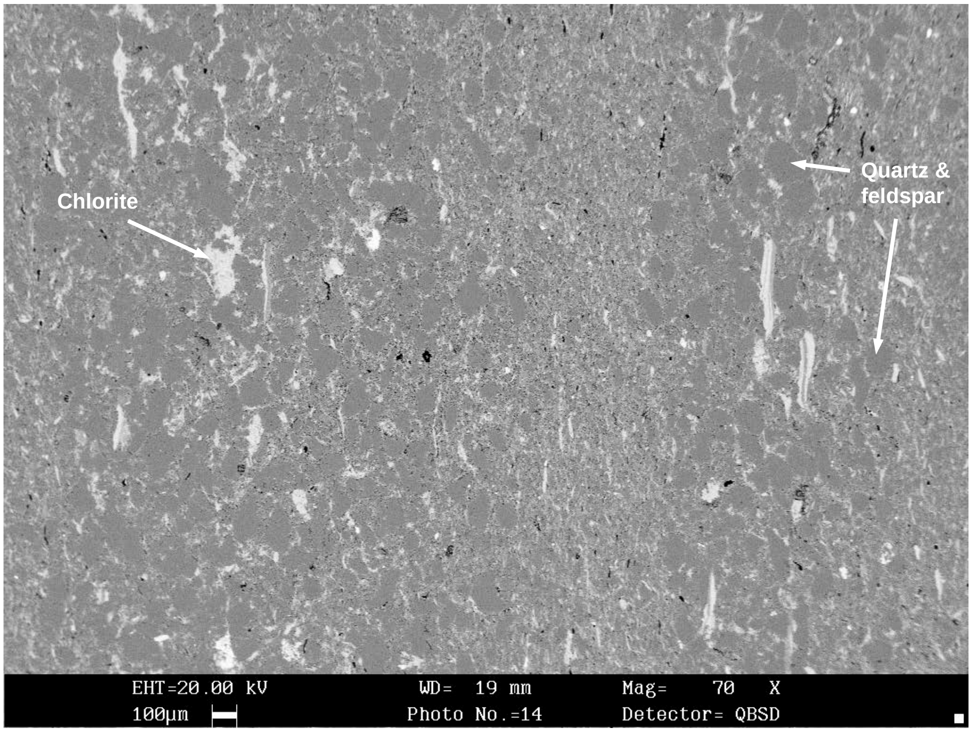


Plate 3. SEM (scanning electron microscope) photomicrograph of very fine to fine grained sandstone (LHR 7), Leahill Quarry, Co. Cork, Ireland General structure shot showing lamination of very fine and fine layers. Coarse bands show grains up to 100µm in size whilst fine bands are <50µm.

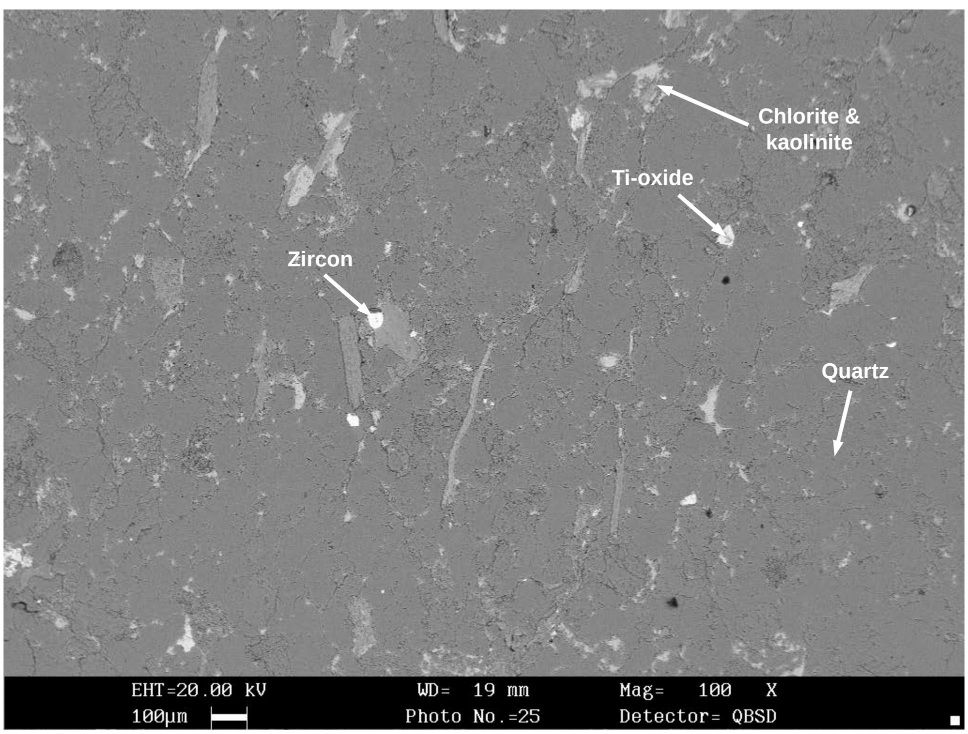


Plate 4. SEM (scanning electron microscope) photomicrograph of fine grained sandstone (LHR 4), Leahill Quarry, Co. Cork, Ireland General shot of sandstone structure showing tightly packed quartz grains with pore filling chlorite and rare poorly crystalline kaolinite. Bright phases are zircon (left) and Ti oxide (right).

Table 4. Chemistry of fluidised bed 'filler' fines and borehole core fines samples, Leahill Quarry, Co Cork, Ireland

	SiO_2 wt%	TiO_2 wt%	Al_2O_3 wt%	$Fe_2O_3^t$ wt%	Na_2O wt%	K_2O wt%
Fluidised bed 'filler' Mean	67.60	1.01	15.59	5.10	1.09	3.29
Min	67.01	0.98	15.27	5.02	1.01	3.02
Max	68.09	1.03	15.94	5.21	1.38	3.42
Borehole core fines Mean	68.24	0.91	14.65	5.04	1.45	2.69
Min	66.26	0.86	13.85	4.27	1.05	2.04
Maximum	70.67	0.99	16.28	6.09	1.91	3.24

Data based on 12 fluidised bed filler fines samples and 10 borehole core fines samples.

The particle-size distribution of the fluidised bed 'filler' fines samples is summarised in Table 5. These 'filler' fines have a relatively consistent 'filler' (material <75 μm) content, ranging between 85 and 93 wt%.

Table 5. Cumulative frequency size data for fluidised bed 'filler' fines and borehole core fines samples, Leahill Quarry, Co Cork, Ireland

	-10 mm	-2 mm	-1 mm	-500 μm	-250 μm	-125 μm	-75 μm	-10 μm	-2 μm
Fluidised bed 'filler' fines Mean	100.0	100.0	100.0	99.9	99.3	95.7	**87.5**	42.0	19.9
Minimum	100.0	100.0	100.0	99.5	98.3	94.4	84.5	38.2	18.2
Maximum	100.0	100.0	100.0	100.0	99.7	97.5	93.0	47.5	21.9
Borehole core fines Mean	100.0	30.3	19.3	13.3	9.6	7.2	**5.9**	3.0	1.2
Minimum	100.0	21.2	12.6	9.0	6.8	5.5	4.6	2.3	0.8
Maximum	100.0	38.3	24.5	16.5	12.2	8.9	7.4	3.5	1.4

Data based on 12 fluidised bed fines samples and 10 borehole core fines samples.

No discernable difference between the properties of the unconditioned (dry) and conditioned (wet) fluidised bed 'filler' fines samples was detected.

5.1.4. Leahill Quarry: Borehole core fines (LHC 1 – 17)

The fines produced from preparation of exploratory borehole core material for aggregate testing consist of dominant quartz (>50 wt%), with major to minor amounts of chlorite and Na-feldspar (7 – 50 wt%), minor amounts of K-feldspar and mica (7 – 20 wt%) and trace amounts of calcite and rutile (<7 wt%). This is similar to the results obtained from quarry fines and from 'filler' fines. The results reflect variations in borehole core lithology, which are summarised in simplified form in Table 6. There is no identifiable correlation between the lithology of the borehole core and the mineralogy of the borehole core fines samples. The mineralogy and chemistry of the rocks are very consistent.

Table 6. Lithological summary of selected of borehole cores, Leahill Quarry, Co Cork, Ireland

Borehole core	**Sandstone** %	Siltstone %	Mudstone %
Sandstone dominated (LHC 3)	95	5	0
Siltstone dominated (LHC 13)	16	81	3
Mudstone enriched (LHC 6)	17	72	11
Average of all borehole core (17 samples)	**64**	**34**	**2**

The chemistry of the borehole core fines is summarised in Table 4. The chemical composition of the borehole core fines is comparable to that of the historic and current production fines (see Table 2). The particle-size distribution of the borehole core fines is summarised in Table 5. The borehole core fines have a consistently low 'filler' (material <75 μm) content, ranging from 5 to 7 wt%.

5.1.5. UK quarries

The quarry residue samples collected from UK quarries represent a range of lithologies including sand and gravel (land and marine), sandstone, limestone, dolomite, trachyte lava, diorite, dolerite and granite. Their mineralogical, chemical and physical properties cannot be simply summarised into tables, but the results are given in the Characterisation Factsheets (Appendix 2). Their mineralogy and chemistry broadly reflect the lithology of the worked material. Their particle-size distribution partly reflects the lithology but mainly the degree of processing the material has undergone. Generally samples of precipitator and lagoon fines have high ‘filler’ (particles <75 µm) contents, ranging from 75 to 93%, whereas samples of plant fines have lower ‘filler’ contents, ranging from 10 to 16%.

5.1.6. Mineral liberation studies

Rock samples: The mineral liberation size of the rock samples, LHR 7 (very fine to fine sandstone) and LHR 4 (fine sandstone) has been determined by SEM image analysis. The modal mineralogy of the two rock samples was also determined (Table 7).

Table 7. Modal mineralogy of rock samples, Leahill Quarry

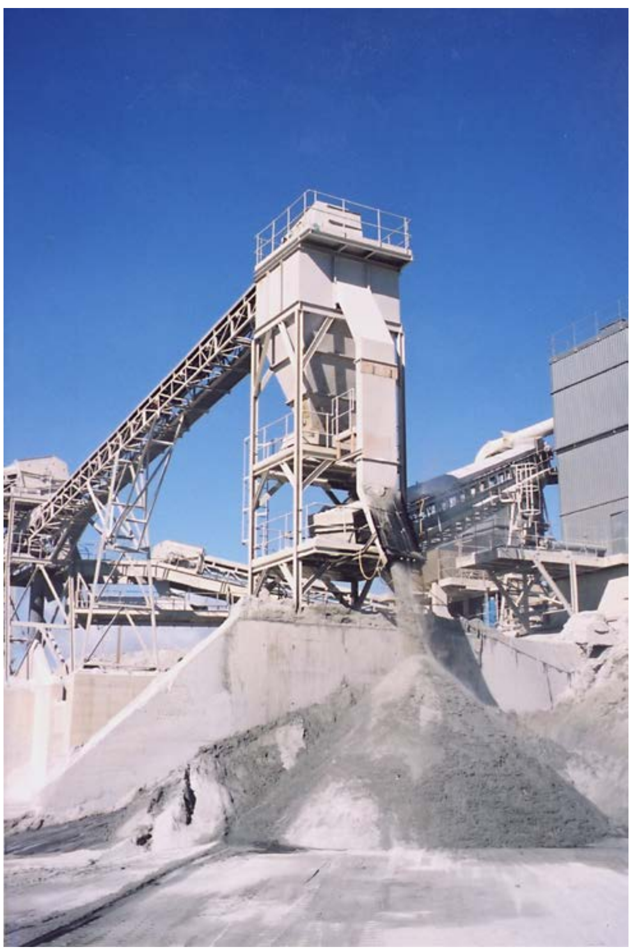
Mineral component	LHR 7 Wt %	LHR 4 Wt %
Quartz	59.07	84.30
Mica	25.70	8.88
Chlorite	12.47	3.59
Feldspar	2.19	2.55
Ti oxides	0.34	0.37
Apatite	0.10	0.18
Fe oxides	0.07	0.05
Calcite	0.01	0.04
Pyrite	<0.01	<0.01
REE phosphate	<0.01	0.01
Zircon	<0.01	<0.01
Unclassified	0.03	0.02
Total	100.00	100.00

The fractional liberation (based on Kings model of mineral liberation) is given in Appendix 1 (Tables D & E). This indicates that to achieve a mineral liberation of 80% (0.8 fractional liberation) both rock samples would have to be ground finer than 10 microns. The predicted grind sizes (based on Petruks model of mineral liberation) are given in Appendix 1 (Tables F & G). This indicates that to achieve 80% liberation the samples would have to be ground finer than 20 to 50 microns. This produces a dilemma. In order for effective mineral separation to occur during processing the proportion of mineral liberation must be high. However, to achieve a high proportion of mineral liberation the Leahill fines would have to be ground to a size at which the processing methods do not work efficiently.

The apparent liberation (Appendix 1: Table H) of the minerals present in the fines (produced at Leahill Quarry) is less than 15% and for the ‘filler’ fines (produced by the fluidised bed plant at Leahill Quarry) it is less than 50%. Mineral processing of the fines and ‘filler’ fines from Leahill, without further grinding, is likely to lead to poor mineral separation and products that contain unacceptably high levels of impurities.

The mineral size data (used to determine mineral liberation) was combined with the modal mineralogy to determine the modal mineralogy of specific size intervals within the rock samples (Appendix 1: Table I). The distribution of the minerals present in sample LHR 7 (a very fine to fine sandstone) does not show any strong trends. The distribution of the minerals present in LHR 4 (a fine sandstone) indicates a decrease in quartz with decreasing particle-size and an increase in mica, chlorite and feldspar with decreasing particle-size.

Plant / filler fines samples: The 'degree of liberation' (i.e. the proportion of liberated grains) of the mineral components of the plant and filler fines samples, LHF 11 (plant fines) and LHF 40 (filler fines) has been determined by petrographic analysis. The 'degree of liberation' of the mineral components, as well as the grain size of the liberated grains, in the heavy media separation products (less-dense and dense) is summarised in Appendix 1 (Tables J and K). Mineral liberation in the fines sample is typically less than 15%, with only quartz showing a high proportion of mineral liberation (30 to 50% in the 10 to 75 μm size fraction). Mineral liberation in the 'filler' fines is also low with quartz showing the highest proportion of liberated grains (50 to 75% in the 10 to 63 μm size fraction). The modal mineralogy of the fines samples was also determined by X-ray diffraction (Table 8).



Fines from the processing plant, Leahill Quarry

Table 8. Modal mineralogy of fines samples, Leahill Quarry

Mineral	**Plant fines** (LHF 11) Wt %	**Filler fines** (LHF 40) Wt %
Quartz	63.7	60.4
Mica	21.7	25.8
Chlorite	7.3	6.7
Feldspar	7.3	7.1
Total	100.0	100.0

NB Data as determined by Dr Vassilis Perdikatsis, Mineralogy & Petrology Department, IGME, Greece.

5.2. Laboratory scale beneficiation tests on residues (Task 3)

The chemistry of the classification products is given in Appendix 1 (Table L) and the 'metallurgical mass balance' of the classification testwork is given in Appendix 1 (Tables M and N). The grade and recovery curves of the mica are given in Appendix 1 (Figures 3 to 6).

The chemical analysis of the classification products indicates an increase in iron and titanium content with decreasing particle size. Also, there is an increase in the alumina, magnesia and potassium contents and a decrease in silica content. Mineralogical analysis indicates an increase in alkali feldspar, mica and chlorite contents and a decrease in quartz content with decreasing particle-size. However, 70 to 80 % of the mica and chlorite remains in the coarsest size fractions (+75 microns). This indicates that the processing trials have been unsuccessful in removing the mica and chlorite to any significant degree from the fines sample.

From the research data it was possible to simulate the processing of filler fines (<75 microns). This was achieved by subtracting the data for the +75 micron products and normalising the data for the –75 micron products. Appendix 1 (Tables O and P) has a summary of the simulated processing of a filler fines sample by air classification and hydrocycloning. It can be seen that a high proportion of mica and chlorite would remain in the coarser size fractions (+10 microns), although the hydrocycloning trials would remove nearly 60% of the mica into the –10 micron products. However, the data generated from the simulated classification trials indicates that processing would largely be unsuccessful in removing the mica and chlorite to any significant degree from filler fines samples.

5.3. Evaluation of products (Task 6)

The proportion of chlorite and mica present in the Leahill material is given in Appendix 1 (Table Q). The chlorite and mica content of the rock samples is apparently proportional to their particle size with the coarsest rocks containing the least (less than 10% combined) whereas the finest rock contains the most (over 60% combined). The plant fines contain 20 to 24% combined chlorite and mica and the fluidised bed filler fines typically contain 30 to 40% combined. The size classification products do not show a strong correlation between chlorite and mica content and particle-size, however there is a broad trend that confirms the general increase with decreasing particle-size.

The proportion of discrete particles of mica and chlorite occurring in the filler fines has been determined by the liberation analysis work (Table 9). This indicates that mineral liberation does not exceed 80% until finer than 10 microns.

Fines from Leahill Quarry are now being used in asphalt manufacture

Table 9. Proportion of discrete mica and chlorite, Filler fines (LHF 40), Leahill Quarry

Size fraction (μm)	**Yield** Wt %	**Mica** Wt %	% discrete*	**Chlorite** Wt %	% discrete*
>75	13.1	-	5	-	2
63 - 75	5.4	-	2	-	2
10 - 75	40.1	-	5	-	5
<10	41.4	-	90	-	90
Overall	100.0	25.8	40	6.7	39

NB * = '% discrete' refers to the proportion of the mineral present that occurs as liberated grains.

Table 9 indicates that 40 % of the mica and chlorite occurring in the filler fines is liberated. Therefore, based upon the modal mineralogy, 10 % of the filler consists of discrete mica particles and another 3 % of the filler fines consist of discrete chlorite particles.

The modal mineralogy of samples was also determined (Appendix 1: Table R). The quartz and feldspar contents generally decrease from the coarser- to the finer-grained rocks, with an increase in mica and chlorite. The plant fines currently produced contain 40% feldspar, 36% quartz, 21% mica and 3% chlorite. The fluidised bed plant 'filler'fines have a consistent mineralogy, averaging 35% quartz, 30% feldspar, 30% chlorite and 5% mica.

The clay mineral smectite has not been identified in the fines from Leahill Quarry. This 'swelling clay mineral' can have seriously detrimental effects on bound material (asphalts). The only clay minerals present are chlorite (iron-rich variety) and illite (mica - muscovite variety).

6. CONCLUSIONS

Fine grained quarry residues from Ireland and the UK have been analysed to determine their chemical, mineralogical and physical properties and their potential for use as raw materials in the construction industry. This included 79 samples from Leahill Quarry, Co. Cork Ireland (which was the main focus for this work) and 49 samples from UK quarries (ranging from sand and gravel pits to hard rock sedimentary and igneous rock quarries).

Leahill Quarry produces crushed rock aggregate from a 'gritstone' deposit that consists of grey coloured, medium-grained siltstones to fine grained sandstones. The main objective of the aggregate plant is to produce high quality aggregates for coated and uncoated roadstone (20mm to 3mm single size and Type 1 materials). The quarry residues, known as dust or 'fines' (3mm to 0mm) produced at Leahill represents about 20% of the tonnage processed by the quarry plant.

The BGS research work has shown that the dust (fines) produced by the quarry plant consist mainly of quartz (35%), feldspar (40%), mica (20%) and chlorite (5%) and have a 'filler' grade (material <75 microns) content of approximately 20 to 25%. A fluidised bed plant, established at the quarry to reduce the 'filler' content of the fines in the aggregate products, produced very fine-grained waste material (referred to here as 'filler' fines). The filler fines have a similar mineralogical composition to the plant fines, with slightly elevated mica and chlorite contents, and a filler grade content of 85 to 90%. The fines produced from several exploratory borehole cores situated throughout the quarry site were also very similar in composition to the plant fines. The key characteristic of the Leahill quarry residue is the highly consistent nature of its chemical and mineralogical composition, regardless of sample type. This is a reflection of the rock lithology, which is broadly consistent across the quarry site.

Test work was carried out on the fines from Leahill Quarry to determine if, through the application of mineral processing methodologies, they could be upgraded to improve their quality. The first stage of this work was a 'mineral liberation' study. This aimed to determine the particle-size at which the mineral components of the quarry waste would be free and amenable to separation. Modelling of mineral size data indicated that 80% liberation would only be achieved if the material was ground finer than 10 microns (Kings model) or 50 microns (Petruks model). The apparent liberation of the minerals present in the quarry waste was as low as 15% for the plant fines and 50% for the filler fines. This gave a strong indication that any mineral processing carried out upon the Leahill Quarry residues would lead to inefficient mineral separation.

The second stage of the test work was to carry out mineral processing trials on samples of the Leahill Quarry fines. The aim was to reduce the amount of mica and chlorite present, thereby reducing the iron and titanium contents. The characterisation work had indicated that these minerals were concentrated in the finest size fractions of the quarry waste.

Therefore, air classification and hydrocycloning, both size classification processes, were chosen for the mineral processing trials. However, the processing trials were unsuccessful in removing the mica and chlorite to any significant degree from the fines.

Evaluation of the fines from Leahill Quarry for use in concrete, asphalt and synthetic soils has recently been carried out in Tarmac central laboratories and is ongoing. In support of this work, the proportion of mica and chlorite present in the fines samples has been investigated by BGS, as the presence of these minerals can have a detrimental effect on the technical properties of bound material. The plant fines generally contain 20% mica and 3% chlorite and the filler fines contain around 30% mica and 5% chlorite. The critical factor in assessing their likely impact upon bound material is the proportion of discrete particles of chlorite and mica (i.e. not interlocked with other minerals in rock fragments). The research has shown that only 40% of the mica and chlorite in the filler fines are present as discrete particles. No swelling clay minerals (such as smectite) were found to be present in the Leahill Quarry fines.

Growing trials in synthetic soils using Leahill Quarry fines mixed with organic waste

The research effort has successfully demonstrated that acceptable asphalt and concrete can be produced using Leahill Quarry fines and currently Tarmac are using a large proportion of the residues, which previously was considered a waste product.

7. REFERENCES

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APPENDIX 1. TECHNICAL DATA

Table A. Sample list

Sample No.	Description	Sample No.	Description
<u>Leahill Quarry rock samples</u> <u>(10)</u>		**<u>Leahill Quarry filler samples</u>** <u>(22)</u>	
	Coarse siltstone, working face.	**LHF 31***	'Filler' fines (fluidised bed plant)
LHR 2*	Very fine sandstone, working face.	**LHF 32***	'Filler' fines (fluidised bed plant)
LHR 3*	Medium siltstone, working face.	**LHF 33***	'Filler' fines (fluidised bed plant)
LHR 4*	Fine sandstone, working face.	**LHF 34***	'Filler' fines (fluidised bed plant)
LHR 5*	Coarse siltstone, working face.	**LHF 35***	'Filler' fines (fluidised bed plant)
LHR 6*	Medium siltstone, working face.	**LHF 36***	'Filler' fines (fluidised bed plant)
LHR 7*	Fine sandstone, working face.	**LHF 37***	'Filler' fines (fluidised bed plant)
LHR 8*	Fine sandstone, working face	**LHF 38***	'Filler' fines (fluidised bed plant)
LHR 9*	Medium siltstone, working face.	**LHF 39***	'Filler' fines (fluidised bed plant)
	Fine sandstone, working face.	**LHF 40***	'Filler' fines (fluidised bed plant)
		LHF 41*	'Filler' fines (fluidised bed plant)
<u>Leahill Quarry fines samples</u> <u>(30)</u>			'Filler' fines (fluidised bed plant)
		LHF 43*	'Filler' fines (fluidised bed plant)
	Plant fines (historic production)	**LHF 44***	'Filler' fines (fluidised bed plant)
LHF 2*	Plant fines (historic production)	**LHF 45***	'Filler' fines (fluidised bed plant)
LHF 3*	Plant fines (historic production)	**LHF 46***	'Filler' fines (fluidised bed plant)
LHF 4*	Plant fines (historic production)	**LHF 47***	'Filler' fines (fluidised bed plant)
LHF 5*	Plant fines (historic production)	**LHF 48***	'Filler' fines (fluidised bed plant)
LHF 6*	Plant fines (historic production)	**LHF 49***	'Filler' fines (fluidised bed plant)

LHF 7*	Plant fines (historic production)		‘Filler’ fines (fluidised bed plant)
LHF 8*	Plant fines (historic production)		‘Filler’ fines (bulk sample)
LHF 9*	Plant fines (historic production)		
LHF 10*	Plant fines (historic production)		
LHF 11*	Plant fines (current production)	**Leahill Quarry borehole samples** (17)	
LHF 12	Plant fines (current production)		
LHF 13*	Plant fines (current production)	**LHC 1***	Borehole core (<10mm) fines
LHF 14	Plant fines (current production)	**LHC 2***	Borehole core (<10mm) fines
LHF 15*	Plant fines (current production)	**LHC 3***	Borehole core (<10mm) fines
LHF 16	Plant fines (current production)	**LHC 4***	Borehole core (<10mm) fines
LHF 17*	Plant fines (current production)	**LHC 5***	Borehole core (<10mm) fines
LHF 18	Plant fines (current production)	**LHC 6***	Borehole core (<10mm) fines
LHF 19*	Plant fines (current production)	**LHC 7***	Borehole core (<10mm) fines
LHF 20	Plant fines (current production)	**LHC 8***	Borehole core (<10mm) fines
LHF 21	Plant fines (historic production)	**LHC 9***	Borehole core (<10mm) fines
LHF 22	Plant fines (historic production)	**LHC 10***	Borehole core (<10mm) fines
LHF 23	Plant fines (historic production)	**LHC 11***	Borehole core (<10mm) fines
LHF 24	Plant fines (historic production)		Borehole core (<10mm) fines
LHF 25	Plant fines (historic production)	**LHC 13***	Borehole core (<10mm) fines
LHF 26	Plant fines (historic production)	**LHC 14***	Borehole core (<10mm) fines
LHF 27	Plant fines (historic production)		Borehole core (<10mm) fines
LHF 28	Plant fines (historic production)	**LHC 16***	Borehole core (<10mm) fines
LHF 29	Plant fines (historic production)	**LHC 17***	Borehole core (<10mm) fines
LHF 30	Plant fines (historic production)		
LHF 52*	Plant fines (bulk sample)		

*** = Sample characterised and data summarised in a factsheet (see Appendix 2).**

Table A. Sample list **(continued)**

Sample No.	Description	Sample No.	Description
UK quarries fines: Batch one (19)		**UK quarries fines: Batch three** (9)	
	Precipitator fines, Arcow	**BDEF 1***	Filler fines, Dene
BAF 2	Lagoon fines, Arcow	**BDEF 2***	Mixed filler fines, Dene
BCHF 1*	Precipitator fines, New Cliffe Hill	**BDEF 3***	Filler fines, Dene
BCHF 2	Precipitator fines, New Cliffe Hill	**BHHF 1***	Plant fines, Hillhead
BEF 1*	Lagoon fines, Ebchester	**BCLF 1***	Filler fines, Cauldon Low
BEF 2	Lagoon fines, Ebchester	**BTHF 1***	Plant fines, Threshfield
BBF 1*	Plant fines, Barrasford	**BTHF 2***	Plant fines, Threshfield
BBF 2	Plant fines, Barrasford	**BHHSF 1***	Filler fines, Holme Hall
BMF 1*	Filler fines, Mootlaw	**BHHSF 2***	Plant fines, Holme Hall
BMF 2	Lagoon fines, Mootlaw	**UK quarries fines: Batch four** (8)	
BHF 1*	Plant fines, Howick		
BHF 2	Plant fines, Howick		
BBOF 1	Plant fines, Borthwick	**BBSF 1***	Plant fines, Blashford
BBOF 2*	Filler fines, Borthwick		Plant fines, Blashford
BBAF 1*	Plant fines, Bangley	**BBSF 3***	Plant fines, Blashford
BBAF 2	Plant fines, Bangley	**BBSF 4**	Plant fines, Blashford
BKR 1	Rock sample (granite), Creetown	**BPHF 1***	Filler fines, Pant (Halkyn)
BKF 1*	Plant fines, Creetown	**BDGF 1***	Plant fines, Denbigh (Graig)
BDF 1*	Plant fines, Dalbeattie	**BSCF 1***	Plant fines, Stancombe (Backwell)
UK quarries fines: Batch two (13)		**BSTF 1***	Plant fines, Stowfield
BBHF 1*	Plant fines, Bayston Hill		
BBHF 2*	Filler fines, Bayston Hill		
BBHF 3*	Reclaimed filler fines, Bayston Hill		
BCHF 1*	Plant fines, Callow Hill		
BLF 1*	Plant fines, Lound		
BLF 2*	Plant fines, Lound		
BLFF 1*	Plant fines, Langford		
BBWF1*	Plant fines, Bedhampton wharf		
BRF 1*	Plant fines, Ridham wharf		
BRF 2*	Plant fines, Ridham wharf		

BNWF 1*	Plant fines, Newhaven wharf		
BSWF 1*	Plant fines, Southampton wharf		
BLHF 1*	Plant fines, Littlehampton wharf		

* = Sample characterised and data summarised in a factsheet (see Appendix 2).

Table B. Summary of analysis work carried out upon quarry residue samples

Samples	Basic characterisation			Detailed characterisation
Leahill Quarry Rock (face samples) (LHR 1-10)	All	4	All	4 samples (Microscopy, SEM, EPMA & XRD **)
Leahill Quarry Historic production fines (LHF 1-10)	All	5	All	5 samples (Binocular microscopy) + 1 sample (XRD **)
Leahill Quarry Current production fines (LHF 11-30)	5	5 *	5	1 sample & process products (Binocular microscopy & XRD **)
Leahill Quarry **Fluidised bed ‘filler (LHF 31-50)**	20	12	20	1 sample (Binocular microscopy & XRD **)
Leahill Quarry **Plant fines (Bulk; LHF 51-52)**	2	2	2	1 sample (Clay mineralogy & XRD **)
Leahill Quarry Borehole core fines (LHC 1-17)	All	10	All	3 samples (XRD **)
Various UK quarries (Batch 1) Current production fines (19 samples)	10	10	10	None
Various UK quarries (Batch 2) Current production fines (13 samples)	13	9	13	None
Various UK quarries (Batch 3) Current production fines (9 samples)	9	6	9	None
Various UK quarries (Batch 4) Current production fines (8 samples)	6	6	6	None

NB 1 = X-ray diffraction (XRD) analysis; 2 = X-ray fluorescence (XRF) analysis; 3 = Particle-size distribution (PSD) analysis. * = Material <75 μm was also analysed as separate sub-samples.
** = Quantification of mica and chlorite by XRD.

Table C. Samples chosen for mica-chlorite quantification, Leahill Quarry

Sample	Description	**Sample**	**Description**
LHR 1	Coarse siltstone	LHF 38	Fluidised bed fines
LHR 3	Medium siltstone	LHF 40	Fluidised bed fines
LHR 4	Fine sandstone	LHF 46	Fluidised bed fines
LHR 7	Very fine –fine sandstone	LHF 51	Fluidised bed fines
LHF 4	Historic plant fines	LHF 11 : E909	A/C product: +10 □m
LHF 11	Current plant fines	LHF 11 : E910	A/C product: +2.5 □m
LHC 3	B/H core: sandstone-rich	LHF 11 : E911	A/C product: -2.5 □m
LHC 6	B/H core: siltstone-rich	LHF 11 : E914	H/C product: One inch U/F
LHC 13	B/H core: mudstone-rich	LHF 11 : E915	H/C product: Ten mm U/F
LHF 31	Fluidised bed fines	LHF 11 : E916	H/C product: Ten mm O/F
LHF 34	Fluidised bed fines		

NB B/H = Borehole; A/C = Air classification; H/C = Hydrocyclone; U/F = Underflow; O/F = Overflow

Table D. Fractional liberation (Kings model) of rock sample, LHR7, Leahill Quarry

Size fraction (µm)	**D** (µm)	**Quartz** 22.2*	**Feldspar** 12.6*	**Mica** 14.5*	**Apatite** 15*	**Chlorite** 20*	**Rutile** 18*
2 to 10	6	0.893	0.824	0.844	0.848	0.883	0.871
10 to 15	12.5	0.797	0.685	0.716	0.723	0.779	0.760
15 to 20	17.5	0.735	0.604	0.639	0.647	0.713	0.690
20 to 30	25	0.656	0.511	0.548	0.557	0.630	0.604
30 to 40	35	0.572	0.423	0.460	0.469	0.544	0.517
40 to 50	45	0.506	0.361	0.396	0.404	0.478	0.451
50 to 60	55	0.453	0.315	0.347	0.355	0.426	0.399
60 to 75	67.5	0.401	0.272	0.301	0.309	0.375	0.350
75 to 125	100	0.309	0.201	0.225	0.231	0.286	0.265
125 to 250	187.5	0.191	0.118	0.134	0.138	0.176	0.161
250 to 500	375	0.106	0.063	0.072	0.074	0.096	0.088
500 to 1000	750	0.056	0.033	0.037	0.038	0.051	0.046

NB * = mean particle-size of mineral in microns; D = mean size fraction interval; 1.0 represents 100% liberation and 0.0 represents 0% liberation.

Table E. Fractional liberation (Kings model) of rock sample, LHR4, Leahill Quarry

	D	Quartz	Feldspar	Mica		Chlorite	Rutile
(μm)	(μm)	68.5*	13.5*	17.5*		22.5*	25*
2 to 10	6	0.963	0.834	0.868		0.895	0.904
10 to 15	12.5	0.926	0.701	0.754		0.799	0.816
15 to 20	17.5	0.899	0.621	0.683		0.737	0.758
20 to 30	25	0.860	0.529	0.597		0.659	0.683
30 to 40	35	0.813	0.441	0.509		0.575	0.602
40 to 50	45	0.770	0.378	0.443		0.509	0.537
50 to 60	55	0.731	0.331	0.392		0.456	0.484
60 to 75	67.5	0.687	0.286	0.343		0.404	0.431
75 to 125	100	0.591	0.213	0.260		0.311	0.335
125 to 250	187.5	0.427	0.126	0.157		0.194	0.211
250 to 500	375	0.268	0.067	0.085		0.107	0.118
500 to 1000	750	0.154	0.035	0.045		0.057	0.063

NB * = mean particle-size of mineral in microns; D = mean size fraction interval; 1.0 represents 100% liberation and 0.0 represents 0% liberation.

Table F. Predicted 'grind' sizes, (Petruks model), LHR 7, Leahill Quarry

Grind size	**Quartz** (μm)	**Feldspar** (μm)	**Mica** (μm)	**Apatite** (μm)	**Chlorite** (μm)	**Rutile** (μm)
Minimum grind (D_{80})	43.9	15.3	18.7	19.7	38.0	35.0
Practical grind (D_{55})	29.3	13.3	15.7	16.9	26.5	23.9
Optimum grind (D_{30})	14.6	11.3	12.6	14.0	14.9	12.8

Table G. Predicted 'grind' sizes (Petruks model), LHR 4, Leahill Quarry

Grind size	**Quartz** (μm)	**Feldspar** (μm)	**Mica** (μm)		**Chlorite** (μm)	**Rutile** (μm)
Minimum grind (D_{80})	126.0	17.0	31.1		49.5	54.0
Practical grind (D_{55})	86.4	14.5	22.3		32.8	34.7
Optimum grind (D_{30})	46.7	11.9	13.4		16.1	15.4

Table H. Apparent liberation, plant & filler fines (Petruks model), Leahill Quarry

Products	**Quartz** %	**Feldspar** %	**Mica** %	**Apatite** %	**Chlorite** %	**Rutile** %
Plant fines (LHF 11)						
LHR 7	9.0	6.0	7.5	7.0	8.5	8.5
LHR 4	14.0	7.0	9.0		12.5	9.0
Filler fines (LHF 40)						
LHR 7	43.5	25.0	28.0	27.0	41.0	40.5
LHR 4	51.5	30.0	40.5		47.5	41.0

NB Apparent liberation is based on a comparison of the mineral particle size distribution (from LHR 7 & 4) with the particle-size distribution of the fines samples (LHF11 and 40). LHR 7 is a very fine sandstone therefore produces a lower apparent liberation percentage than LHR 4, which is a fine sandstone. LHF 11 is a plant fines sample and LHF 40 is a filler fines sample (**NB** As used in the IGME collaboration work).

Table I. Modal mineralogy of size intervals, rock samples, Leahill Quarry

Mineral	**>75 µm** wt %	**10 – 75 µm** wt %	**2 – 10 µm** wt %
LHR 7			
- Quartz	88.6	54.8	86.3
- Mica	0.00	28.6	10.0
- Chlorite	11.2	13.9	1.2
- Feldspar	0.0	2.2	2.4
- Ti oxide	0.2	0.4	<0.1
- Apatite	0.0	0.1	<0.1
- Total	100.0	100.0	100.0
LHR 4			
- Quartz	98.6	75.8	0.0
- Mica	0.5	14.3	28.6
- Chlorite	0.9	5.3	11.5
- Feldspar	0.0	4.0	57.5
- Ti oxide	0.0	0.6	2.4
- Total	100.0	100.0	100.0

NB The modal mineralogy of the <2 µm could not be determined due to lack of size data.

Table J. Liberation characteristics, Plant fines (LHF 11), Leahill Quarry

Mineral	**>500 □m**				**125 – 500 □m**			
	Dense		Less-dense		Dense		Less-dense	
	% liberation	Size □m	% liberation	Size □m	% liberation	Size □m	% liberation	Size □m
Quartz	-	-	~1	<500	-	-	~10	200
Mica	-	-	-	-	-	-	-	-
Chlorite	-	-	-	-	~10	<500	-	-
Feldspar	-	-	-	-	-	-	-	-
Ti oxides	-	-	-	-	<1	<100	-	-
Fe oxides + pyrite	~15	<1300	-	-	~15	<500	-	-
Calcite	-	-	-	-	~10	<500	-	-
Zircon	-	-	-	-	<1	<100	-	-
Sphene + leucoxene	-	-	-	-	<1	<100	-	-
Tourmaline	-	-	-	-	-	-	-	-

NB Data as determined by Mrs Stavroula Karantassi, Mineralogy & Petrology Department, IGME.

Table J cont/d. Liberation characteristics, Plant fines (LHF 11), Leahill Quarry

Mineral	75 - 125 □m				10 - 75 □m			
	Dense		Less-dense		Dense		Less-dense	
	% liberation	Size □m	% liberation	Size □m	% liberation	Size □m	% liberation	Size □m
Quartz	-	-	~15	<130	~50	<50	~30	<100
Mica	-	-	-	-	~2	<10	~2	<20
Chlorite	~15	<130	~2	<100	~2	<30	~3	<50
Feldspar	-	-	~2	<100	~1	<50	~2	<50
Ti oxides	~1	<50	-	-	~1	<20	~1	<10
Fe oxides + pyrite	~15	<130	-	-	~5	<50	~3	<100
Calcite	~5	<100	<1	<100	~3	<50	~3	<100
Zircon	~2	<100	-	-	~2	<50	~2	<40
Sphene + leucoxene	~3	<100	-	-	~3	<50	3	<50
Tourmaline	-	-	~2	<100	~1	<50	~2	<50

NB Data as determined by Mrs Stavroula Karantassi, Mineralogy & Petrology Department, IGME.

Table K. Liberation characteristics, Filler fines (LHF 40), Leahill Quarry

Mineral	>75 μm				63 – 75 μm			
	Dense		Less-dense		Dense		Less-dense	
	% liberation	Size μm	% liberation	Size μm	% liberation	Size μm	% liberation	Size μm
Quartz	~3	<150	~15	<150	-	-	~25	<100
Mica	~4	<50	~5	<50	~2	<100	~2	<100
Chlorite	~20	<150	~1	<50	~7	<100	~2	<100
Feldspar	-	-	-	-	-	-	~1	<100
Ti oxides	~1	<50	-	-	~3	<100	-	-
Fe oxides + pyrite	~10	<130	~2	<100	~8	<100	~2	<100
Calcite	~15	<150	~1	<100	~5	<100	~1	<100
Zircon	~1	<100	-	-	~4	<100	-	-
Sphene + leucoxene	~5	<150	~1	<50	~7	<100	~2	<100
Tourmaline	~1	<70	-	-	~2	<100	-	-

NB Data as determined by Mrs Stavroula Karantassi, Mineralogy & Petrology Department, IGME.

Table K cont/d. Liberation characteristics, Filler fines (LHF 40), Leahill Quarry

Mineral	**10 – 63 □m**			
	Dense		Less-dense	
	% liberation	Size □m	% liberation	Size □m
Quartz	~50	<50	~75	<50
Mica	~5	<50	~5	<50
Chlorite	~5	<50	~5	<50
Feldspar	-	-	~1	<50
Ti oxides	~1	<50	~1	<50
Fe oxides + pyrite	~5	<50	~3	<50
Calcite	~3	<50	~1	<50
Zircon	~2	<50	~1	<50
Sphene + leucoxene	~3	<50	~2	<50
Tourmaline	~1	<50	~1	<50

NB Data as determined by Mrs Stavroula Karantassi, Mineralogy & Petrology Department, IGME.

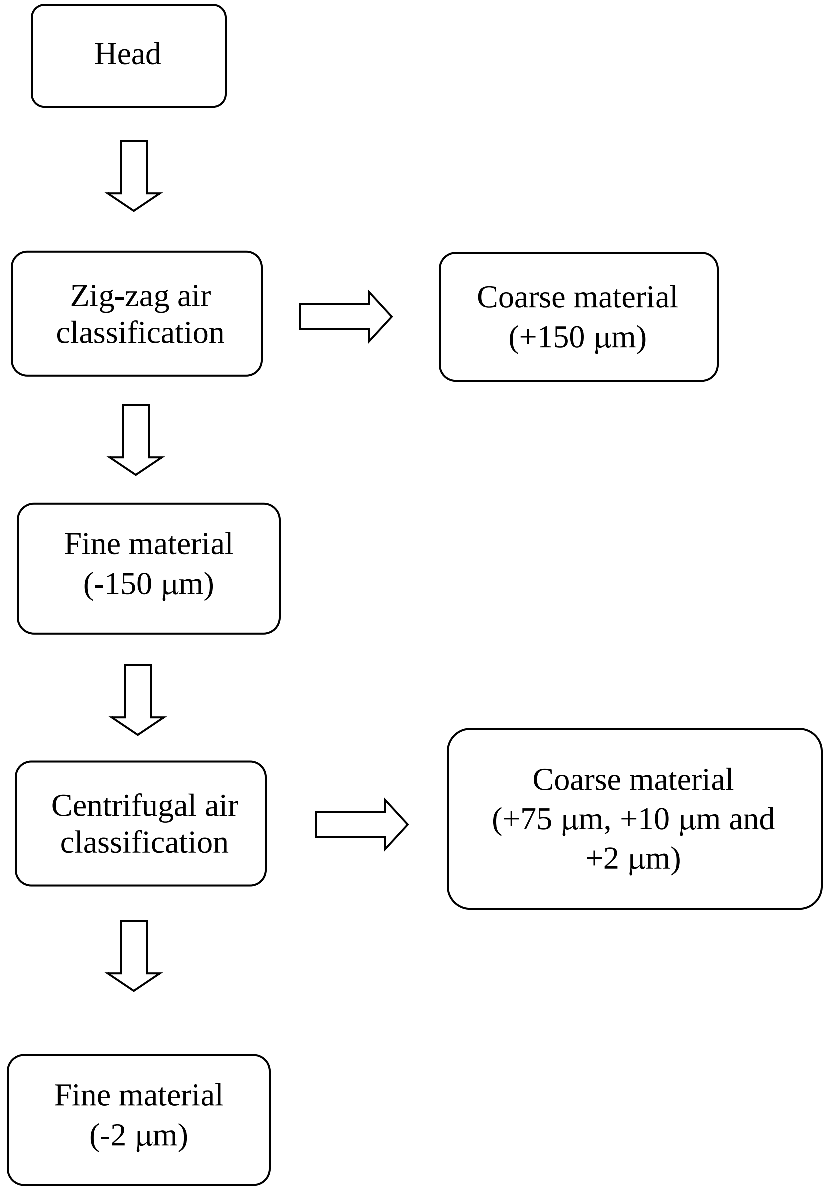


Figure 1. Flowchart of dry size classification testwork

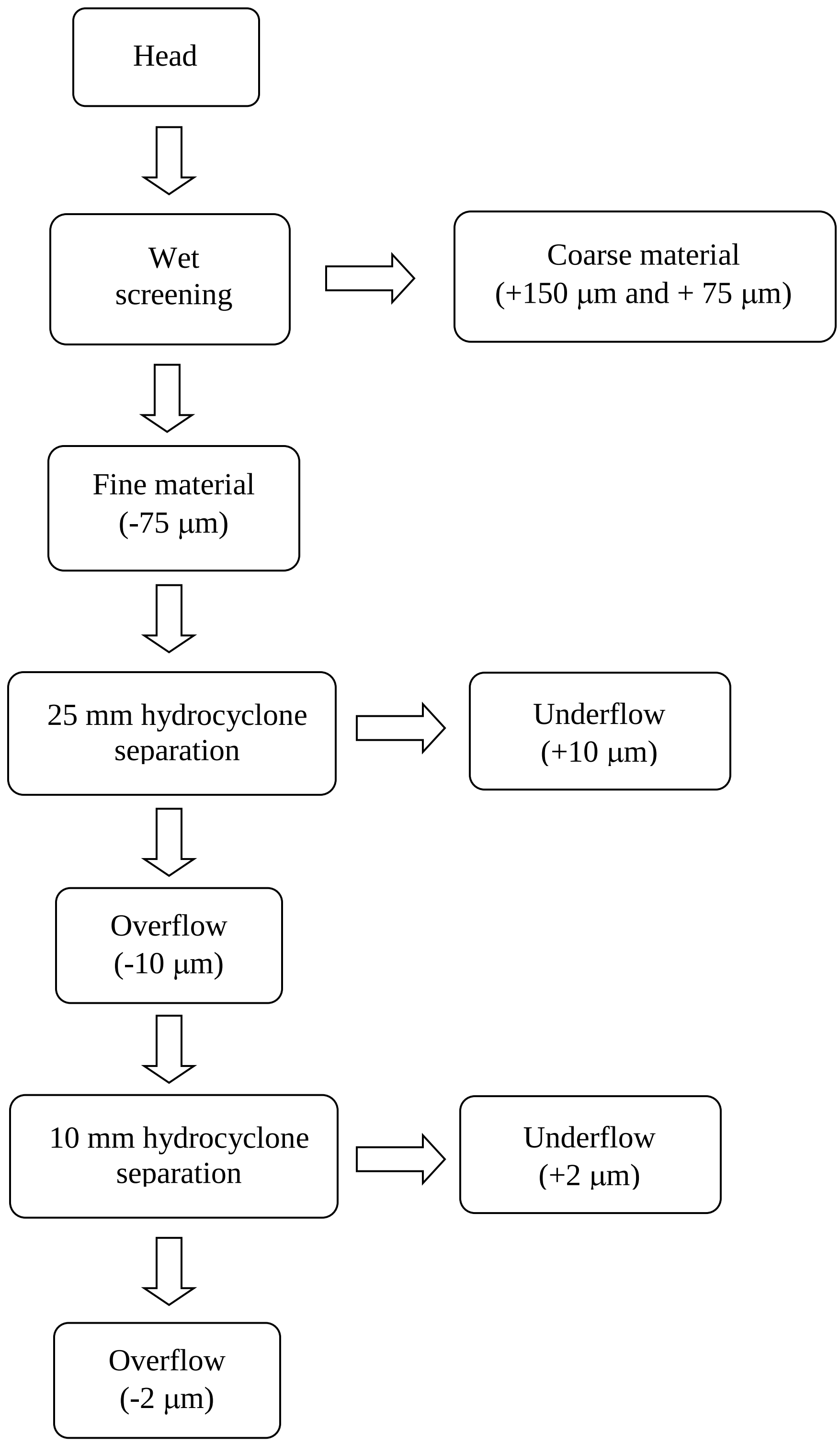


Figure 2. Flowchart of wet size classification testwork

Table L. Selected chemistry of mineral processing products

Dry size classification	SiO_2 wt %	TiO_2 wt %	Al_2O_3 wt %	Fe_2O_3t wt %	Na_2O wt %	K_2O wt %
Head	69.37	0.86	14.56	5.06	1.32	2.52
A/C +150 µm [1]	69.16	0.86	14.52	5.11	1.33	2.54
A/C +75 µm [2]	72.66	0.81	12.69	4.47	1.29	2.18
A/C -75 µm [3]	64.80	1.04	16.89	5.72	1.33	3.06
A/C +10 µm [2]	72.95	0.82	12.38	4.59	1.51	1.98
A/C +2 µm [2]	60.62	0.90	18.88	6.92	1.28	3.53
A/C -2 µm [3]	51.18	1.40	24.55	7.95	0.94	5.04
Wet size classification	**SiO_2** wt %	**TiO_2** wt %	**Al_2O_3** wt %	**Fe_2O_3t** wt %	**Na_2O** wt %	**K_2O** wt %
Head	69.37	0.86	14.56	5.06	1.32	2.52
H/C +150 µm [4]	69.91	0.84	14.10	5.01	1.33	2.44
H/C +75 µm [4]	72.23	0.83	12.95	4.62	1.40	2.18
H/C -75 µm [5]	64.80	1.04	16.89	5.72	1.33	3.06
H/C +10 µm [6]	69.60	0.94	14.10	5.16	1.51	2.37
H/C +2 µm [7]	56.41	1.19	21.17	7.06	1.16	4.13
H/C –2 µm [8]	49.34	1.43	25.65	7.49	0.95	5.29

NB A/C = Air classification product; H/C =Hydrocycloning product
1 = Underflow (coarse material) from zig-zag air classification; 2 = Underflow (coarse material) from centrifugal air classification; 3 = Overflow (fine material) from centrifugal air classification;
4 = Coarse material retained on sieves after wet screening; 5 = Fine material passing through sieves after wet screening; 6 = 25 mm hydrocyclone underflow; 7 = 10 mm hydrocyclone underflow;
8 = 10 mm hydrocyclone overflow.

Table M. Air classification trials mass balance, fines LHF 11, Leahill Quarry

Product	Yield wt%	Mica		Chlorite	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	21.10	100.00	3.40	100.00
A/C +75µm [1]	81.00	18.50	71.00	3.15	75.63
A/C +10µm [2]	12.61	34.80	20.80	4.40	16.32
A/C +2µm [2]	4.43	16.50	3.47	4.10	5.35
A/C -2µm [3]	1.96	51.00	4.73	4.70	2.70
Total	100.00	-	100.00	-	100.00

Product	Yield wt%	Feldspar		Quartz	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	39.50	100.00	36.00	100.00
A/C +75µm [1]	81.00	43.00	88.29	35.35	79.37
A/C +10µm [2]	12.61	5.90	1.88	54.90	19.23
A/C +2µm [2]	4.43	69.10	7.76	10.30	1.26
A/C -2µm [3]	1.96	41.80	2.07	2.50	0.14
Total	100.00	-	100.00	-	100.00

NB A/C = Air classification product; 1 = Underflow (coarse material) from zig-zag air classification; 2 = Underflow (coarse material) from centrifugal air classification; 3 = Overflow (fine material) from centrifugal air classification.

Table N. Hydrocyclone trials mass balance, fines sample LHF 11, Leahill Quarry

Product	Yield wt%	Mica		Chlorite	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	21.10	100.00	3.40	100.00
+75µm [1]	86.02	19.27	78.54	3.16	79.82
H/C +10µm [2]	8.72	21.50	8.89	4.80	12.31
H/C +2µm [3]	2.72	54.50	7.03	6.00	4.80
H/C -2µm [4]	2.54	46.00	5.54	4.10	3.07
Total	100.00	-	100.00	-	100.00

Product	Yield wt%	Feldspar		Quartz	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	39.50	100.00	36.00	100.00
+75µm [1]	86.02	40.38	87.92	37.20	88.88
H/C +10µm [2]	8.72	35.20	7.77	38.50	9.33
H/C +2µm [3]	2.72	18.10	1.25	21.40	1.62
H/C -2µm [4]	2.54	47.50	3.06	2.40	0.17
Total	100.00	-	100.00	-	100.00

NB H/C =Hydrocycloning product; 1 = Coarse material retained on sieves after wet screening; 2 = 25 mm hydrocyclone underflow; 3 = 10 mm hydrocyclone underflow; 4 = 10 mm hydrocyclone overflow.

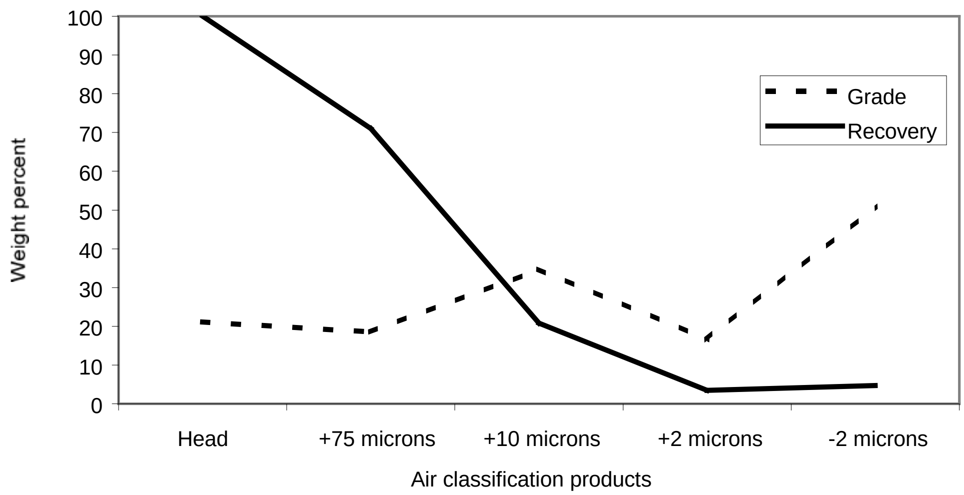


Figure 3. Mica grade-recovery, air classification trials, LHF 11, Leahill Quarry

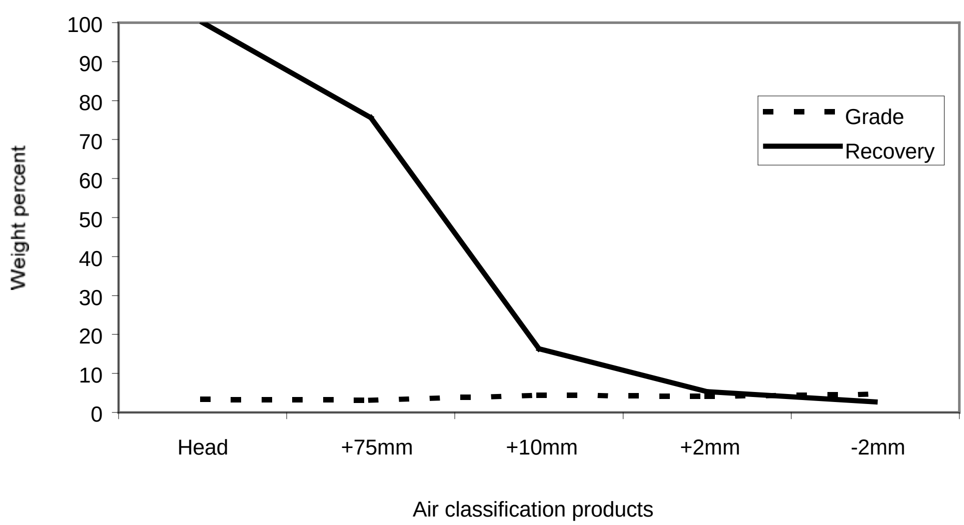


Figure 4. Chlorite grade-recovery, air classification trials, LHF 11, Leahill Quarry

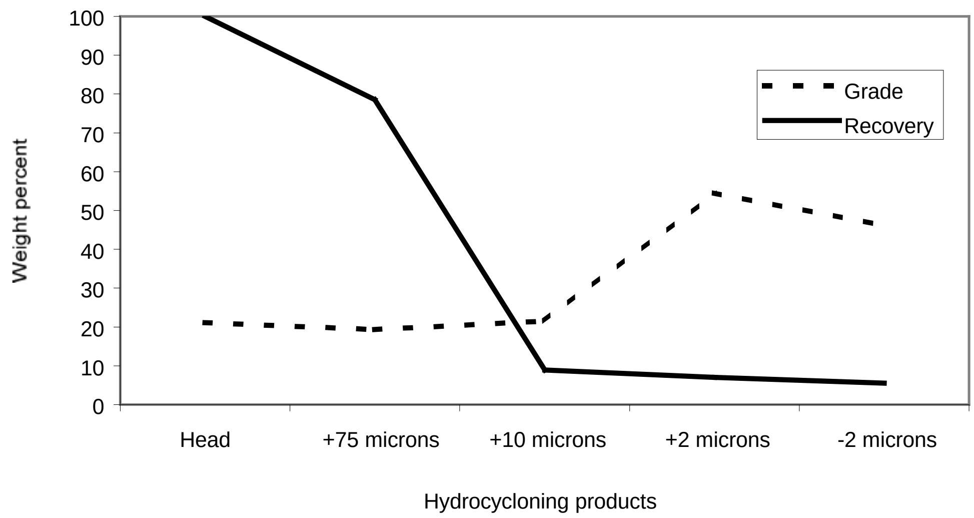


Figure 5. Mica grade-recovery, hydrocycloning trials, LHF 11, Leahill Quarry

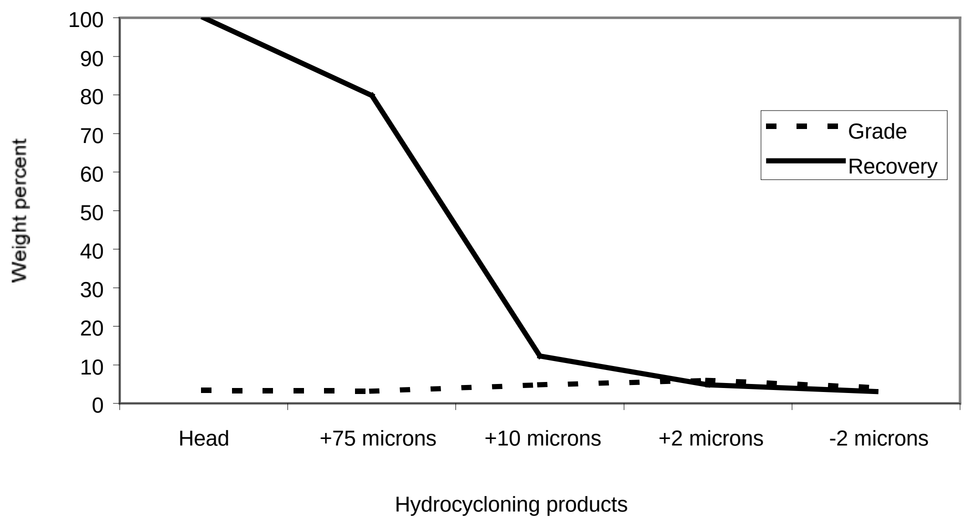


Figure 6. Chlorite grade-recovery, hydrocycloning trials, LHF 11, Leahill Quarry

Table O. Air classification trials mass balance, simulated filler fines, Leahill Quarry

Product	Yield wt%	Mica		Chlorite	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	32.20	100.00	4.35	100.00
A/C +10 μm [1]	66.37	34.80	71.74	4.40	66.96
A/C +2 μm [1]	23.34	16.50	11.96	4.10	21.94
A/C -2 μm [2]	10.29	51.00	16.30	4.70	11.10
Total	100.00	-	100.00	-	100.00

Product	Yield wt%	Feldspar		Quartz	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	24.35	100.00	39.10	100.00
A/C +10 μm [1]	66.37	5.90	16.08	54.90	93.19
A/C +2 μm [1]	23.34	69.10	66.25	10.30	6.15
A/C -2 μm [2]	10.29	41.80	17.67	2.50	0.66
Total	100.00	-	100.00	-	100.00

NB A/C = Air classification product; 1 = Underflow (coarse material) from centrifugal air classification; 2 = Overflow (fine material) from centrifugal air classification.

Table P. Hydrocyclone trials mass balance, simulated filler fines, Leahill Quarry

Product	Yield wt%	Mica		Chlorite	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	32.38	100.00	4.90	100.00
H/C +10 μm [1]	62.35	21.50	41.40	4.80	61.00
H/C +2 μm [2]	19.46	54.50	32.76	6.00	23.80
H/C -2 μm [3]	18.19	46.00	25.84	4.10	15.20
Total	100.00	-	100.00	-	100.00

Product	Yield wt%	Feldspar		Quartz	
		Grade wt%	Recovery wt%	Grade wt%	Recovery wt%
Head	100.00	34.11	100.00	28.61	100.00
H/C +10 μm [1]	62.35	35.20	64.35	38.50	83.92
H/C +2 μm [2]	19.46	18.10	10.33	21.40	14.56
H/C -2 μm [3]	18.19	47.50	25.32	2.40	1.52
Total	100.00	-	100.00	-	100.00

NB H/C =Hydrocycloning product; 1 = 25 mm hydrocyclone underflow; 2 = 10 mm hydrocyclone underflow; 3 = 10 mm hydrocyclone overflow.

Table Q. Mica-chlorite contents of selected samples, Leahill Quarry

Sample	Mica wt %	Chlorite wt %	**Sample**	**Mica** wt %	**Chlorite** wt %
Rock samples			**Borehole core fines**		
LHR 4 (Fine sandstone)	7.6	1.0	**LHC 3** (Sandstone-rich)	36.4	6.0
LHR 7 (Very fine to fine sandstone)	36.2	4.0	**LHC 6** (Siltstone-rich)	32.3	4.2
LHR 1 (Coarse siltstone)	23.4	5.1	**LHC 13** (Mudstone-rich)	25.2	4.6
LHR 3 (Medium siltstone)	56.1	5.4			
Fluidised bed fines			**Size classification products** (LHF 11)		
LHF 31	30.0	4.4	**A/C +150** □m	34.4	4.4
LHF 34	28.0	4.3	**A/C +75** □m	15.9	3.9
LHF 38	34.7	5.1	**A/C –75** □m	50.9	4.7
LHF 40	30.3	4.2	**A/C +10** □m	21.0	4.6
LHF 46	25.5	4.2	**A/C +2** □m	54.5	6.0
LHF 51	28.4	5.3	**A/C –2** □m	48.9	4.4
Plant fines					
LHF 4 (Historic fines)	17.4	3.0			
LHF 11 (current production)	20.6	3.3			

Table R. Modal mineralogy of rock, borehole core, fines and fluidised bed filler fines samples, Leahill Quarry

Sample No.	Description	Modal Mineralogy (normalised)				
		Mica	Chlorite	Feldspar	Quartz	Total
		wt %	wt %	wt %	wt %	wt %
Rock samples						
LHR 4	Fine sandstone	7.7	1.0	23.7	67.6	100.0
LHR 7	Very fine - fine sandstone	35.9	4.0	21.3	38.8	100.0
LHR 1	Coarse siltstone	23.1	5.0	48.1	23.8	100.0
LHR 3	Medium siltstone	53.8	5.2	20.2	20.9	100.0
Borehole core samples						
LHC 3	sandstone dominated	37.1	6.2	12.0	44.7	100.0
LHC 6	siltstone dominated	32.6	4.3	29.1	34.0	100.0
LHC 13	mudstone enriched	26.2	4.8	29.8	39.1	100.0
Fines samples						
LHF 4	Historic plant fines	17.6	3.0	36.4	43.0	100.0
LHF 11	Current fines production	21.1	3.4	39.5	36.1	100.0
Fluidised bed filler fines samples						
LHF 31	4-2-99	30.4	4.4	28.5	36.7	100.0
LHF 34	18-2-99	28.4	4.3	33.9	33.4	100.0
LHF 38	3-3-99	34.9	5.1	21.2	38.8	100.0
LHF 40	15-3-99	30.6	4.3	28.7	36.4	100.0
LHF 46	13-4-99	25.8	4.3	35.1	34.8	100.0
LHF 51	Asphalt testing sample	29.3	5.5	36.2	29.0	100.0

REFILL: Development of novel processing for the production of low-cost by-product fillers as a replacement for high-cost primary fillers

This document contains the 'quarry waste factsheets' produced by the British Geological Survey for the EC BriteEuRam project REFILL (BE97-5078). The objective of this industrial research project was to develop low cost 'by-product' fillers as a replacement for high cost 'primary' fillers, in a range of industrial products where neither the production specification nor end use demands a high grade filler product. The source of the 'by-product' fillers was the mineral residues of crushed rock aggregate quarrying

The factsheets (total 102) summarise the characterisation work (mineralogical, chemical and particle-size analysis) carried out by the BGS on waste samples (plant fines, tailings and dust) collected from numerous quarries in the UK and from Leahill Quarry in Co. Cork, Ireland, which was the focus for the research. The factsheets are grouped as follows for easy reference:

REFILL characterisation factsheets:

UK quarry waste: England

ARCOW QUARRY

Location: Arcow Quarry, Horton-in-Ribblesdale, Settle, North Yorkshire, UK

Sample type: Precipitator fines **Rock type:** Sandstone (Austwick Formation, Silurian)

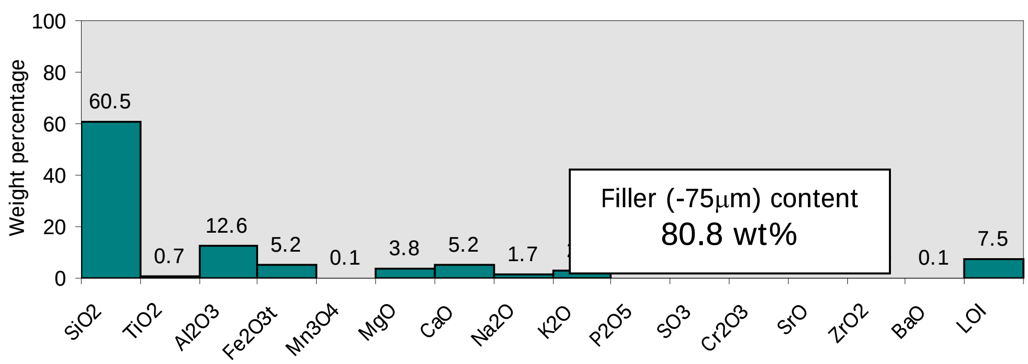
Sampling: prEN-932-1 (Draft European Standard) **Sample code:** BAF1 / CJM535 **Date:** 17/11/98

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar and calcite
Trace	Mica, chlorite, ?rutile (TiO_2) and ?dolomite.

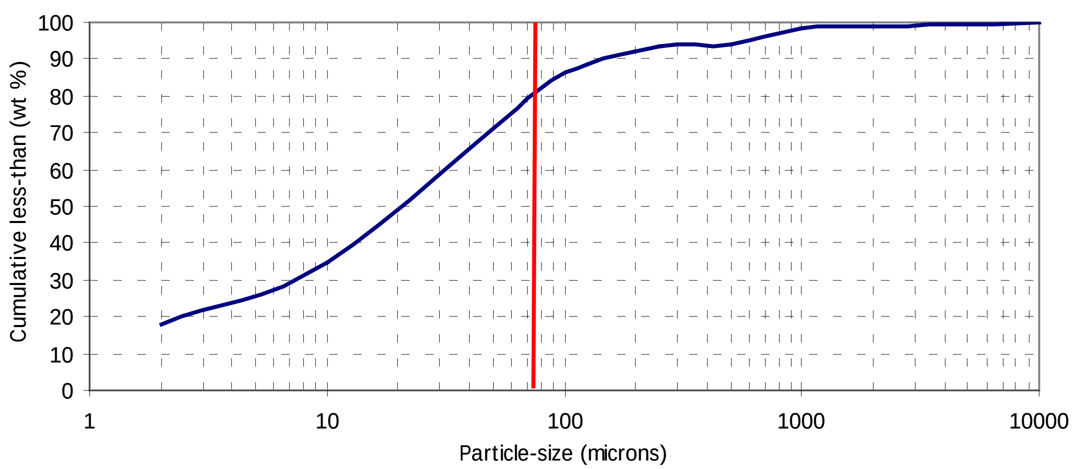
Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Summary of data

Particle-size distribution



This sample represents the precipitator fines produced during aggregate production from Arcow Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar and calcite and trace amounts of mica, chlorite, ?rutile and ?dolomite. Chemical analysis determined that the sample contains 61% SiO_2, 13% Al_2O_3, 4% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a high filler content, 81 % <75 µm.

NEW CLIFFE HILL QUARRY

Location: New Cliffe Hill Quarry, Battleflat Lane, Ellistown, Leicester, UK

Sample type: Precipitator fines **Rock type:** Diorite (Precambrian)

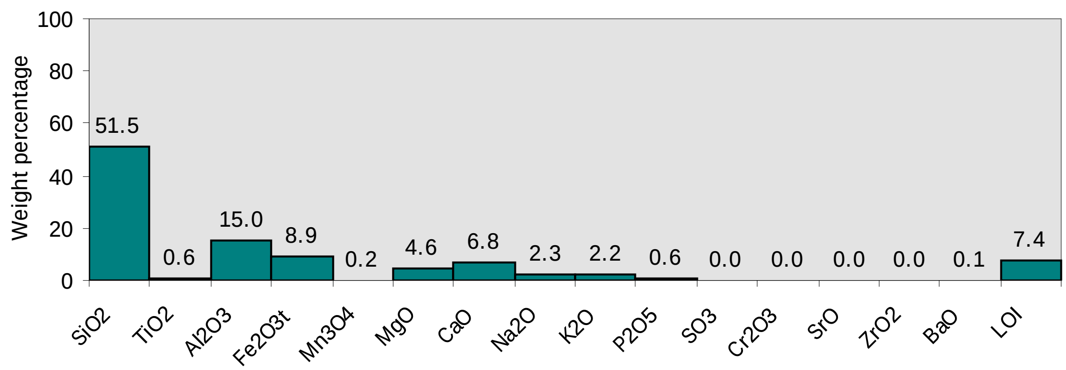
Sampling: Spot sampling **Sample code:** BCHF1 / CJM537 **Date:** 23/11/98

Mineralogy

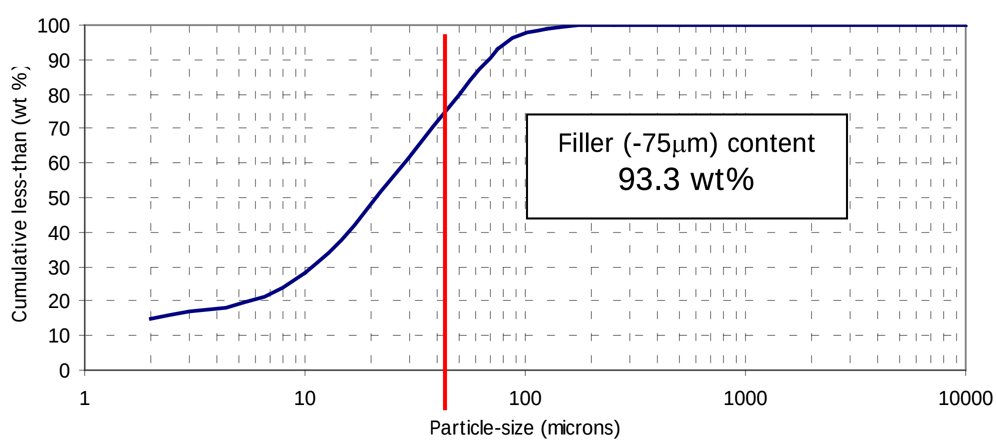
Dominant	
Major	Quartz and plagioclase feldspar
Minor	Hornblende and hypersthene
Trace	Mica, chlorite and alkali (Na- & K-) feldspar

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the precipitator fines produced during aggregate production from New Cliffe Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of major quartz and plagioclase feldspar, minor amounts of hornblende and hypersthene, minor amounts of mica, chlorite and alkali (Na-&K-) feldspar. Chemical analysis determined that the sample contains 52% SiO_2, 15% Al_2O_3, 11% alkali earths (MgO & CaO), 5% alkalis (Na_2O & K_2O), <1% TiO_2 and 9% Fe_2O_3. The sample has a high filler content, 93 % <75 µm.

EBCHESTER QUARRY

Location: Ebchester Quarry, Hedley, Stocksfield, Northumberland, UK

Sample type: Lagoon fines **Rock type:** Glacial sand & gravel (Quaternary)

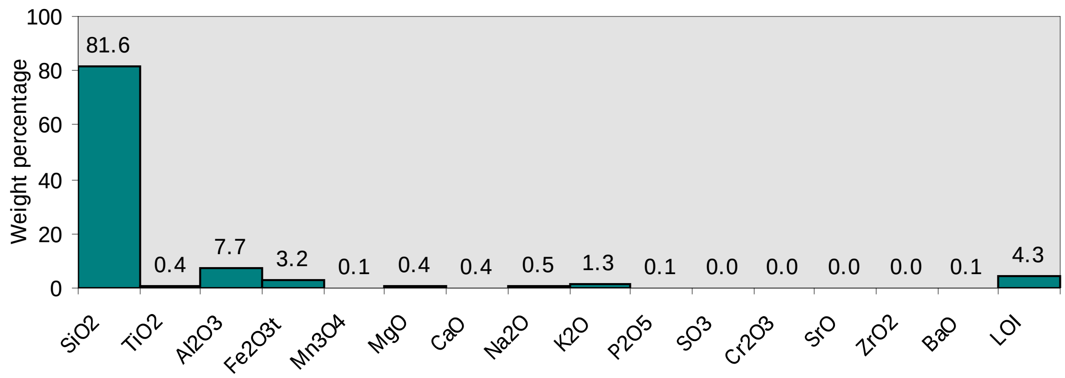
Sampling: Spot sampling **Sample code:** BEF1 / CJM539 **Date:** 1/12/98

Mineralogy

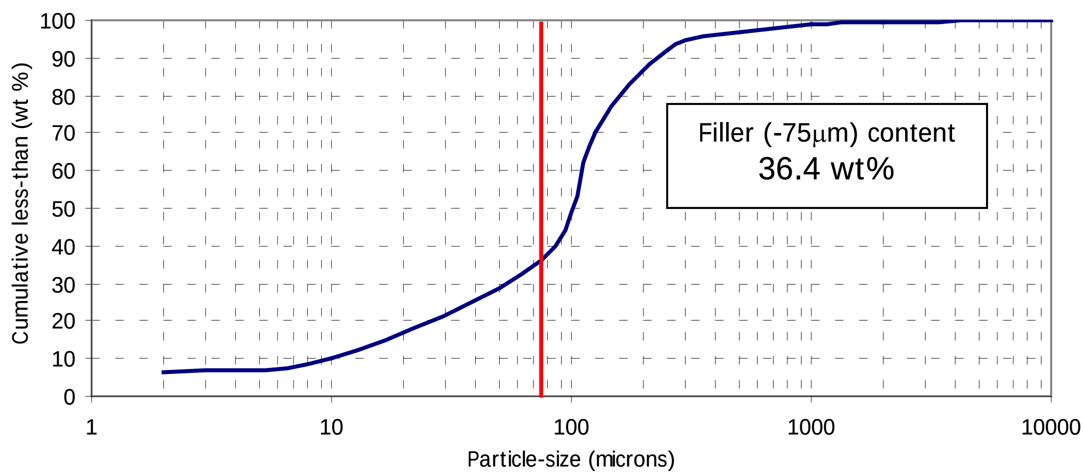
Dominant	Quartz
Major	
Minor	
Trace	Alkali (Na- & K-) feldspar, mica, ?rutile (TiO_2) and kaolinite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during aggregate production from Ebchester sand and gravel quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz with trace amounts of alkali (Na- &K-) feldspar, mica, rutile and kaolinite. Chemical analysis determined that the sample contains 82% SiO_2, 8% Al_2O_3, 2% alkalis (Na_2O & K_2O), <1% TiO_2 and 3% Fe_2O_3. The sample has a moderately low filler content, 36 % <75 µm.

BARRASFORD QUARRY

Location: Barrasford Quarry, Barrasford, Hexham, Northumberland, UK

Sample type: Plant fines **Rock type:** Dolerite (Whin Sill, Carboniferous)

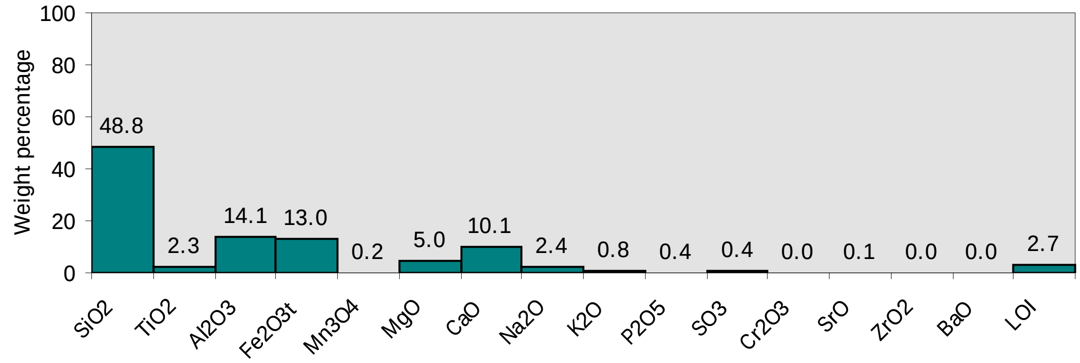
Sampling: Spot sampling **Sample code:** BBF1 / CJM542 **Date:** 1/12/98

Mineralogy

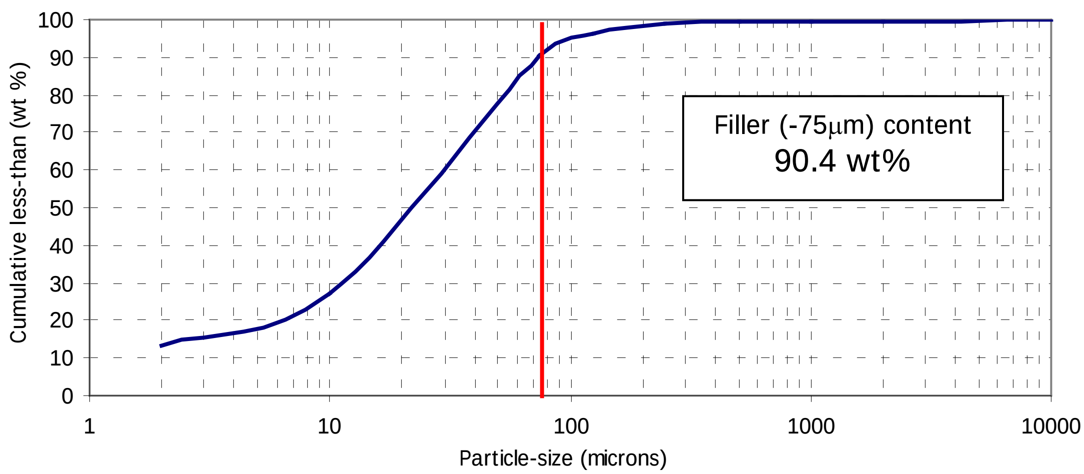
Dominant	Plagioclase feldspar
Major	Augite
Minor	Quartz and ilmenite
Trace	Mica, kaolinite and ?rutile (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Barrasford Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant plagioclase feldspar, major augite, minor quartz and ilmenite, and trace amounts of mica, kaolinite and rutile. Chemical analysis determined that the sample contains 49% SiO_2, 14% Al_2O_3, 15% alkali earths (MgO & CaO), 3% alkalis (Na_2O & K_2O), 2% TiO_2 and 13% Fe_2O_3. The sample has a high filler content, 90% <75 µm.

MOOTLAW QUARRY

Location: Mootlaw Quarry, Maften, Newcastle-upon-Tyne, Northumberland, UK

Sample type: Filler fines **Rock type:** Limestone (Great Limestone, Namurian, Carboniferous)

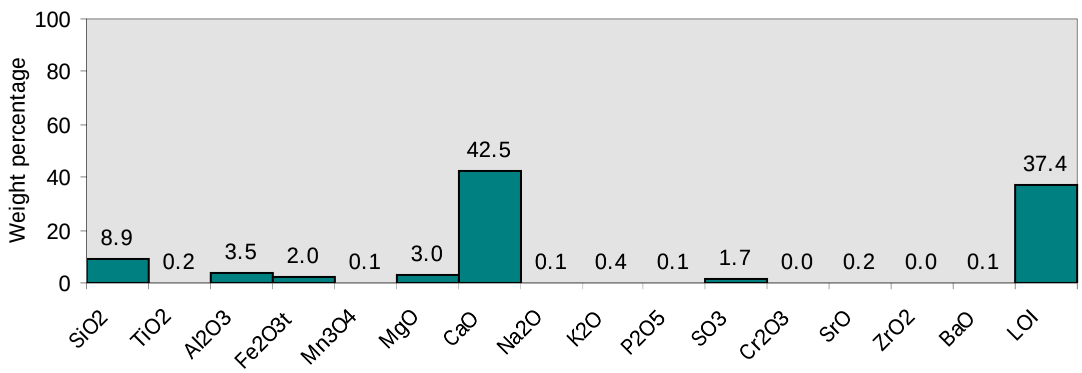
Sampling: Unknown **Sample code:** BMF1 / CJM543 **Date:** 1/12/98

Mineralogy

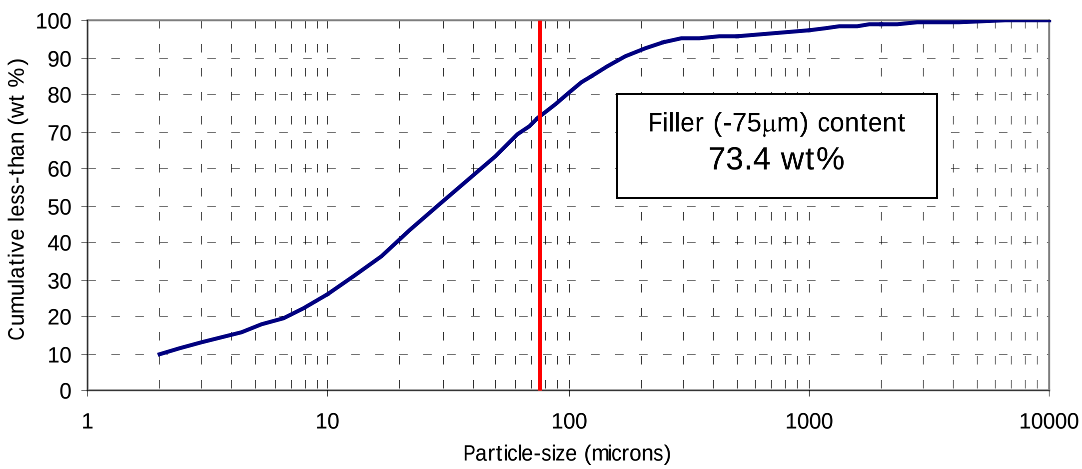
Dominant	Calcite
Major	
Minor	
Trace	Dolomite, ?ankerite, quartz, mica, kaolinite and ?hematite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during aggregate production from Mootlaw Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite with trace amounts of dolomite, ankerite, quartz, mica, kaolinite and hematite. Chemical analysis determined that the sample contains 9% SiO_2, 4% Al_2O_3, 46% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and 2% Fe_2O_3. The sample has a moderately high filler content, 73 % <75 µm.

HOWICK QUARRY

Location: Howick Quarry, Little Houghton, Alnwick, Northumberland, UK

Sample type: Plant fines

Rock type: Dolerite (Whin Sill, Carboniferous)

Sampling: prEN-932-1 (Draft European Standard)

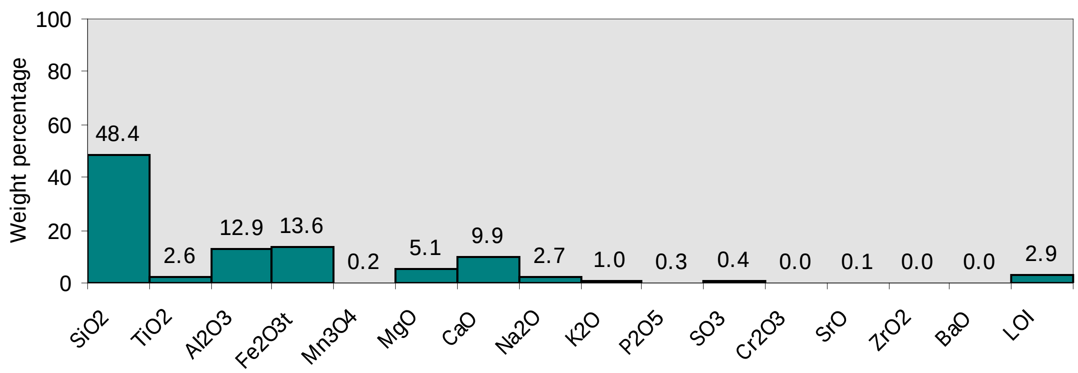
Sample code: BHF1 / CJM545 **Date:** 1/12/98

Mineralogy

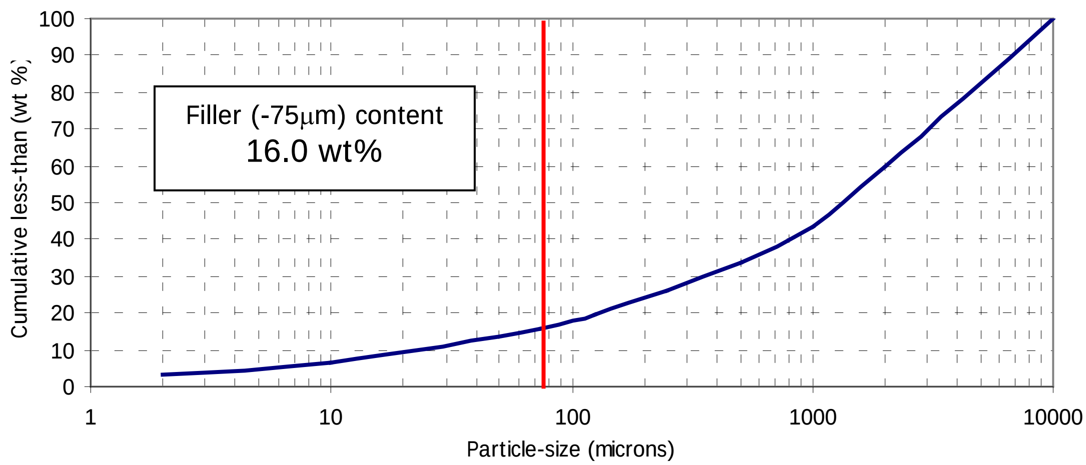
Dominant	Plagioclase feldspar
Major	Augite
Minor	Olivine and quartz
Trace	Kaolinite, ?ilmenite and ?mica.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during aggregate production from Howick Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant plagioclase feldspar, major augite, minor olivine and quartz and trace amounts of kaolinite, ilmenite and mica. Chemical analysis determined that the sample contains 48% SiO_2, 13% Al_2O_3, 15% alkali earths (MgO & CaO), 4% alkalis (Na_2O & K_2O), 3% TiO_2 and 14% Fe_2O_3. The sample has a low filler content, 16 % <75 µm.

LOUND QUARRY

Location: Lound Quarry, Chainbridge Lane, Lound, Retford, Nottinghamshire, UK

Sample type: Plant fines **Rock type:** Sand and gravel (River Idle, Quaternary)

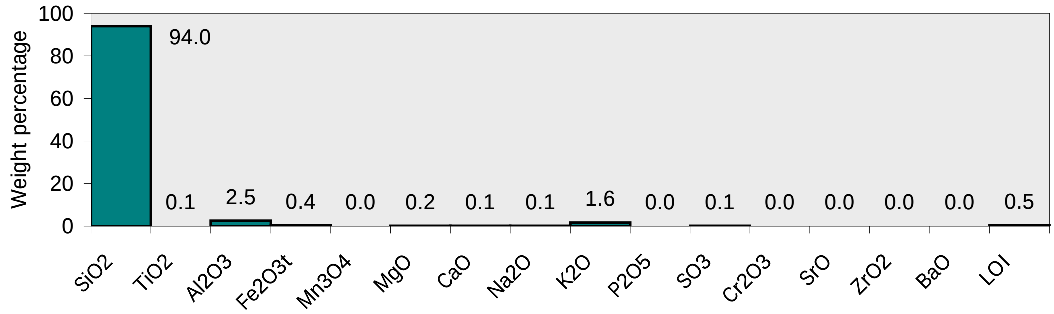
Sampling: Spot sampling (lagoon) **Sample code:** BLF1 / F059 **Date:** 22/4/99

Mineralogy

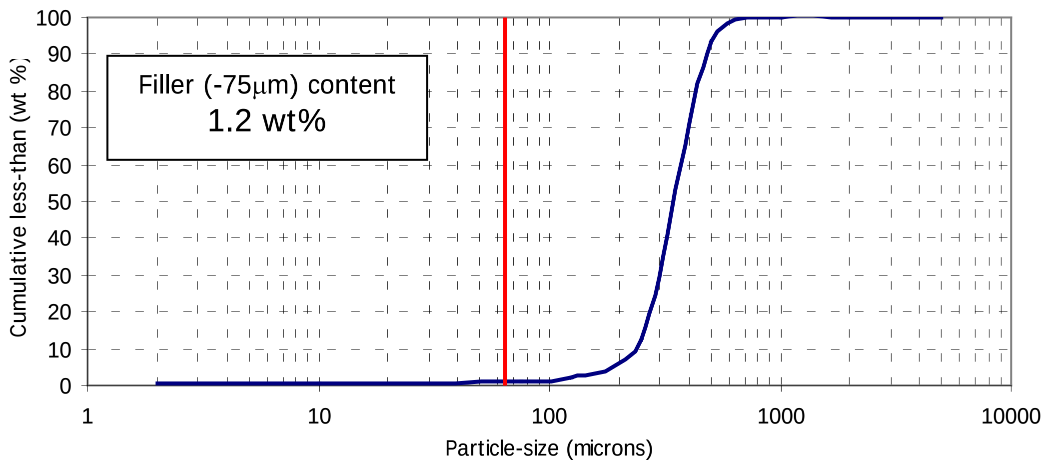
Dominant	Quartz
Major	
Minor	K-feldspar
Trace	Mica

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines (lagoon) produced during aggregate production (sand and gravel) from Lound Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, minor K-feldspar and trace amounts of mica. Chemical analysis determined that the sample contains 94% SiO_2, 3% Al_2O_3, <1% alkali earths (MgO & CaO), 2% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a very low filler content, 1% <75 µm.

LOUND QUARRY

Location: Lound Quarry, Chainbridge Lane, Lound, Retford, Nottinghamshire, UK

Sample type: Plant fines **Rock type:** Sand and gravel (River Idle, Quaternary)

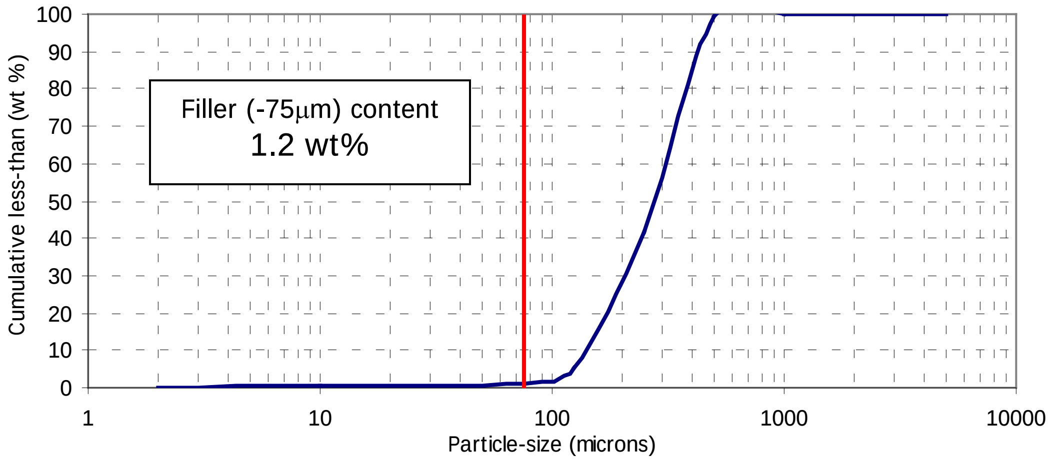
Sampling: Spot sampling (lagoon) **Sample code:** BLF2 / F060 **Date:** 22/4/99

Mineralogy

Dominant	Quartz
Major	
Minor	K-feldspar
Trace	Na-feldspar, mica and kaolinite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the plant fines (lagoon) produced during aggregate production (sand and gravel) from Lound Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, minor K-feldspar and trace amounts of Na-feldspar, mica and kaolinite. The sample has a very low filler content, 1% <75 µm.

LANGFORD QUARRY

Location: Langford Lowfields Quarry, Langford, Newark, Nottinghamshire, UK

Sample type: Plant fines **Rock type:** Sand and gravel (River Trent, Quaternary)

Sampling: Spot sampling (lagoon) **Sample code:** BLFF3 / F061 **Date:** 22/4/99

Mineralogy

Dominant Quartz

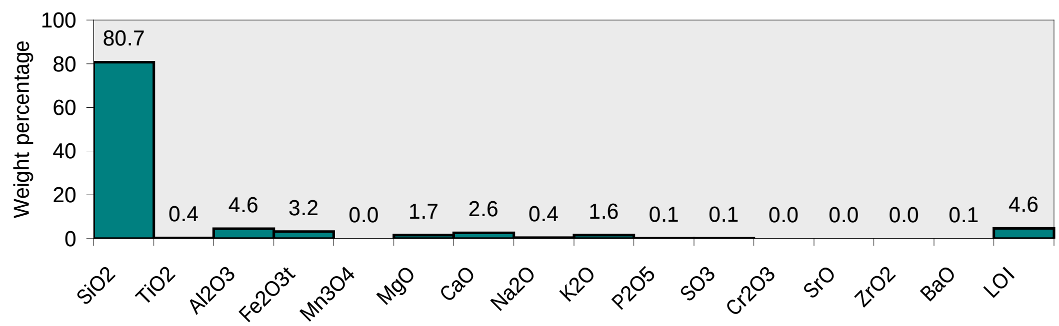
Major

Minor

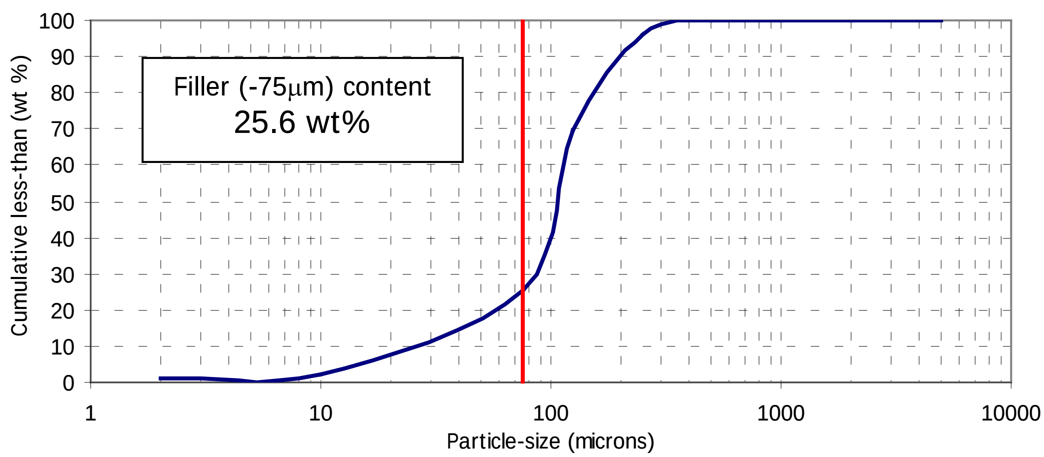
Trace Alkali (Na- & K-) feldspar, mica, calcite, kaolinite and hematite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines (lagoon) produced during aggregate production (sand and gravel) from Langford Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz and trace amounts of alkali (Na- & K-) feldspar), mica, calcite, kaolinite and hematite. Chemical analysis determined that the sample contains 81% SiO_2, 5% Al_2O_3, 4% alkali earths (MgO & CaO), 2% alkalis (Na_2O & K_2O), <1% TiO_2 and 3% Fe_2O_3. The sample has a filler content of 26% <75 µm.

BEDHAMPTON WHARF

Location: Bedhampton Wharf, Bedhampton, Hampshire

Sample type: Plant fines **Rock type:** Sand and gravel (Marine, Quaternary)

Sampling: Unknown **Sample code:** BBWF1 / F062 **Date:** 1999

Mineralogy

Dominant Quartz

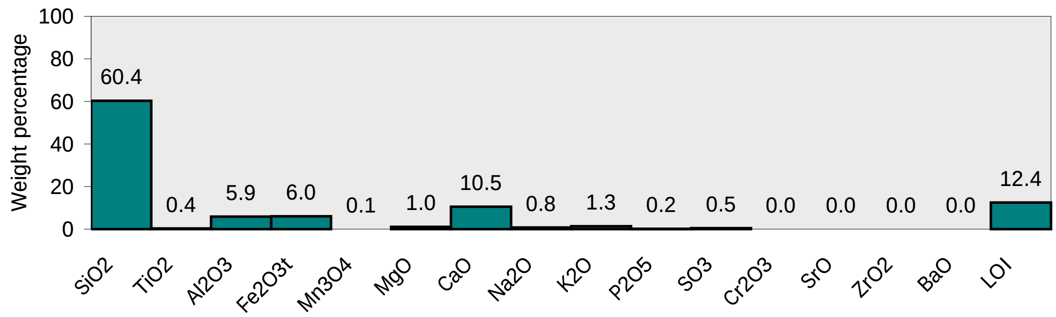
Major Calcite

Minor

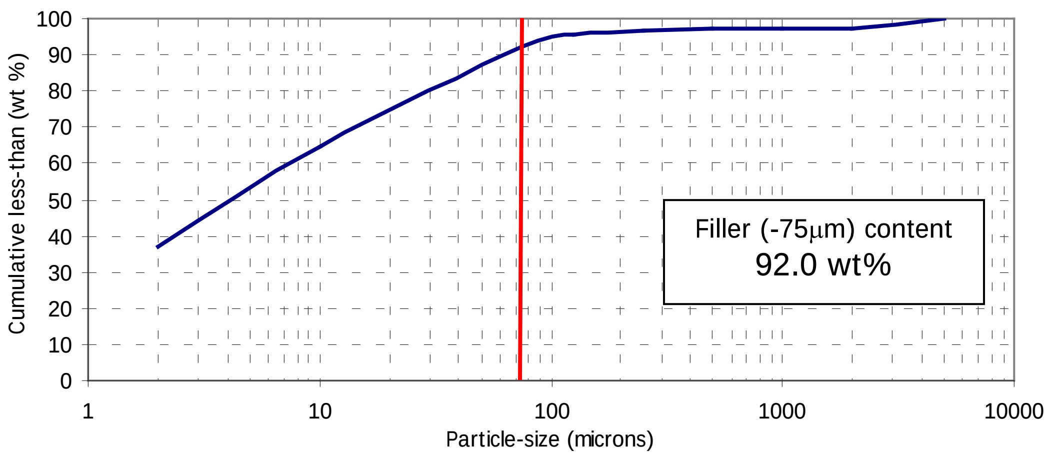
Trace K-feldspar, mica, kaolinite, aragonite and halite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production (marine sand and gravel) from the material landed at Bedhampton Wharf. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major calcite and trace amounts of K-feldspar, mica, kaolinite, aragonite and halite. Chemical analysis determined that the sample contains 60% SiO_2, 6% Al_2O_3, 12% alkali earths (MgO & CaO), 2% alkalis (Na_2O & K_2O), <1% TiO_2 and 6% Fe_2O_3. The sample has a very high filler content, 92% <75 µm.

RIDHAM WHARF

Location: Ridham Wharf, Thames Estuary

Sample type: Plant fines **Rock type:** Sand and gravel (Marine, Quaternary)

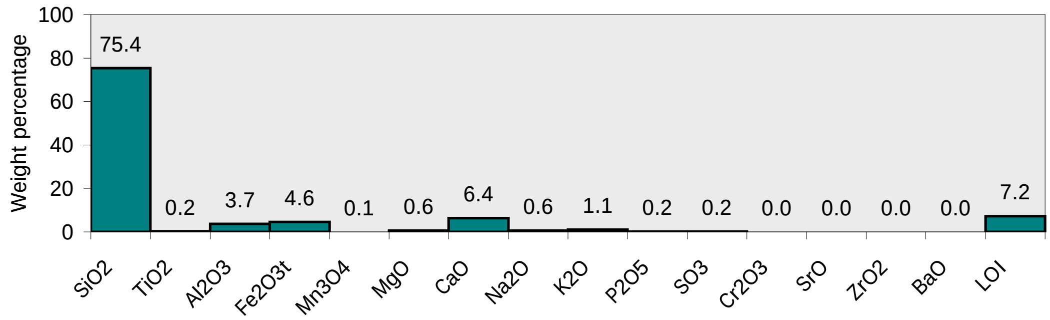
Sampling: Unknown **Sample code:** BRF1 / F063 **Date:** 1999

Mineralogy

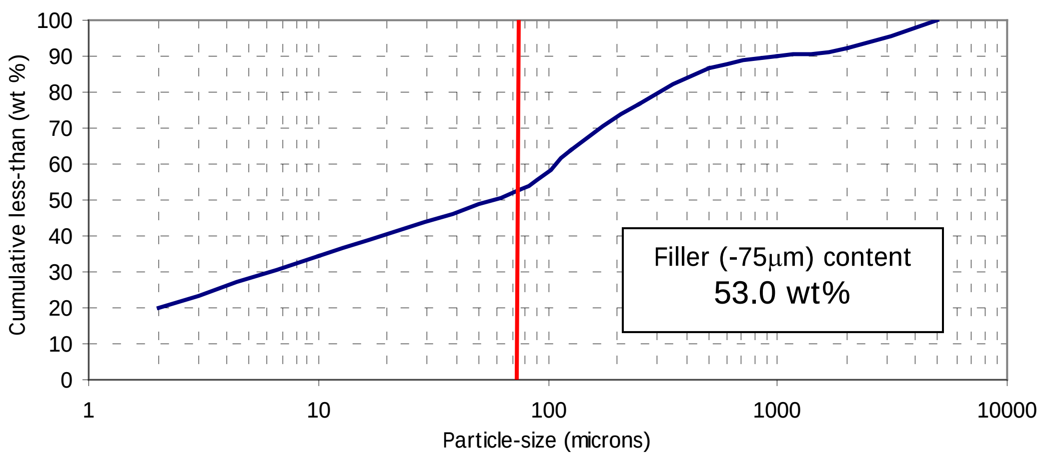
Dominant	Quartz
Major	
Minor	
Trace	Alkali (Na- & K-) feldspar, mica, chlorite, calcite, aragonite and halite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production (marine sand and gravel) from the material landed at Ridham Wharf. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz and trace amounts of alkali (Na- & K-) feldspar, mica, chlorite, calcite, aragonite and halite. Chemical analysis determined that the sample contains 75% SiO_2, 4% Al_2O_3, 7% alkali earths (MgO & CaO), 2% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a high filler content, 53% <75 µm.

RIDHAM WHARF

Location: Ridham Wharf, Thames Estuary

Sample type: Plant fines **Rock type:** Sand and gravel (Marine, Quaternary)

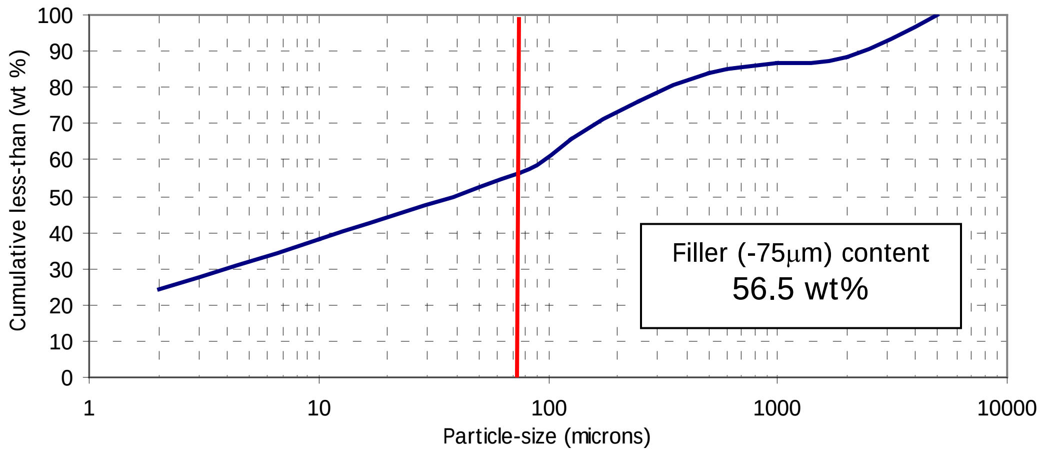
Sampling: Unknown **Sample code:** BRF2 / F064 **Date:** 1999

Mineralogy

Dominant	Quartz
Major	
Minor	
Trace	Alkali (Na- & K-) feldspar, mica, chlorite, calcite, kaolinite, aragonite and halite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production (marine sand and gravel) from the material landed at Ridham Wharf. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz and trace amounts of alkali (Na- & K-) feldspar, mica, chlorite, calcite, kaolinite, aragonite and halite. The sample has a high filler content, 57% <75 µm.

NEWHAVEN WHARF

Location: Newhaven Wharf, Newhaven, East Sussex

Sample type: Plant fines **Rock type:** Sand and gravel (Marine, Quaternary)

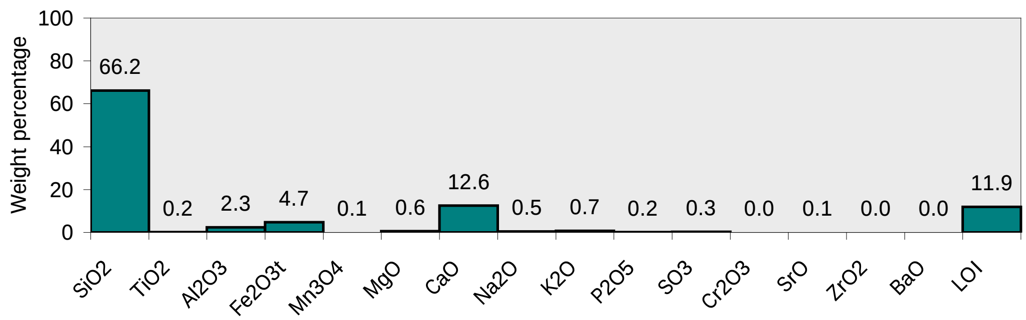
Sampling: Unknown **Sample code:** BNWF1 / F065 **Date:** 1999

Mineralogy

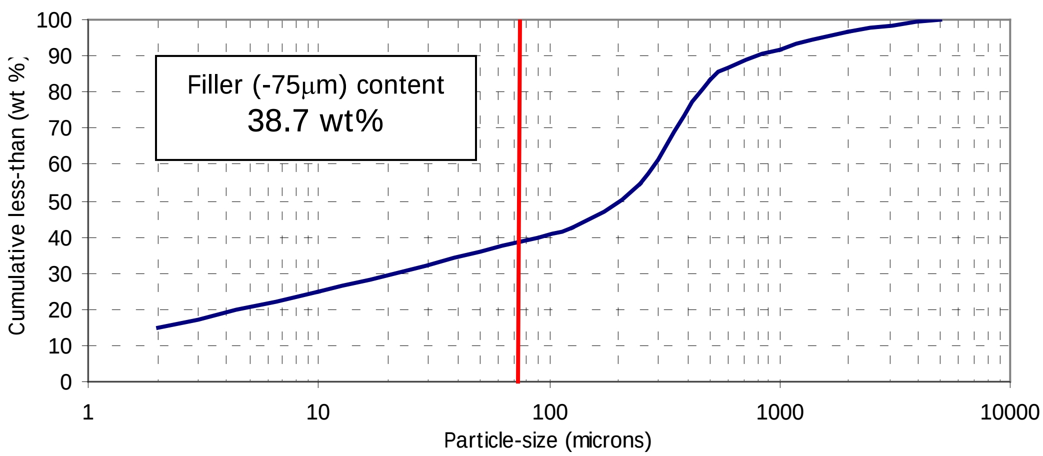
Dominant	Quartz
Major	Calcite
Minor	
Trace	Alkali (Na- & K-) feldspar, mica, kaolinite, aragonite and halite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production (marine sand and gravel) from the material landed at Newhaven Wharf. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major calcite and trace amounts of alkali (Na- & K-) feldspar, mica, kaolinite, aragonite and halite. Chemical analysis determined that the sample contains 66% SiO_2, 2% Al_2O_3, 13% alkali earths (MgO & CaO), 1% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a filler content of 39% <75 µm.

SOUTHAMPTON WHARF

Location: Southampton Wharf, Southampton, Hampshire

Sample type: Plant fines **Rock type:** Sand and gravel (Marine, Quaternary)

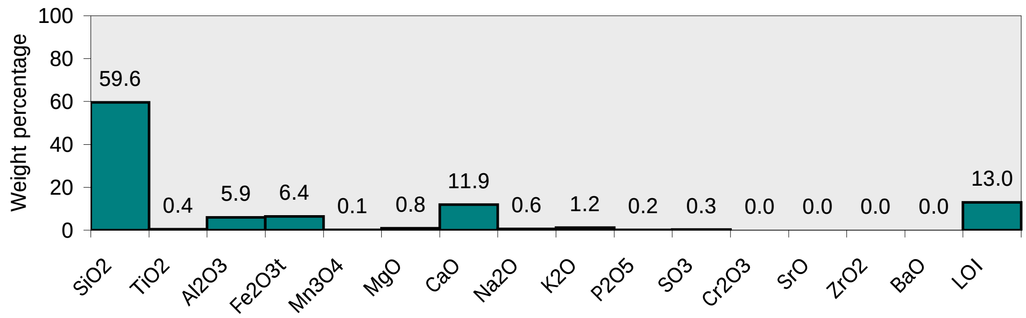
Sampling: Unknown **Sample code:** BSWF1 / F066 **Date:** 1999

Mineralogy

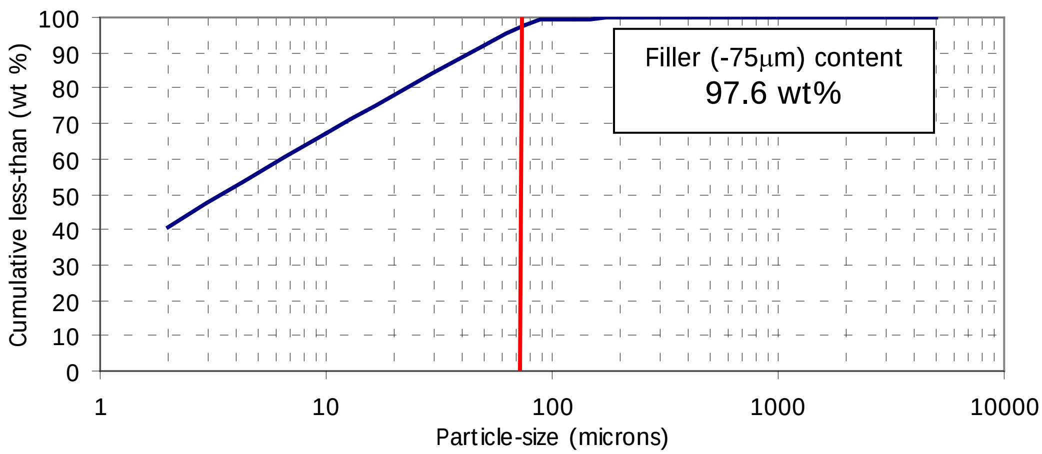
Dominant	Quartz
Major	Calcite
Minor	
Trace	K-feldspar, mica, kaolinite, aragonite and halite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production (marine sand and gravel) from the material landed at Southampton Wharf. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major calcite and trace amounts of K-feldspar, mica, kaolinite, aragonite and halite. Chemical analysis determined that the sample contains 60% SiO_2, 6% Al_2O_3, 13% alkali earths (MgO & CaO), 2% alkalis (Na_2O & K_2O), <1% TiO_2 and 6% Fe_2O_3. The sample has a very high filler content, 98% <75 µm.

LITTLEHAMPTON WHARF

Location: Littlehampton Wharf, West Sussex

Sample type: Plant fines **Rock type:** Sand and gravel (Marine, Quaternary)

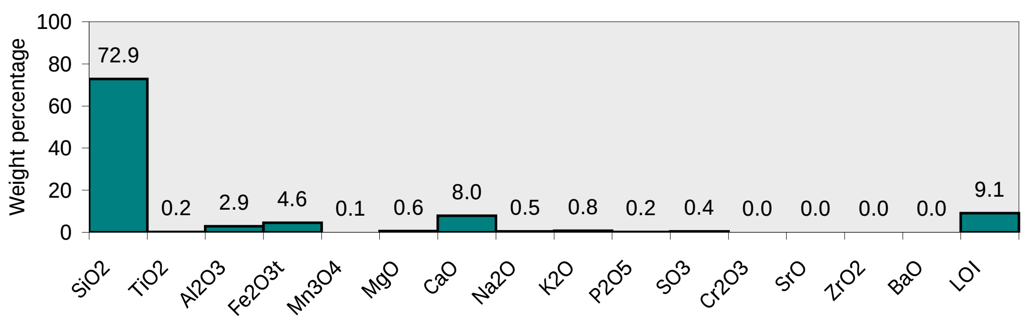
Sampling: Unknown **Sample code:** BLHF1 / F067 **Date:** 1999

Mineralogy

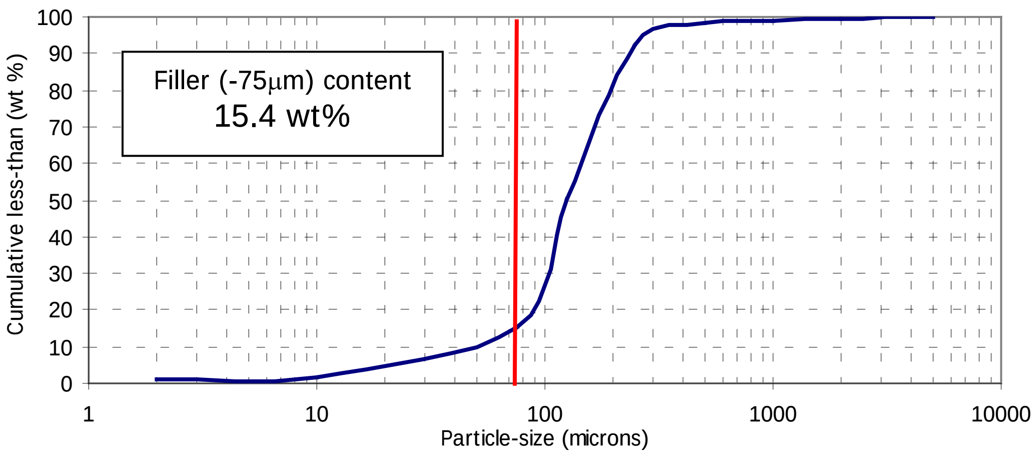
Dominant	Quartz
Major	
Minor	K-feldspar and calcite
Trace	Mica, aragonite and halite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production (marine sand and gravel) from the material landed at Littlehampton Wharf. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, minor K-feldspar and calcite and trace amounts of mica, aragonite and halite. Chemical analysis determined that the sample contains 73% SiO_2, 3% Al_2O_3, 9% alkali earths (MgO & CaO), 1% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 15% <75 µm.

BAYSTON HILL QUARRY

Location: Bayston Hill Quarry, Sharpstones Lane, Bayston Hill, Shrewsbury, Shropshire, UK

Sample type: Plant fines

Rock type: Sandstone (Bayston – Oakwood Formation, Precambrian)

Sampling: prEN-932-1 (Draft European Standard)

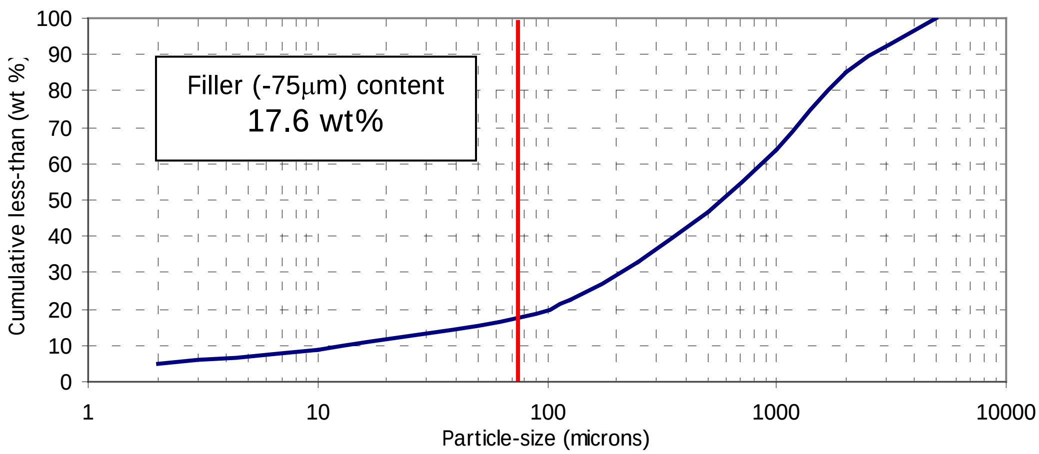
Sample code: BBHF1 / F068 **Date:** 10/3/99

Mineralogy

Dominant	Quartz
Major	Na-feldspar
Minor	Calcite
Trace	Mica, chlorite, dolomite and hematite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Bayston Hill Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major Na-feldspar, minor calcite and trace amounts of mica, chlorite, dolomite and hematite. The sample has a low filler content, 18% <75 µm.

BAYSTON HILL QUARRY

Location: Bayston Hill Quarry, Sharpstones Lane, Bayston Hill, Shrewsbury, Shropshire, UK

Sample type: Filler fines

Rock type: Sandstone (Bayston – Oakwood Formation, Precambrian)

Sampling: prEN-932-1 (Draft European Standard)

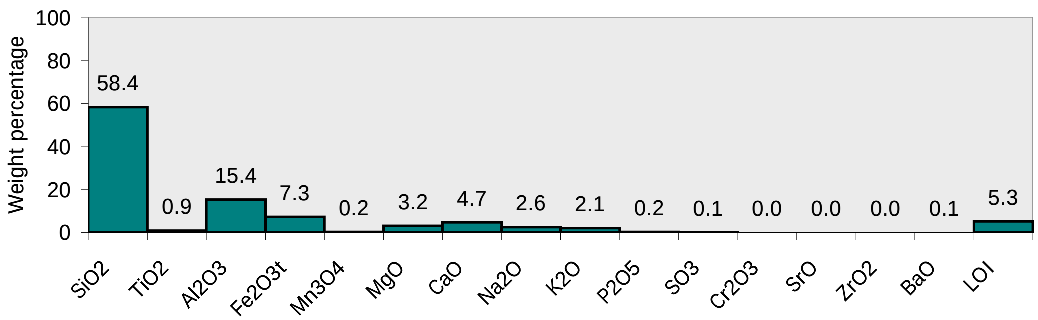
Sample code: BBHF2 / F069 **Date:** 10/3/99

Mineralogy

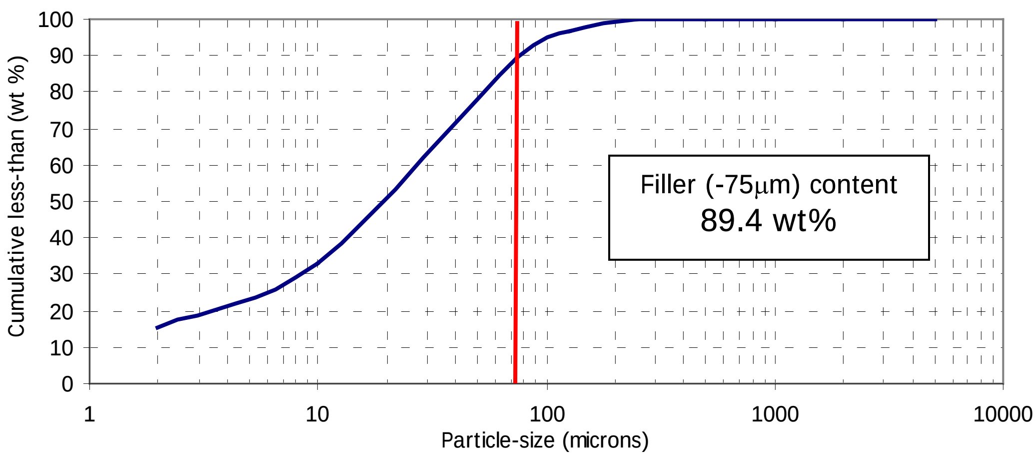
Dominant	Quartz
Major	Na-feldspar
Minor	Mica, chlorite and calcite
Trace	Dolomite and hematite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the filler fines produced during aggregate production from Bayston Hill Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major Na-feldspar, minor mica, chlorite and calcite and trace amounts of dolomite and hematite. Chemical analysis determined that the sample contains 58% SiO_2, 15% Al_2O_3, 8% alkali earths (MgO & CaO), 5% alkalis (Na_2O & K_2O), <1% TiO_2 and 7% Fe_2O_3. The sample has a high filler content, 89% <75 µm.

BAYSTON HILL QUARRY

Location: Bayston Hill Quarry, Sharpstones Lane, Bayston Hill, Shrewsbury, Shropshire, UK

Sample type: Reclaimed filler fines

Rock type: Sandstone (Bayston – Oakwood Formation, Precambrian)

Sampling: prEN-932-1 (Draft European Standard)

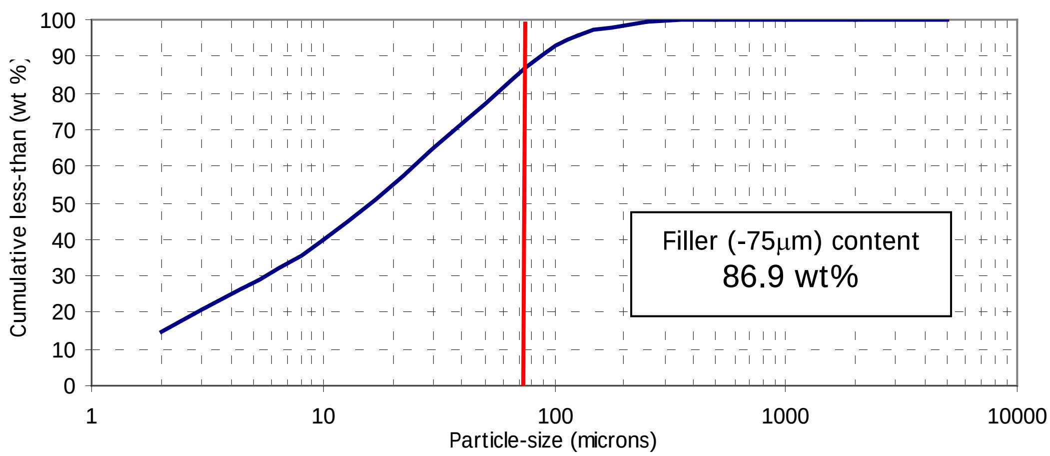
Sample code: BBHF3 / F070 **Date:** 10/3/99

Mineralogy

Dominant	Quartz
Major	Na-feldspar and calcite
Minor	Mica
Trace	Chlorite, dolomite and hematite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the reclaimed filler fines produced during aggregate production from Bayston Hill Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major Na-feldspar and calcite, minor mica and trace amounts of chlorite, dolomite and hematite. The sample has a high filler content, 87% <75 µm.

CALLOW HILL QUARRY

Location: Callow Hill Quarry, Callow Lane, Minsterley, Shrewsbury, Shropshire, UK

Sample type: Plant fines

Rock type: Sandstone (Mytton & Tankerville Flags, Ordovician)

Sampling: prEN-932-1 (Draft European Standard)

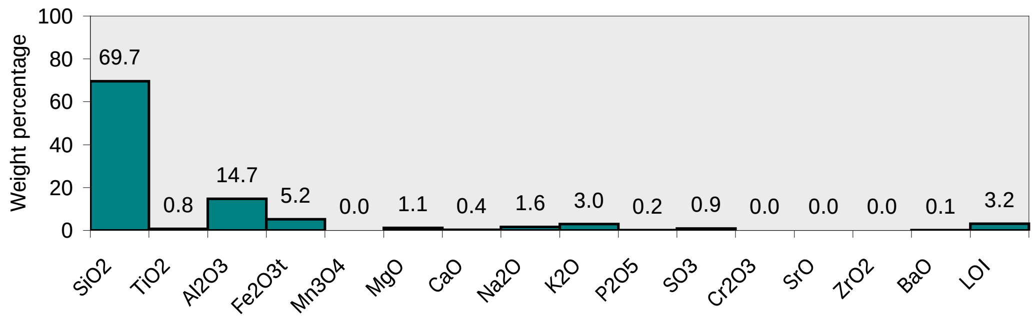
Sample code: BCHF1 / F071 **Date:** 10/3/99

Mineralogy

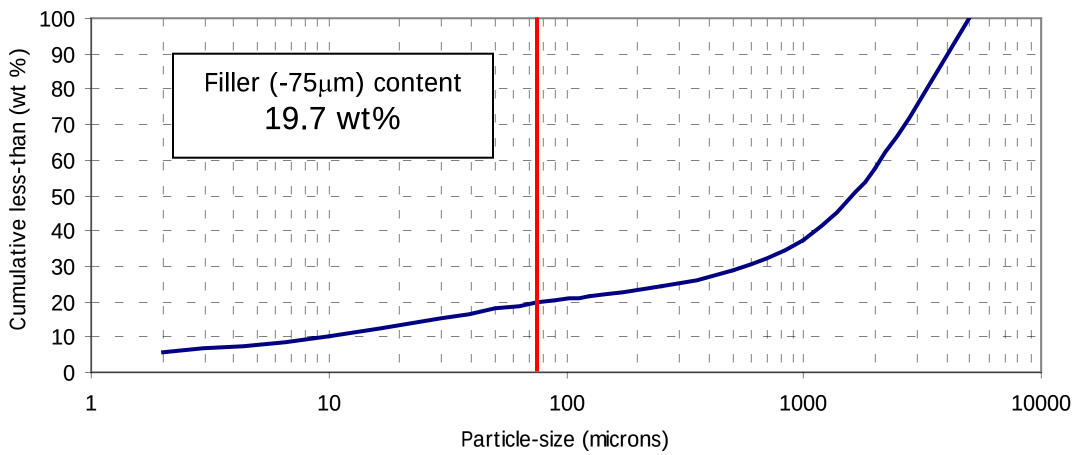
Dominant	Quartz
Major	Na-feldspar
Minor	Mica
Trace	Chlorite and hematite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Callow Hill Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major Na-feldspar, minor mica and trace amounts of chlorite and hematite. Chemical analysis determined that the sample contains 70% SiO_2, 15% Al_2O_3, 2% alkali earths (MgO & CaO), 5% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a filler content of 20% <75 µm.

DENE QUARRY

Location: Dene Quarry, Cromford, Matlock, Derbyshire, UK

Sample type: Filler fines (primary crusher)
Sampling: prEN-932-1 (Draft European Standard)

Rock type: Limestone (Knoll Reef & Eyam Limestone, Carboniferous)
Sample code: BDEF1 / F226 **Date:** 16/9/1999

Mineralogy

Dominant Calcite

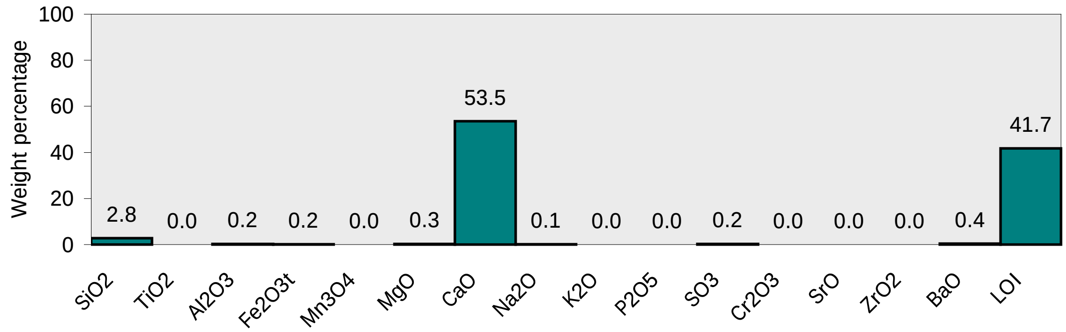
Major

Minor

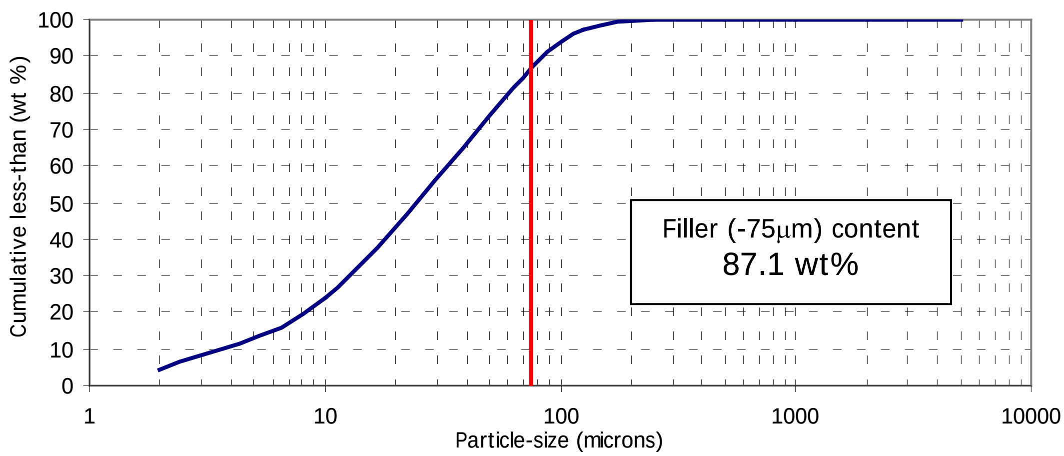
Trace Quartz, kaolinite, ?fluorite and ?barite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the filler fines produced from the primary crusher during aggregate production from Dene Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite and trace amounts of quartz, kaolinite, fluorite and barite. Chemical analysis determined that the sample contains 3% SiO_2, <1% Al_2O_3, 54% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a high filler content, 87% <75 µm.

DENE QUARRY

Location: Dene Quarry, Cromford, Matlock, Derbyshire, UK

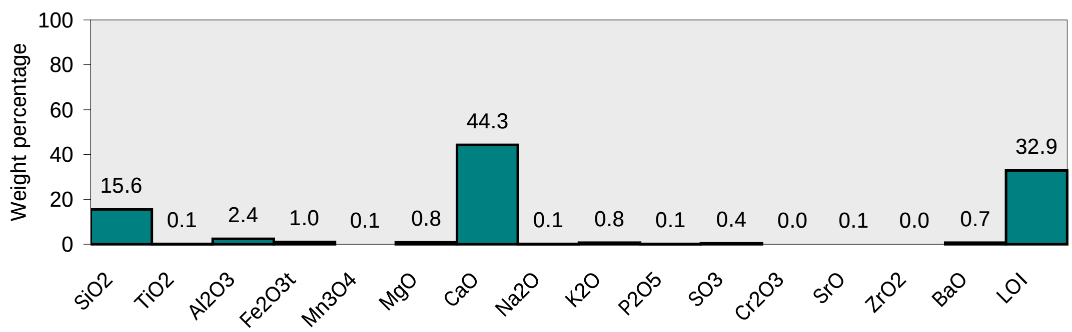
Sample type:	Mixed filler (asphalt plant)	**Rock type:**	Limestone (Eyam Limestone, Cliff Hill granite and Bestwood sand, Carboniferous)
Sampling:	prEN-932-1 (Draft European Standard)	**Sample code:**	BDEF2 / F227 **Date:** 16/9/1999

Mineralogy

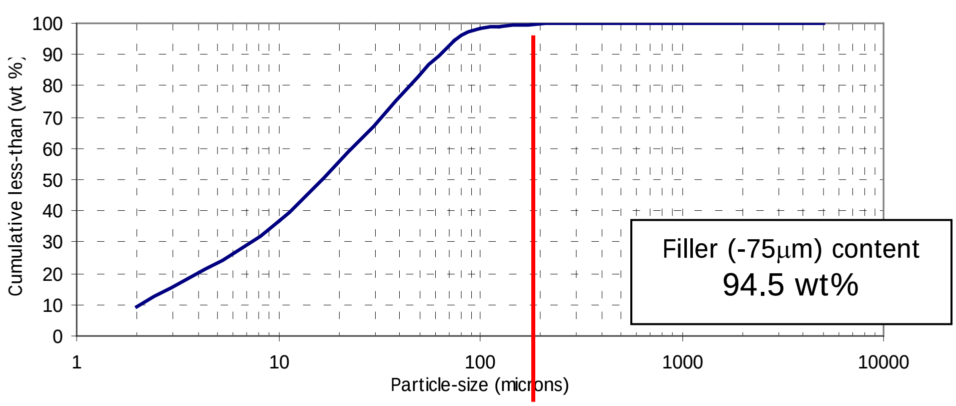
Dominant	Calcite
Major	
Minor	Quartz
Trace	Kaolinite, ?barite, K-feldspar, ?fluorite, ?dolomite and ?hematite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the mixed filler fines from a mix of limestone, granite and sand produced during asphalt production from Dene Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite, minor quartz and trace amounts of kaolinite, barite, K-feldspar, fluorite, dolomite and hematite. Chemical analysis determined that the sample contains 16% SiO_2, 2% Al_2O_3, 45% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and 1% Fe_2O_3. The sample has a very high filler content, 95% <75 µm.

DENE QUARRY

Location: Dene Quarry, Cromford, Matlock, Derbyshire, UK

Sample type: Filler fines

Rock type: Limestone
(Eyam Limestone, Cliff Hill granite
and Bestwood sand, Carboniferous)

Sampling: prEN-932-1
(Draft European Standard)

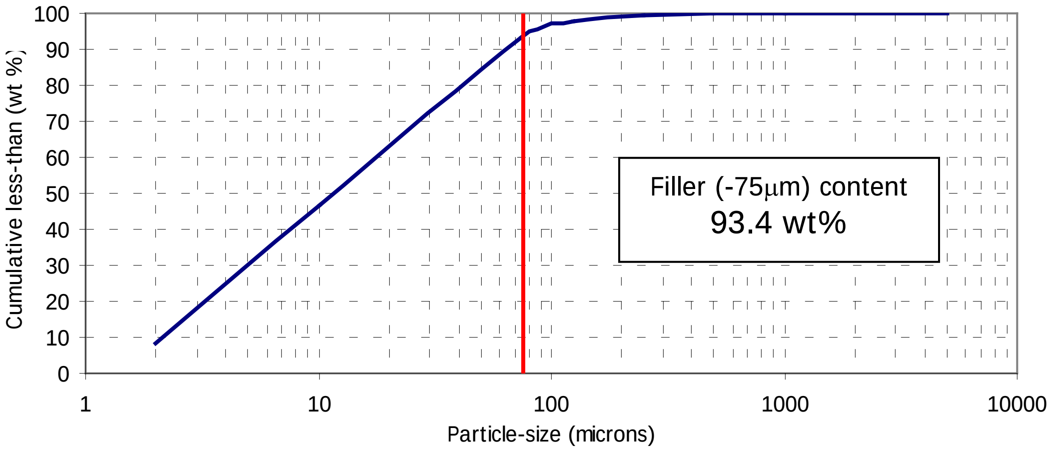
Sample code: BDEF3 / F228 **Date:** 16/9/1999

Mineralogy

Dominant	Calcite
Major	
Minor	Quartz
Trace	Chlorite, mica, kaolinite, Alkali (Na- & K-) feldspar, ?barite, ?fluorite, ?dolomite and ?pyrite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the mixed filler fines from a mix of limestone, granite and sand produced during asphalt production from Dene Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite, minor quartz and trace amounts of chlorite, mica, kaolinite, alkali (Na- & K-) feldspar, barite, fluorite, dolomite and pyrite. The sample has a very high filler content, 93% <75 µm.

HILLHEAD QUARRY

Location: Hillhead Quarry, Hindlow, Buxton, Derbyshire, UK

Sample type: Plant fines

Rock type: Limestone (Bee Low Limestone, Carboniferous)

Sampling: prEN-932-1 (Draft European Standard)

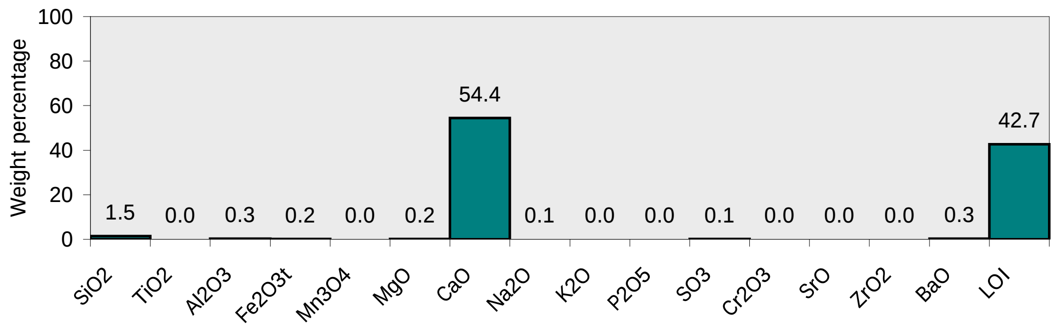
Sample code: BHHF1 / F229 **Date:** 16/9/1999

Mineralogy

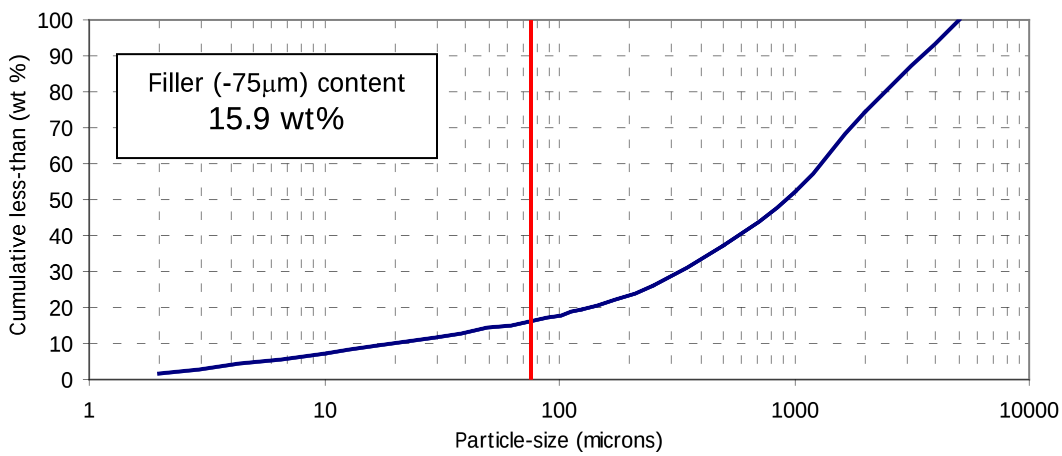
Dominant	Calcite
Major	
Minor	
Trace	Quartz, kaolinite, ?barite and ?K-feldspar.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines (3 mm to dust) produced during aggregate production from Hillhead Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite and trace amounts of quartz, kaolinite, barite and K-feldspar. Chemical analysis determined that the sample contains <2% SiO_2, <1% Al_2O_3, 55% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a low filler content, 16% <75 µm.

CAULDON LOW QUARRY

Location: Cauldon Low Quarry, PO Box 1, Stoke-on-Trent, Staffordshire, UK

Sample type: Filler fines **Rock type:** Limestone (Milldale Limestone, Carboniferous)

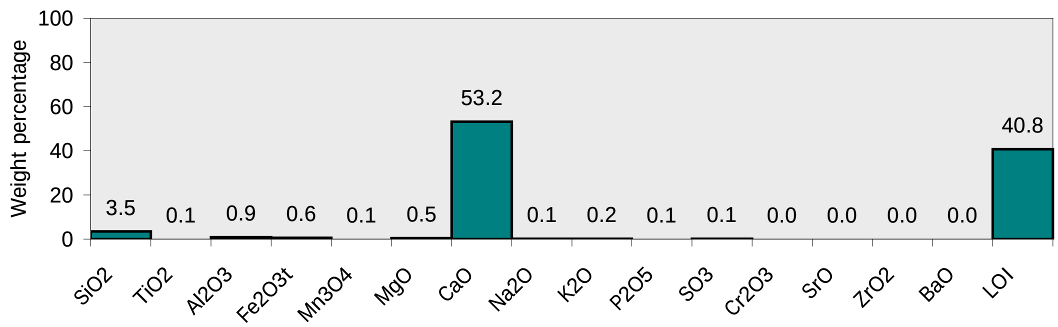
Sampling: Unknown **Sample code:** BCLF1 / F230 **Date:** 16/9/1999

Mineralogy

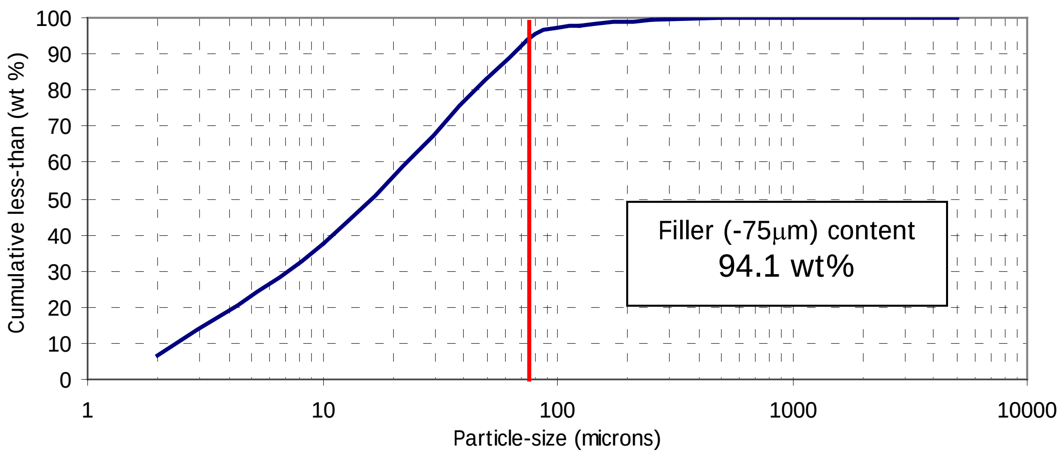
Dominant	Calcite
Major	
Minor	
Trace	Quartz

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the filler fines (used in asphalt production) produced during aggregate production from Cauldon Low Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite and a trace amount of quartz. Chemical analysis determined that the sample contains nearly 4% SiO_2, <1% Al_2O_3, 54% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a very high filler content, 94% <75 μm.

THRESHFIELD QUARRY

Location: Threshfield Quarry, Skyrethornes Lane, Threshfield, Skipton, North Yorkshire, UK

Sample type: Plant fines (scalpings) **Rock type:** Limestone (Cove Limestone, Carboniferous)

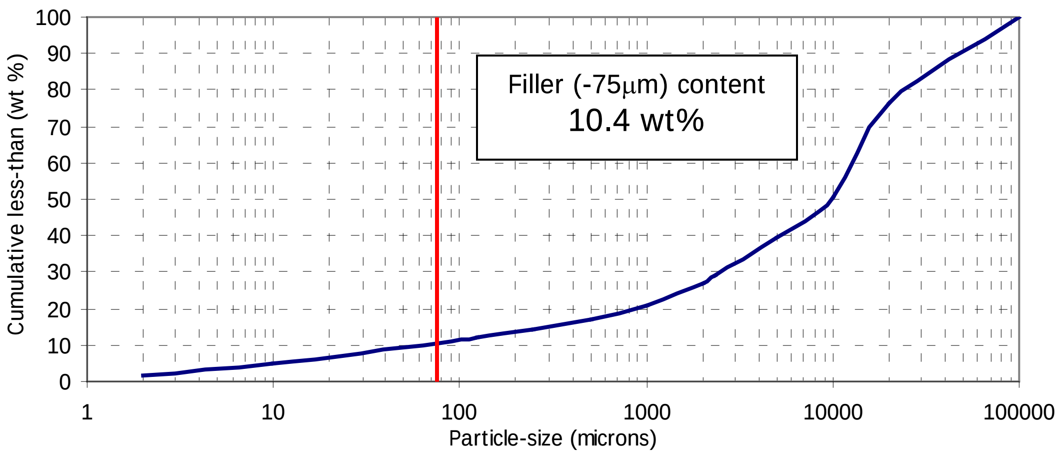
Sampling: prEN-932-1 (Draft European Standard) **Sample code:** BTHF1 / F231 **Date:** 21/9/1999

Mineralogy

Dominant	Calcite
Major	
Minor	
Trace	Mica, quartz, ?barite, ?dolomite and ?pyrite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



NB This cumulative frequency particle-size distribution graph is plotted to 100000 microns (100 mm) unlike the other factsheets which are plotted to 10000 microns (10 mm).

Summary of data

This sample represents the 40 mm to dust waste product (scalpings) from lower quality zones produced during aggregate production from Threshfield Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite and trace amounts of mica, quartz, barite, dolomite and pyrite. The sample has a low filler content, 10% <75 μm (**NB** This sample contains a high proportion of material coarser than 2mm, 73%).

THRESHFIELD QUARRY

Location: Threshfield Quarry, Skyrethornes Lane, Threshfield, Skipton, North Yorkshire, UK

Sample type: Plant fines **Rock type:** Limestone (Cove Limestone, Carboniferous)

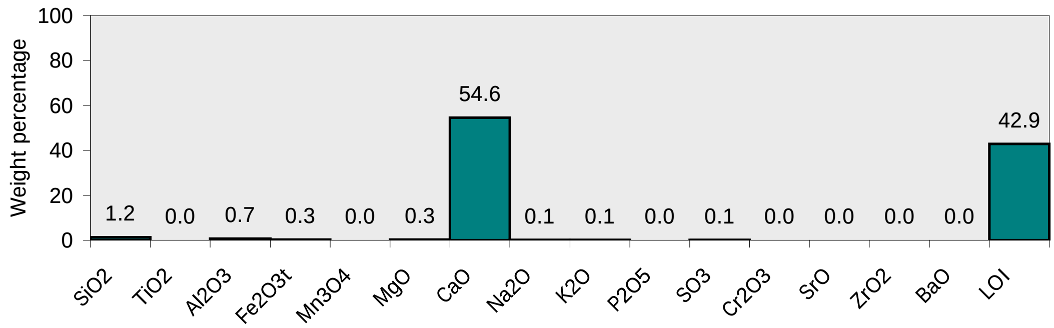
Sampling: prEN-932-1 (Draft European Standard) **Sample code:** BTHF2 / F232 **Date:** 21/9/1999

Mineralogy

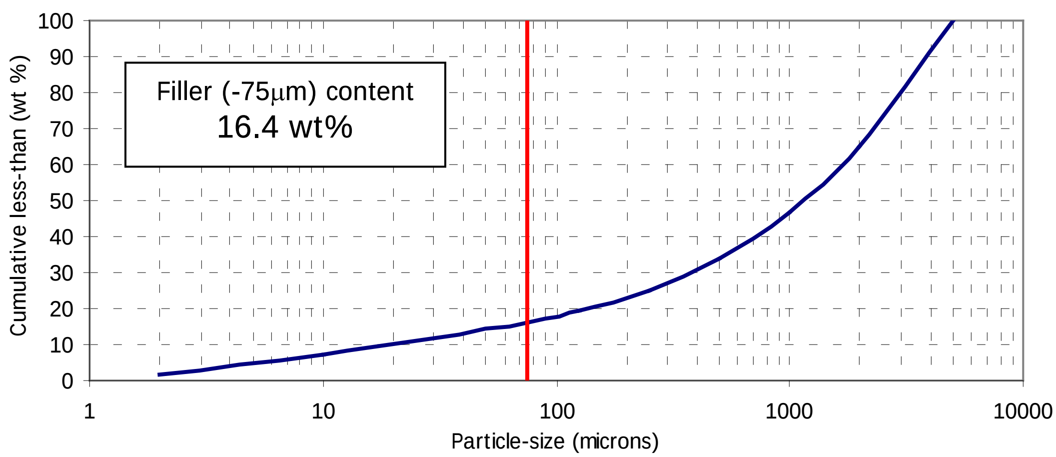
Dominant	Calcite
Major	
Minor	
Trace	Quartz and dolomite

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines (used in asphalt and concrete products) produced during aggregate production from Threshfield Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite and trace amounts of quartz and dolomite. Chemical analysis determined that the sample contains 1% SiO_2, <1% Al_2O_3, 55% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a low filler content, 16% <75 µm.

HOLME HALL QUARRY

Location: Holme Hall Quarry, Stainton, Maltby, Rotherham, South Yorkshire, UK

Sample type: Filler fines **Rock type:** Limestone (Cadeby Magnesian Limestone, Permian)

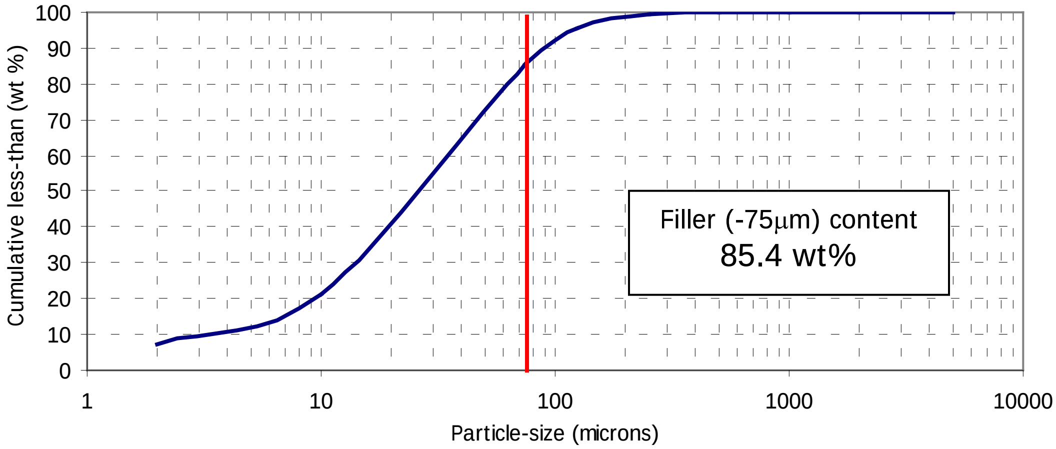
Sampling: Unknown **Sample code:** BHHSF1 / F233 **Date:** 21/9/1999

Mineralogy

Dominant	Dolomite
Major	
Minor	
Trace	Calcite, quartz and Na-feldspar

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the filler fines produced during aggregate production from Holme Hall Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant dolomite and trace amounts of calcite, quartz and Na-feldspar. The sample has a high filler content, 85% <75 µm.

HOLME HALL QUARRY

Location: Holme Hall Quarry, Stainton, Maltby, Rotherham, South Yorkshire, UK

Sample type: Plant fines | **Rock type:** Limestone (Cadeby Magnesian Limestone, Permian)

Sampling: Unknown | **Sample code:** BHHSF2 / F234 **Date:** 21/9/1999

Mineralogy

Dominant Dolomite

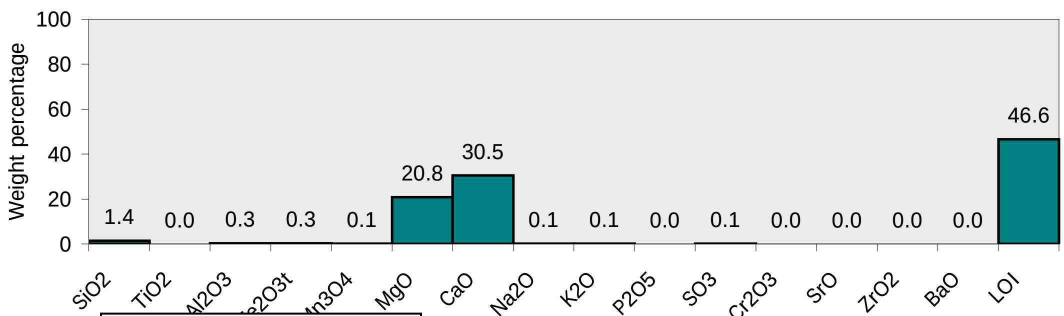
Major

Minor

Trace Calcite and quartz

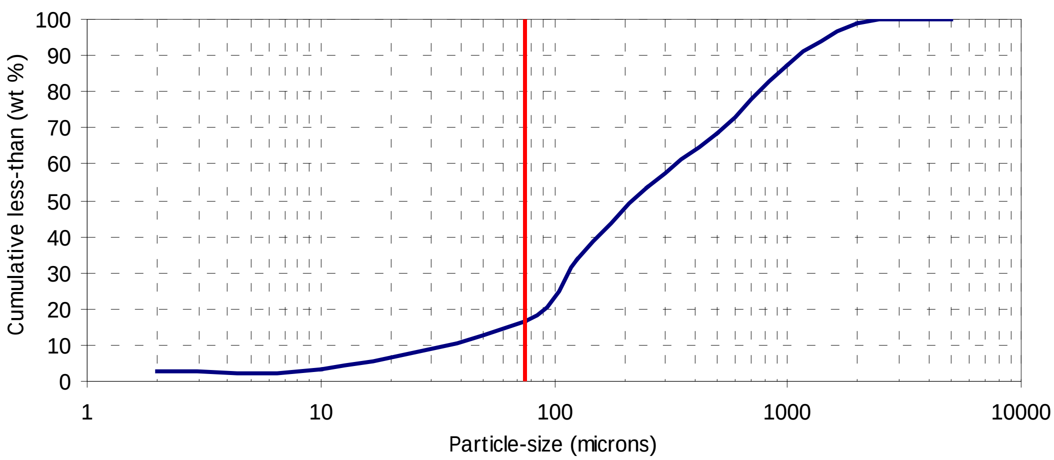
Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Filler (-75µm) content
16.6 wt%

Particle-



Summary of data

This sample represents the fines produced from the processing plant during aggregate production from Holme Hall Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant dolomite and trace amounts of calcite and quartz. Chemical analysis determined that the sample contains 1% SiO_2, <1% Al_2O_3, 51% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a low filler content, 17% <75 µm.

BLASHFORD QUARRY (Tarmac Quarry Products Southern)

Location: Blashford Quarry, Salisbury Road, Blashford, Ringwood, Hampshire, UK

Sample type: Plant fines **Rock type:** Sand and gravel (Ellingham Sand & Gravel) (River Avon gravel, Quaternary)

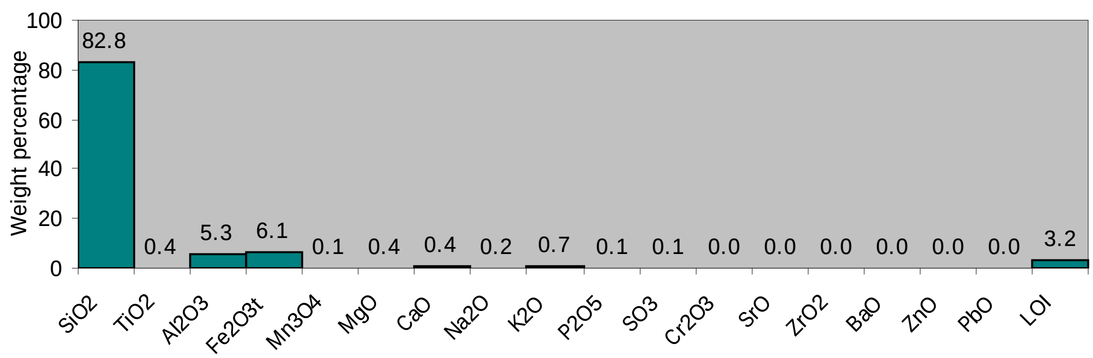
Sampling: Unknown **Sample code:** BBSF1 / F727 **Date:** 1999

Mineralogy

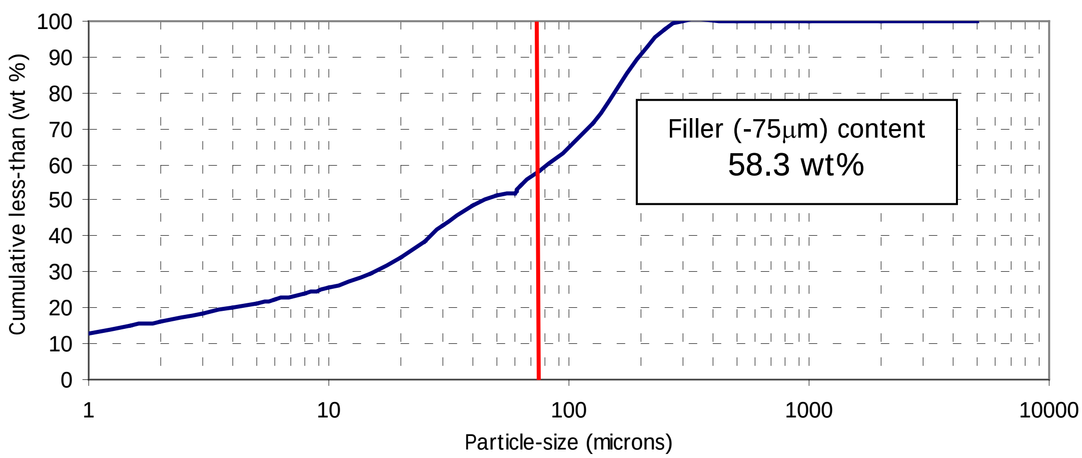
Dominant	Quartz
Major	
Minor	
Trace	Mica?, alkali (Na- & K-) feldspar ? & anatase?

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Blashford Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz and trace amounts of mica, alkali (Na- & K-) feldspar and anatase. Chemical analysis determined that the sample contains 83% SiO_2, 5% Al_2O_3, <1% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and 6% Fe_2O_3. The sample has a high filler content, 58% <75 μm.

BLASHFORD QUARRY (Tarmac Quarry Products Southern)

Location: Blashford Quarry, Salisbury Road, Blashford, Ringwood, Hampshire, UK

Sample type: Plant fines **Rock type:** Sand and gravel (Nea Farm) (River Avon gravel, Quaternary)

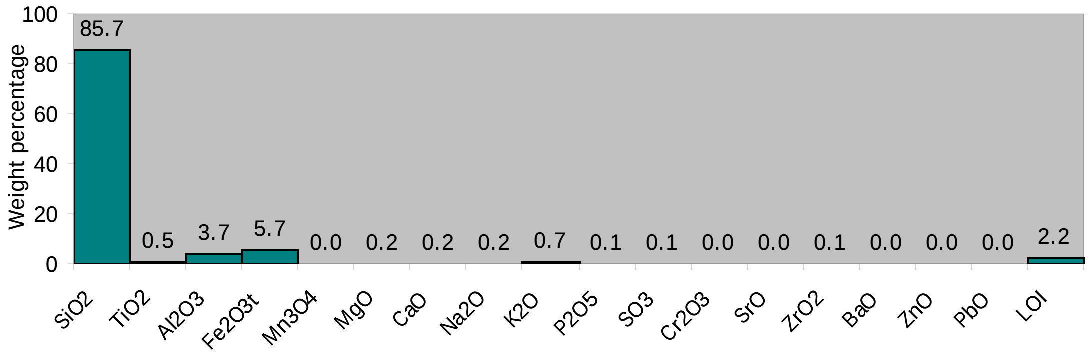
Sampling: Unknown **Sample code:** BBSF3 / F728 **Date:** 1999

Mineralogy

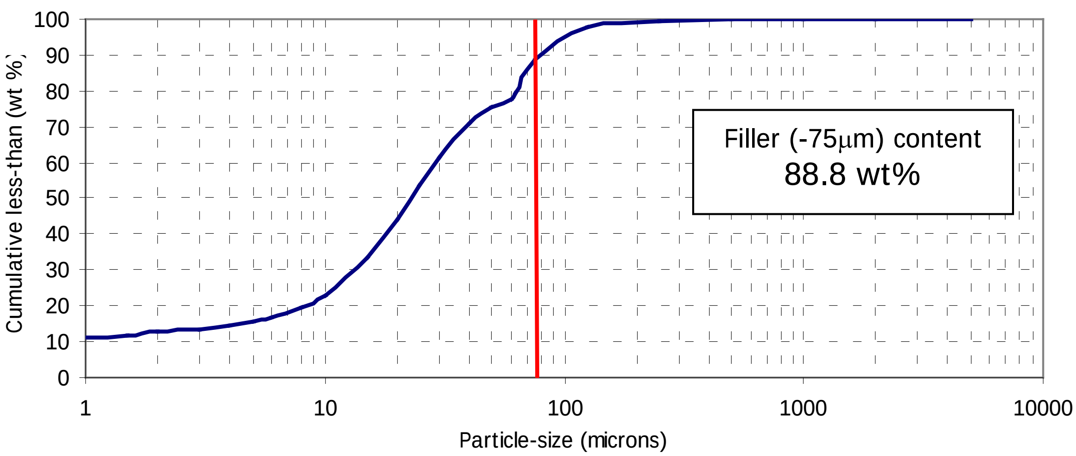
Dominant	Quartz
Major	
Minor	
Trace	Mica?, alkali (Na- & K-) feldspar ? & anatase?

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Blashford Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz and trace amounts of mica, alkali (Na- & K-) feldspar and anatase. Chemical analysis determined that the sample contains 86% SiO_2, 4% Al_2O_3, <1% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and 6% Fe_2O_3. The sample has a very high filler content, 89% <75 μm.

STANCOMBE QUARRY (Tarmac Quarry Products Southern)

Location: Stancombe Quarry, Stancombe Lane, Flax Bourton, North Somerset, UK

Sample type: Plant fines **Rock type:** Limestone (Clifton Down Limestone, Carboniferous)

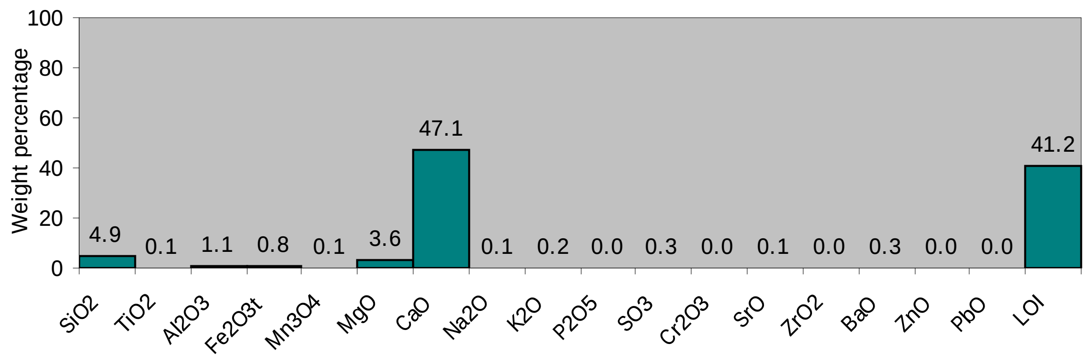
Sampling: Unknown **Sample code:** BSCF1 / F731 **Date:** 1999

Mineralogy

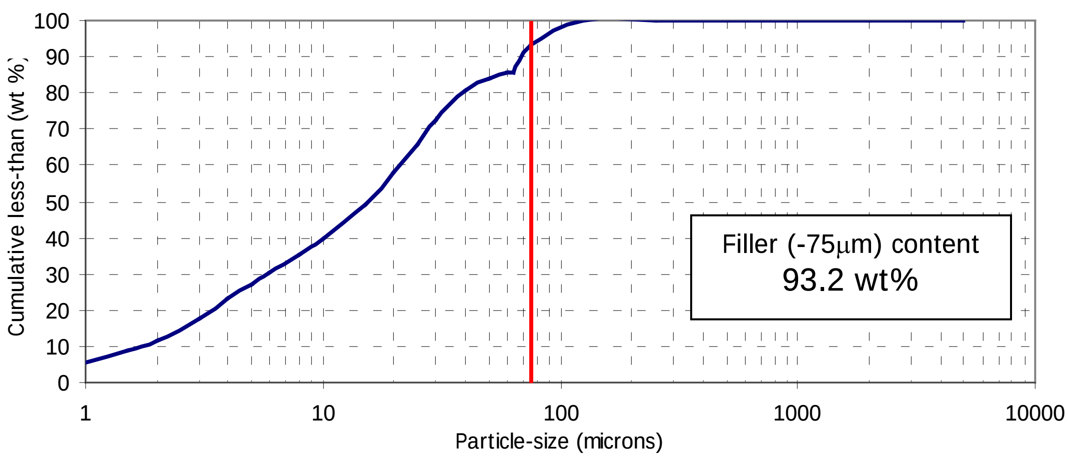
Dominant	Calcite
Major	
Minor	Dolomite
Trace	Quartz & kaolinite ?

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Stancombe Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite, minor amounts of dolomite and trace amounts of quartz and kaolinite. Chemical analysis determined that the sample contains 5% SiO_2, <1% Al_2O_3, 51% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a very high filler content, 93% <75 µm.

STOWFIELD QUARRY (Tarmac Quarry Products Southern)

Location: Stowfield Quarry, Scowles Pitch, Coleford, Gloucestershire, UK

Sample type: Plant fines **Rock type:** Limestone (Black Rock Dolomite, Carboniferous)

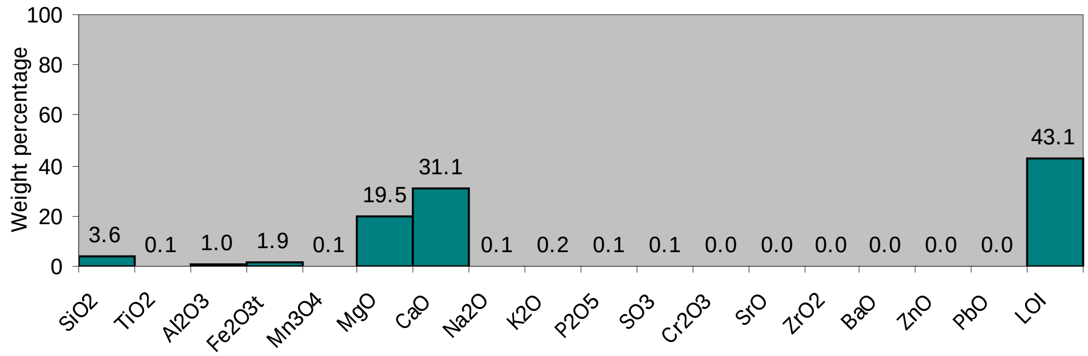
Sampling: Unknown **Sample code:** BSTF1 / F732 **Date:** 1999

Mineralogy

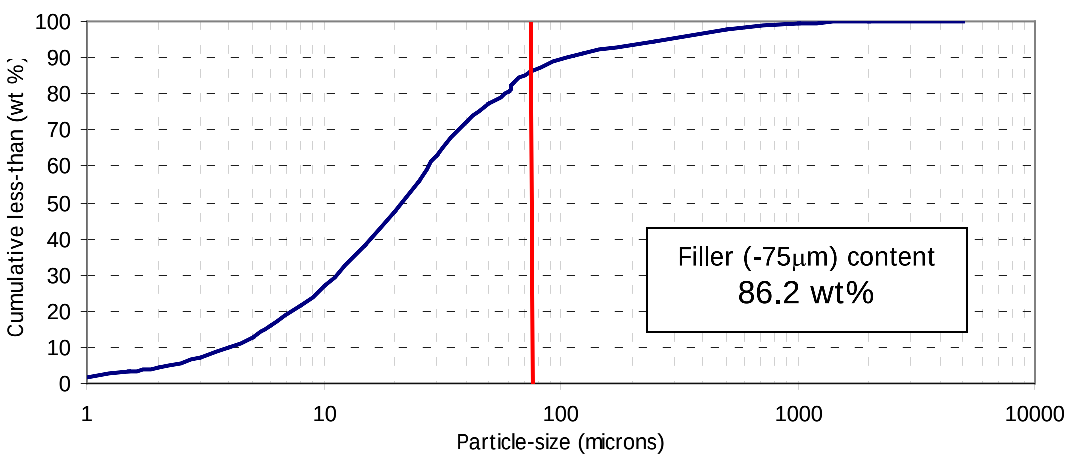
Dominant	Dolomite
Major	
Minor	
Trace	Calcite & quartz

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Stowfield Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant dolomite and trace amounts of calcite and quartz. Chemical analysis determined that the sample contains 4% SiO_2, 1% Al_2O_3, 51% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and 2% Fe_2O_3. The sample has a high filler content, 86% <75 µm.

REFILL characterisation factsheets:

UK quarry waste: Scotland

BORTHWICK QUARRY

Location: Borthwick Quarry, Borthwick, Duns, The Borders, UK

Sample type: Filler fines

Rock type: Olivine dolerite (Sill, Carboniferous)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: BBOF2 / CJM548

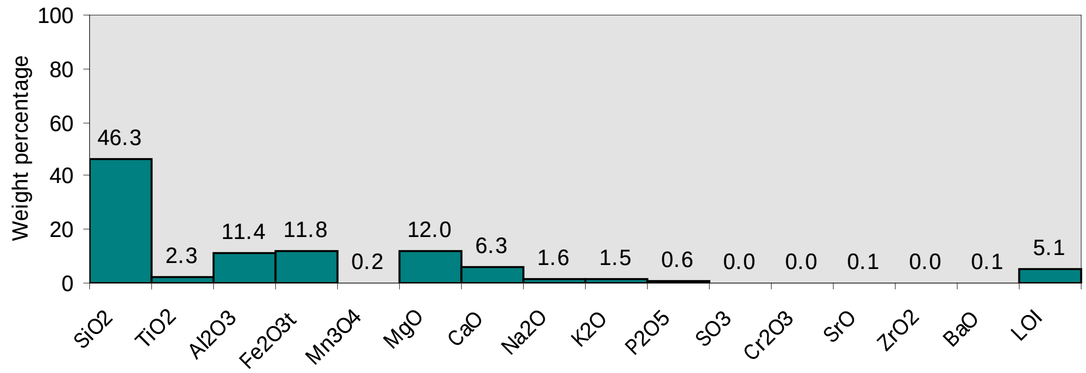
Date: 2/12/98

Mineralogy

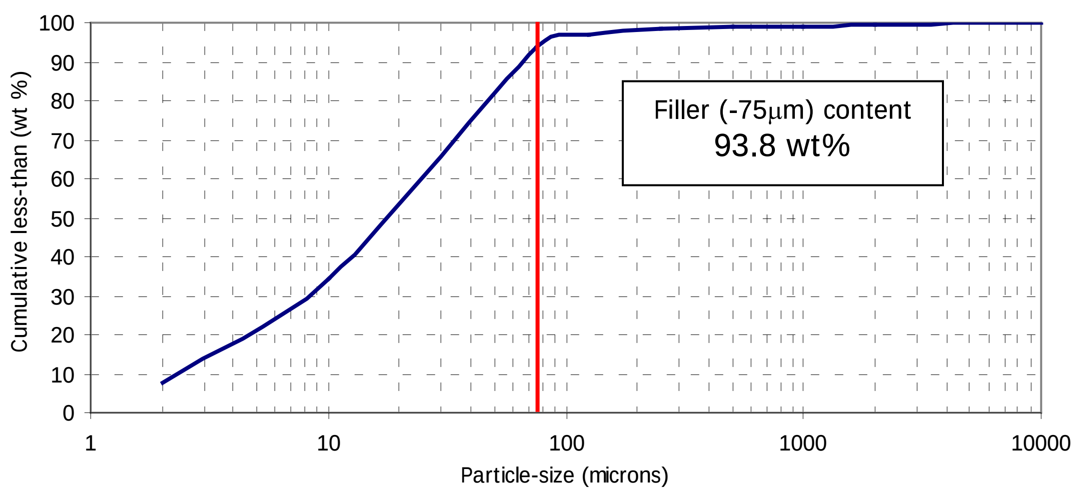
Dominant	Plagioclase feldspar.
Major	Augite.
Minor	Olivine and analcime.
Trace	Ilmenite, magnetite and serpentine.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during aggregate production from Borthwick Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant plagioclase feldspar, major augite, minor amounts of olivine and analcime and trace amounts of ilmenite, magnetite and serpentine. Chemical analysis determined that the sample contains 46% SiO_2, 11% Al_2O_3, 18% alkali earths (MgO & CaO), 3% alkalis (Na_2O & K_2O), 2% TiO_2 and 12% Fe_2O_3. The sample has a high filler content, 94% <75 μm.

BANGLEY QUARRY

Location: Bangley Quarry, Haddington, East Lothian, Scotland, UK

Sample type: Plant fines **Rock type:** Trachyte lava (Carboniferous)

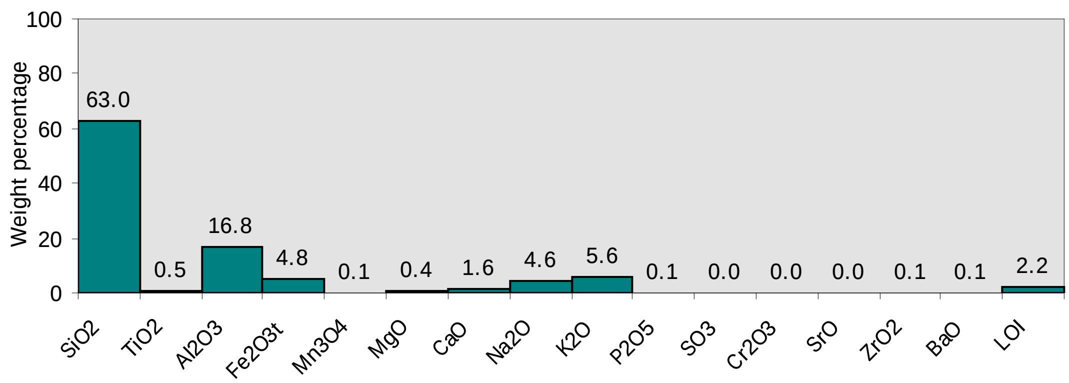
Sampling: prEN-932-1 (Draft European Standard) **Sample code:** BBAF1 / CJM549 **Date:** 2/12/98

Mineralogy

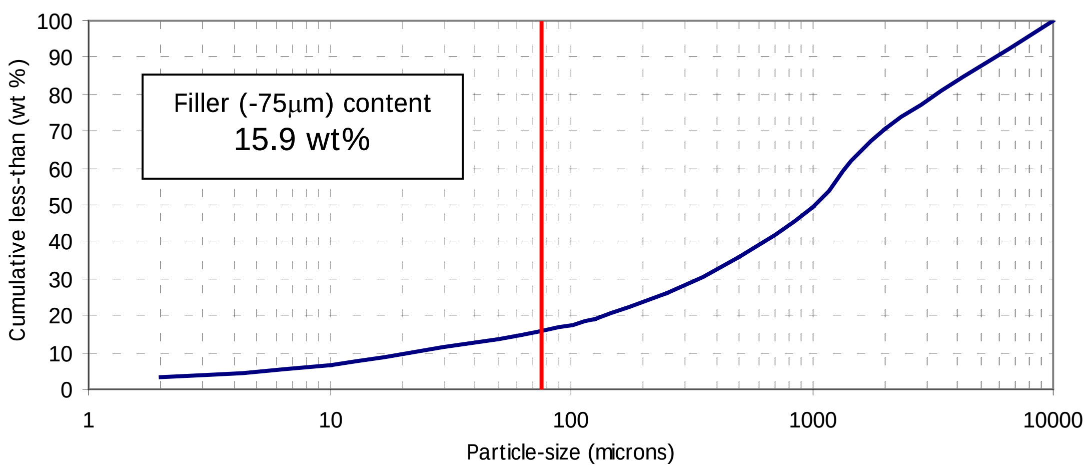
Dominant	
Major	Alkali (Na- & K-) feldspar.
Minor	Quartz and augite.
Trace	?Hematite, ?rutile and ?chlorite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Bangley Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of major alkali (Na- & K-) feldspar, minor quartz and augite, and trace amounts of hematite, rutile and chlorite. Chemical analysis determined that the sample contains 63% SiO_2, 17% Al_2O_3, 2% alkali earths (MgO & CaO), 10% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 16% <75 µm.

CREETOWN QUARRY

Location: Creetown Quarry, Creetown, Newton Stewart, Dumfries & Galloway, Scotland, UK

Sample type: Plant fines **Rock type:** Granite (Creetown granite, Silurian)

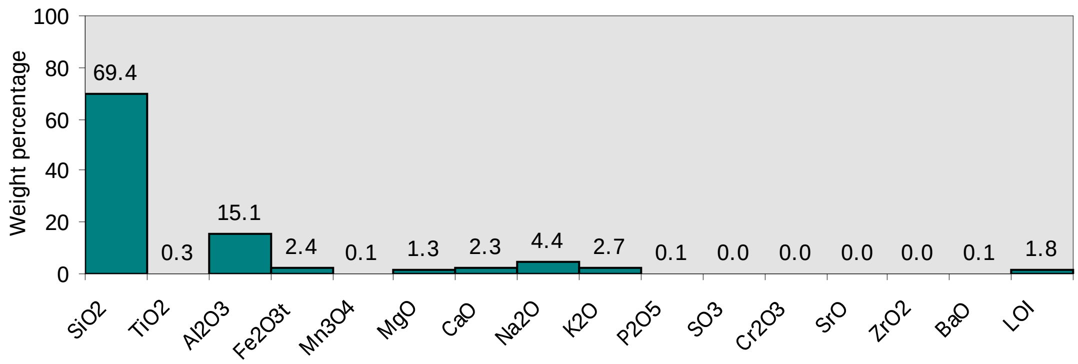
Sampling: Spot sampling **Sample code:** BKF1 / CJM552 **Date:** 3/12/98

Mineralogy

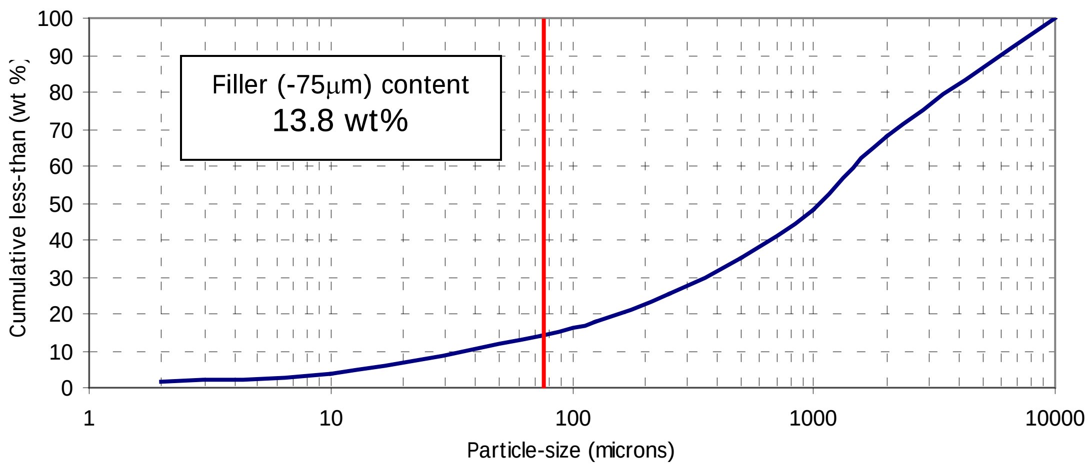
Dominant	Quartz
Major	Na-feldspar.
Minor	K-feldspar and mica.
Trace	?Kaolinite, ?calcite and ?rutile.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Creetown Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major Na-feldspar, minor K-feldspar and mica, and trace amounts of kaolinite, calcite and rutile. Chemical analysis determined that the sample contains 69% SiO_2, 15% Al_2O_3, 4% alkali earths (MgO & CaO), 7% alkalis (Na_2O & K_2O), <1% TiO_2 and 2% Fe_2O_3. The sample has a low filler content, 14% <75 µm.

CRAIGNAIR QUARRY

Location: Craignair Quarry, Dalbeattie, Dumfries & Galloway, Scotland, UK

Sample type: Plant fines **Rock type:** Granite (Criffel Granite, Silurian)

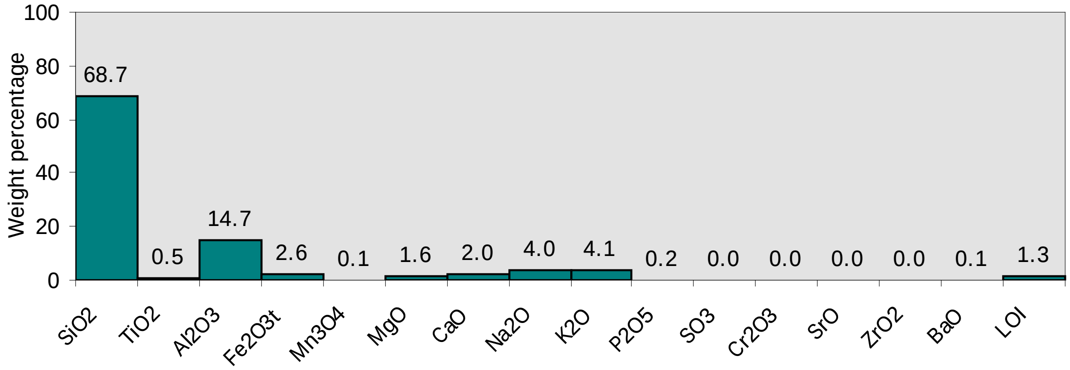
Sampling: Spot sampling **Sample code:** BDF1 / CJM553 **Date:** 3/12/98

Mineralogy

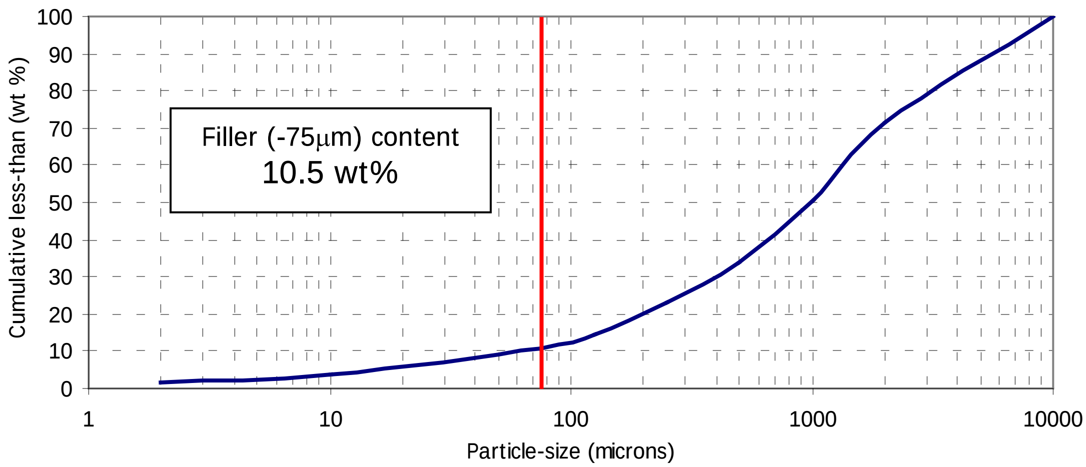
Dominant	Quartz
Major	Alkali (Na- & K-feldspar)
Minor	Mica.
Trace	?Hematite, ?rutile, ?chlorite and ?hornblende.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Craignair Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major alkali (Na- & K-) feldspar, minor mica, and trace amounts of hematite, rutile, chlorite and hornblende. Chemical analysis determined that the sample contains 69% SiO_2, 15% Al_2O_3, 4% alkali earths (MgO & CaO), 8% alkalis (Na_2O & K_2O), <1% TiO_2 and 3% Fe_2O_3. The sample has a low filler content, 11% <75 µm.

REFILL characterisation factsheets:

UK quarry waste: Wales

PANT QUARRY

Location: Pant Quarry, Halkyn, Holywell, North Wales, UK

Sample type: Filler fines **Rock type:** Limestone (Loggerheads – Cefn Mawr Limestone, Carboniferous)

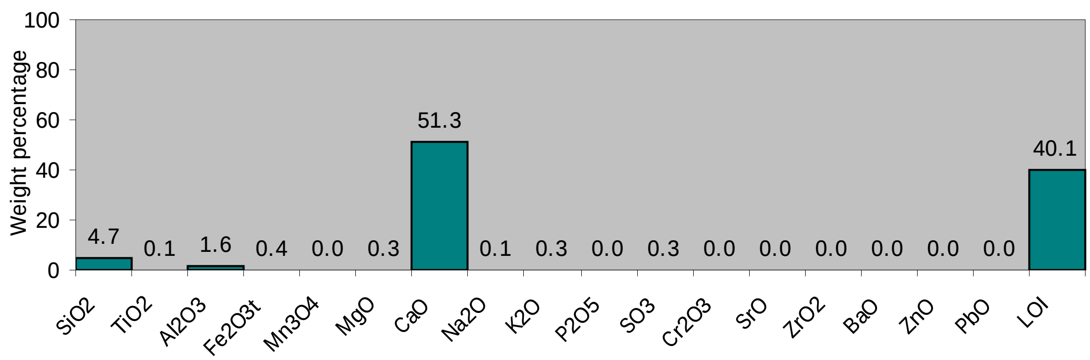
Sampling: Unknown **Sample code:** BPHF1 / F729 **Date:** 1999

Mineralogy

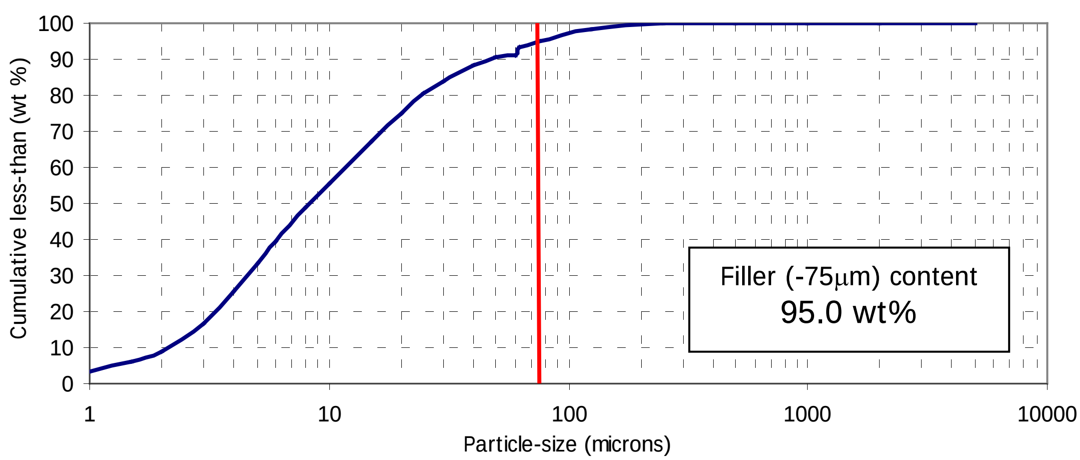
Dominant	Calcite
Major	
Minor	
Trace	Quartz, kaolinite ?, alkali (Na- & K-) feldspar ? & fluorite ?

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the filler fines produced during aggregate production from Pant Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite and trace amounts of quartz, kaolinite, alkali (Na- & K-) feldspar and flourite. Chemical analysis determined that the sample contains 5% SiO_2, 2% Al_2O_3, 52% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a very high filler content, 95% <75 µm.

DENBIGH QUARRY

Location: Denbigh Quarry, Graig Road, Ruthin, Denbigh, North Wales, UK

Sample type: Plant fines

Rock type: Limestone (Dyserth Limestone, Carboniferous)

Sampling: Unknown

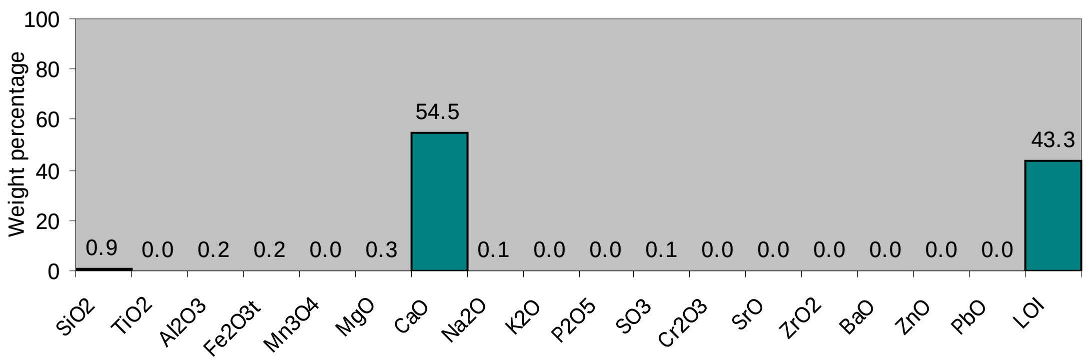
Sample code: BDGF1 / F730 **Date:** 1999

Mineralogy

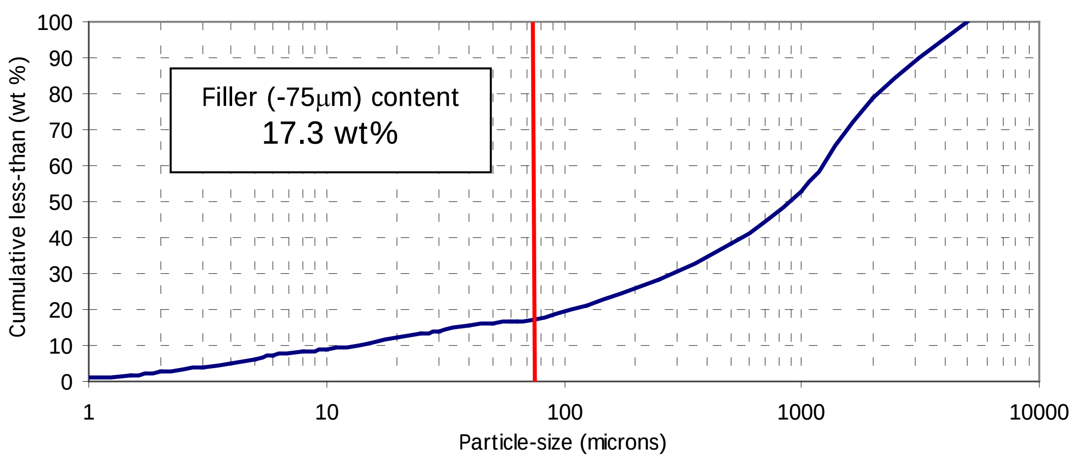
Dominant	Calcite
Major	
Minor	
Trace	Quartz ?

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the plant fines produced during aggregate production from Denbigh Quarry. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant calcite and trace amounts of quartz. Chemical analysis determined that the sample contains <1%% SiO_2, <1% Al_2O_3, 55% alkali earths (MgO & CaO), <1% alkalis (Na_2O & K_2O), <1% TiO_2 and <1% Fe_2O_3. The sample has a low filler content, 17% <75 µm.

REFILL characterisation factsheets:

Leahill Quarry raw material:

Rock samples

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample

Rock type: Coarse siltstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample

Sample code: LHR1 / CJM494

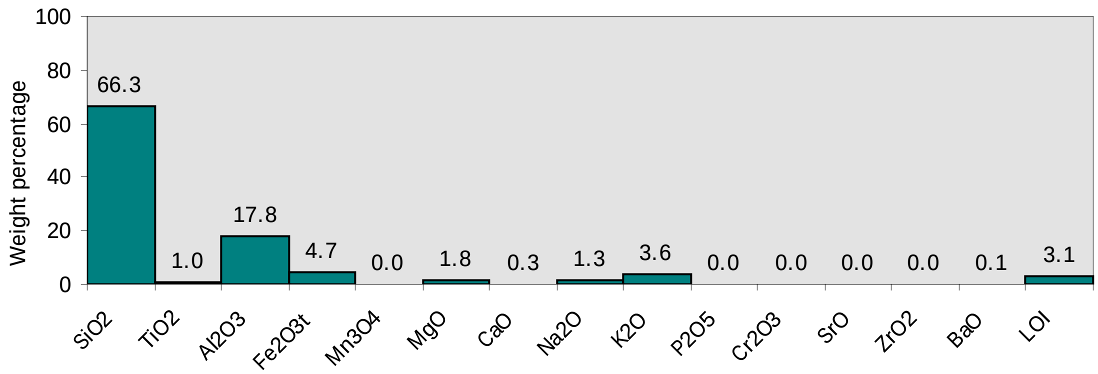
Date: 11/8/98

Mineralogy

Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	Calcite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Petrography

Greenish-grey in hand specimen. Consists of fine quartz grains (average size 40-80 µm) in a fine matrix (of chlorite, mica and quartz). Chlorite and mica mark out a faint lineation (relict bedding?). Quartz grains are generally sub-angular to sub-rounded with a slight elongation parallel to lineation. Opaque and other accessory mineral grains occur disseminated throughout (<5%) up to 50 µm in size, on average 10-20 µm. Detailed petrographic analysis, using a Scanning Electron Microscope, determined that rutile is the dominant accessory mineral. Zircon, rare earth phosphates and apatite were also identified.

Summary of data

Coarse siltstone, greenish-grey in colour, with faint lineations. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. Accessory minerals are dominated by rutile, with trace amounts of zircon, rare earth phosphate and apatite. Mineralogical analysis indicated that the feldspar is alkali (Na- & K-) feldspar and that a small proportion of calcite is present. Chemical analysis determined that the sample contains 66% SiO_2, 18% Al_2O_3, 5% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample **Rock type:** Very fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample **Sample code:** LHR2 / CJM495 **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, chlorite and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Petrography

Purplish-grey in hand specimen. Similar in appearance to LHR1, consisting of quartz grains (average size 60-120 µm) in a fine matrix (of chlorite, mica and quartz). Lineation (relict bedding?) is more evident, marked out by chlorite and mica. Quartz grains are sub-angular to sub-rounded with a slight elongation parallel to the lineation. Opaque mineral grains occur disseminated throughout up to 120 µm in size, on average 20-60 µm.

Summary of data

Very fine sandstone, purplish-grey in colour, with marked lineations. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. This was confirmed by mineralogical analysis, which also indicated that the feldspar is alkali (Na- & K-) feldspar.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample **Rock type:** Medium siltstone (Toe Head or Old Head Formation, Upper Devonian)

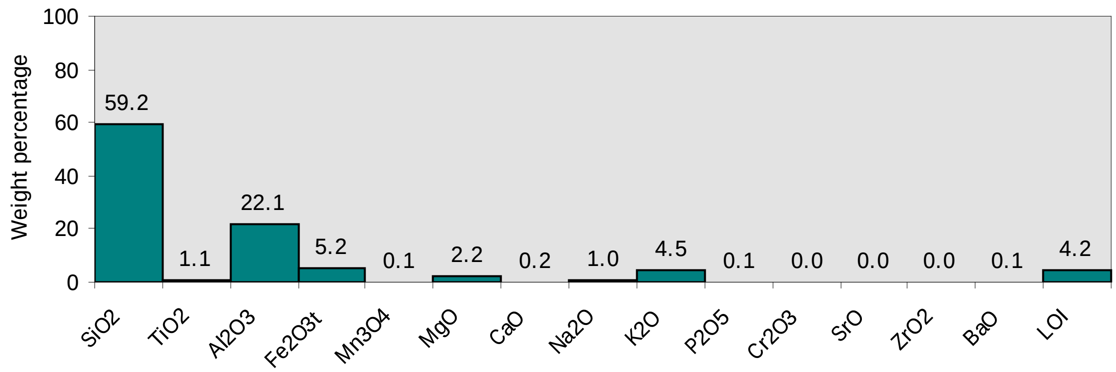
Sampling: Spot sample **Sample code:** LHR3 / CJM496 **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	Chlorite and mica.
Minor	Alkali (Na- & K-) feldspar.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Petrography

Grey to dark-grey in hand specimen. Uniform texture consisting of quartz, chlorite and mica, with few clasts larger than the matrix. Irregular bands of paler and darker grey material are present (no obvious mineralogical or grain size variation). The quartz (average size 15-30 µm) is rounded to sub-rounded with a slight elongation parallel to the lineation. Opaque mineral grains occur disseminated throughout on average <30 µm in size. Detailed petrographic analysis, using a Scanning Electron Microscope, determined that rutile is the dominant accessory mineral. Zircon, rare earth phosphate and apatite were also identified.

Summary of data

Medium siltstone, grey to dark-grey in colour, with irregular banding of paler and darker grey material. Petrographic analysis shows that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. Accessory minerals are dominated by rutile, with a trace amount of zircon, rare earth phosphate and apatite. Mineralogical analysis indicated that the feldspar is alkali (Na- & K-) feldspar. Chemical analysis determined that the sample contains 59% SiO_2, 22% Al_2O_3, 5% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample

Rock type: Fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample

Sample code: LHR4 / CJM497

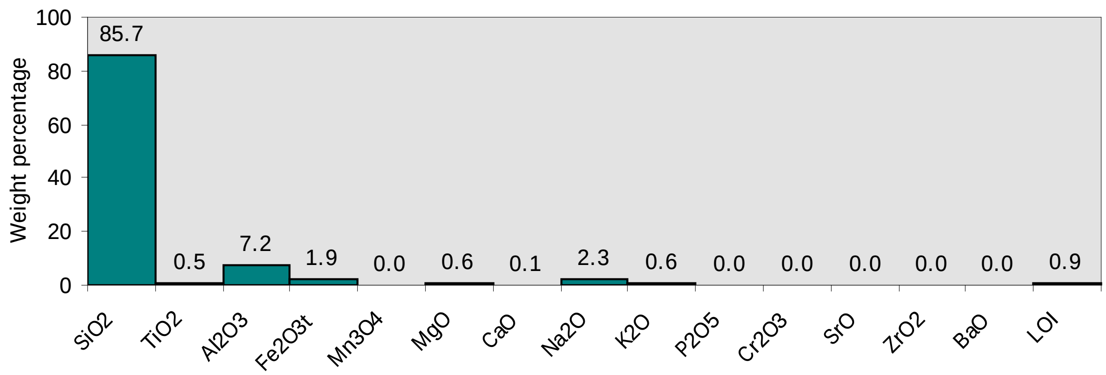
Date: 11/8/98

Mineralogy

Dominant	Quartz.
Major	Na-feldspar.
Minor	K-feldspar, chlorite and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Petrography

Pale-grey in hand specimen. Consists of closely interlocking quartz grains (average size 120-180 µm) with a small amount of interstitial fine-grained material (similar to matrix in LHR1). Quartz grains typically display undulose extinction and triple-point/fused grain boundaries. A small proportion (<1%) of plagioclase feldspar, mica (<2%) and opaque mineral grains (<2%) also occur. Opaque mineral grains up to 150 µm in size, average 30-100 µm. Detailed petrographic analysis, using a Scanning Electron Microscope, determined that rutile is the dominant accessory mineral. Leucoxene, zircon, rare earth phosphate and magnetite were also identified.

Summary of data

Fine sandstone, pale-grey in colour, with a homogeneous appearance. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. Accessory minerals are dominated by rutile, with trace amounts of leucoxene, zircon, rare earth phosphate and magnetite. This was confirmed by mineralogical analysis, which also proved that the feldspar is alkali (Na- & K-) feldspar. Chemical analysis determined that the sample contains 87% SiO_2, 7% Al_2O_3, 3% alkalis (Na_2O & K_2O), <1% TiO_2 and 2% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample | **Rock type:** Medium - coarse siltstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample | **Sample code:** LHR5 / CJM498 | **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Petrography

Grey in hand specimen. Consists of quartz grains (average size 20-40 µm) in a fine matrix (of chlorite, mica and quartz), with occasional bands of coarser quartz (average size 60-120 µm). No apparent sedimentary structures / lineations. Mica occurs as discrete platy grains. A small proportion of relatively coarse calcite (240-300 µm) occurs in a small aggregate, possibly a shell fragment? Opaque mineral grains are disseminated throughout up to 60 µm in size, average 15-25 µm.

Summary of data

Medium - coarse siltstone, grey in colour, with no apparent lineations. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz, with occasional coarse crystals of calcite. Mineralogical analysis indicated that the feldspar is alkali (Na- & K-) feldspar.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample **Rock type:** Medium siltstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample **Sample code:** LHR6 / CJM499 **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Petrography

Greenish-grey in hand specimen. Consists of quartz (average size 16-32 μm) in a fine-grained matrix (of chlorite, mica and quartz). The mica present occurs as discrete platy grains that form anastomosing bands and define the bedding / sedimentary structures. The quartz also occurs in bands of coarser-grained material (average size 40-60 μm). Opaque mineral grains are disseminated throughout up to 100 μm in size, average 20-40 μm.

Summary of data

Medium siltstone, greenish-grey in colour, with faint lineations and relict sedimentary texture. Petrographic analysis showed that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. This was confirmed by mineralogical analysis, which also indicated that the feldspar is alkali (Na- & K-) feldspar.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample **Rock type:** Very fine – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

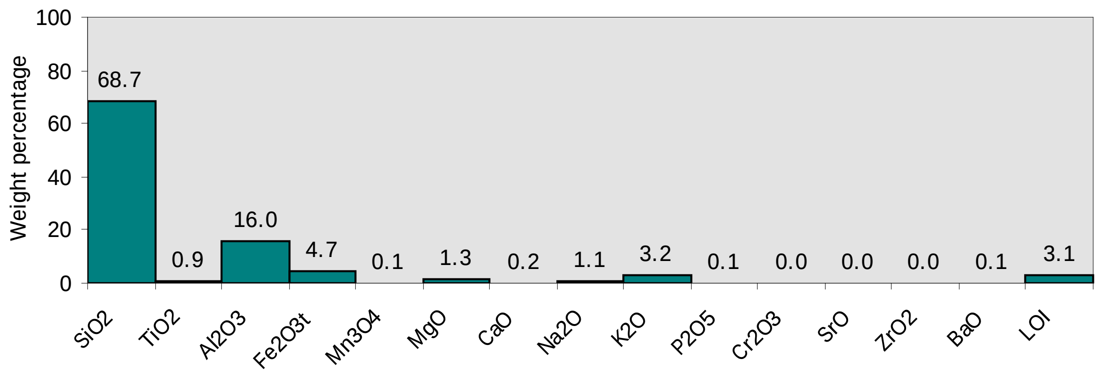
Sampling: Spot sample **Sample code:** LHR7 / CJM500 **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Petrography

Dark grey in hand specimen. Laminated, with quartz-rich bands (average 1 mm thick) and silt-rich bands (on average 800 µm thick). The silt-rich bands consist mainly of quartz (average 20-40 µm) with mica (parallel to the laminations), chlorite and opaque mineral grains (similar size to the quartz). The quartz-rich bands consist mainly of quartz (average 100-150 µm) with mica, chlorite and opaque mineral grains (of a similar size to the quartz). Detailed petrographic analysis, using a Scanning Electron Microscope, determined that rutile is the dominant accessory mineral. Leucoxene, zircon, rare earth phosphate, pyrite, chalcopyrite and galena were also identified.

Summary of data

Coarse siltstone, dark-grey in colour, with faint lineations. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. Accessory minerals are dominated by rutile, with trace amounts of leucoxene, zircon, rare earth phosphate, pyrite, chalcopyrite and galena. Mineralogical analysis proved that the feldspar is alkali (Na- & K-) feldspar. Chemical analysis determined that the sample contains 69% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample **Rock type:** Very fine – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample **Sample code:** LHR8 / CJM501 **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Petrography

Medium-grey in hand specimen. Consists of relatively closely packed quartz grains (average 100-150 µm) in a fine matrix (of chlorite, mica and quartz), with thin anastomosing laminae of opaque mineral grains (carbon?) forming bands 1-2 mm thick. Quartz occurs in these bands as fine grains (less than 50 µm). Mica is disseminated throughout as discrete grains, concentrated in the laminae. Rare grains of plagioclase feldspar also occur. Opaque mineral grains are sparsely disseminated throughout, average size 60-100 µm. Chlorite occurs disseminated throughout.

Summary of data

Very fine sandstone, medium-grey in colour, with faint laminae and banding. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. Mineralogical analysis showed that the feldspar is alkali (Na- & K-) feldspar.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample

Rock type: Medium - coarse siltstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample

Sample code: LHR9 / CJM502

Date: 11/8/98

Mineralogy

Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Petrography

Dark-grey in hand specimen. Consists of quartz grains (average size 20-40 µm) in a fine matrix (of chlorite, mica and quartz of a similar size to the quartz). No apparent texture / sedimentary features, apart from a faint lamination. This occurs as thin bands of lighter and darker grey material, with no apparent differences in mineralogy or grain size. Opaque mineral grains occur disseminated throughout up to 100 µm in size, on average 20-40 µm.

Summary of data

Medium - coarse siltstone, dark-grey in colour, with no apparent lineations. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. Mineralogical analysis proved that the feldspar is alkali (Na- & K-) feldspar.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Rock sample **Rock type:** Very fine – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: Spot sample **Sample code:** LHR10 / CJM503 **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	Na-feldspar.
Minor	K-feldspar, mica and chlorite.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Petrography

Pale-grey to greyish-white in hand specimen. Consists of relatively coarse quartz (average size 100-200 μm) grains closely packed with a small amount of interstitial fine matrix material (chlorite, mica and quartz). Quartz occurs as irregular to rounded grains, with triple-point contacts. Mica, chlorite and (rare) plagioclase feldspar occur disseminated throughout as interstitial grains (similar size to the quartz) and as components of the interstitial matrix material. Opaque mineral grains also occur disseminated throughout up to 100 μm in size, average 40-80 μm.

Summary of data

Very fine to fine grained sandstone, pale-grey to greyish-white in colour, with no apparent lineations. Petrographic analysis indicated that it is composed of quartz and feldspar grains in a matrix of fine-grained chlorite, mica and quartz. Mineralogical analysis indicated that the feldspar is alkali (Na- & K-) feldspar.

REFILL characterisation factsheets:

Leahill Quarry waste: Plant fines

('historic' and old plant)

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines (Mobile secondary crusher)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHF1 / CJM504

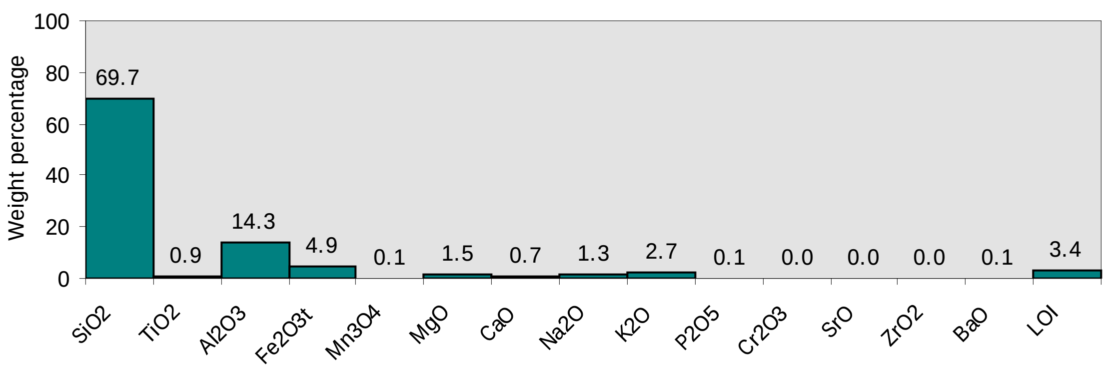
Date: 11/8/98

Mineralogy

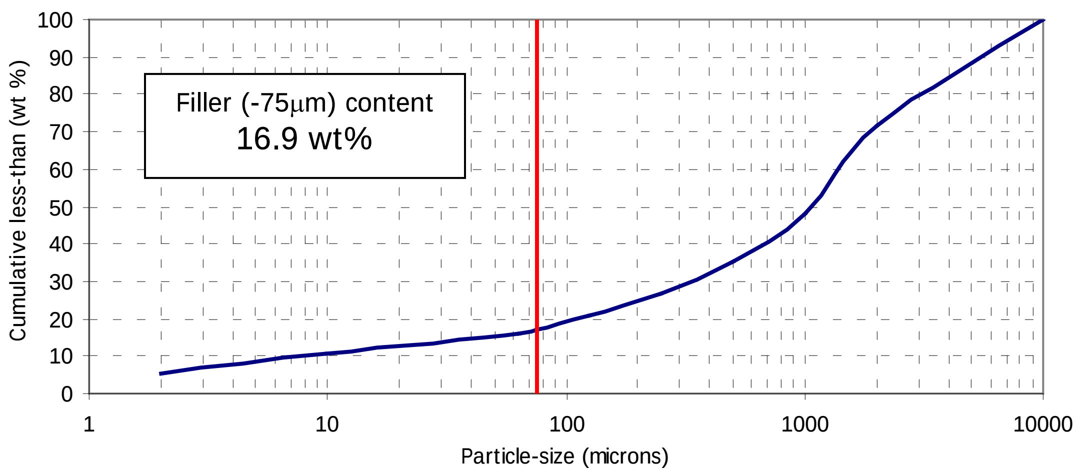
Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during aggregate production (mobile secondary crusher). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- &K-) feldspar and mica. Chemical analysis determined that the sample contains 70% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 17% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines (Mobile primary crusher)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHF2 / CJM505

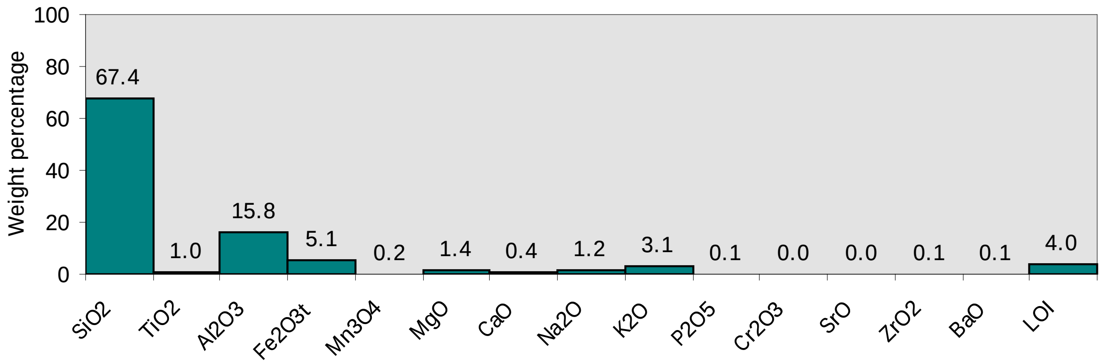
Date: 11/8/98

Mineralogy

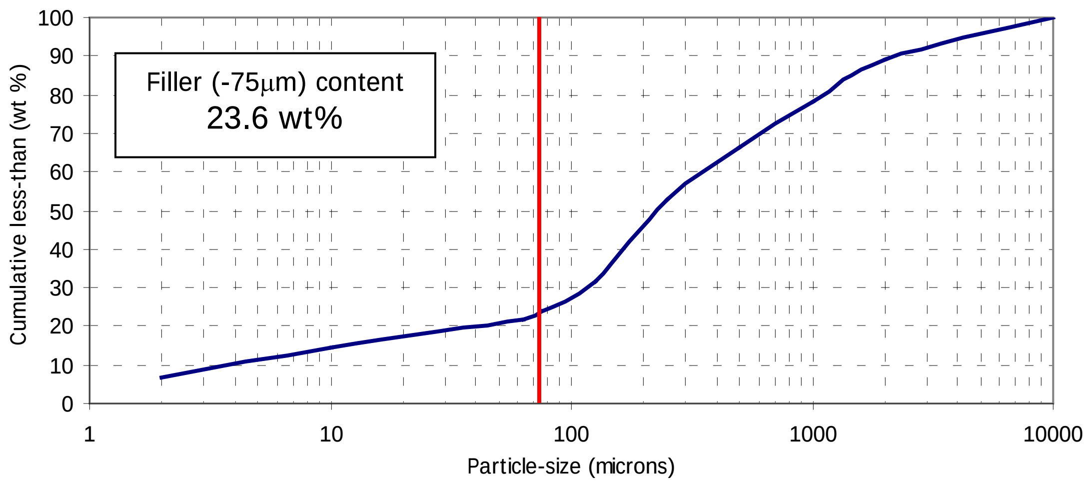
Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during aggregate production (mobile primary crusher). Mineralogical analysis showed that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- &K-) feldspar and mica. Chemical analysis determined that the sample contains 67% SiO_2, 16% Al_2O_3, 3% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 24% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines (Mobile Tertiary crusher)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

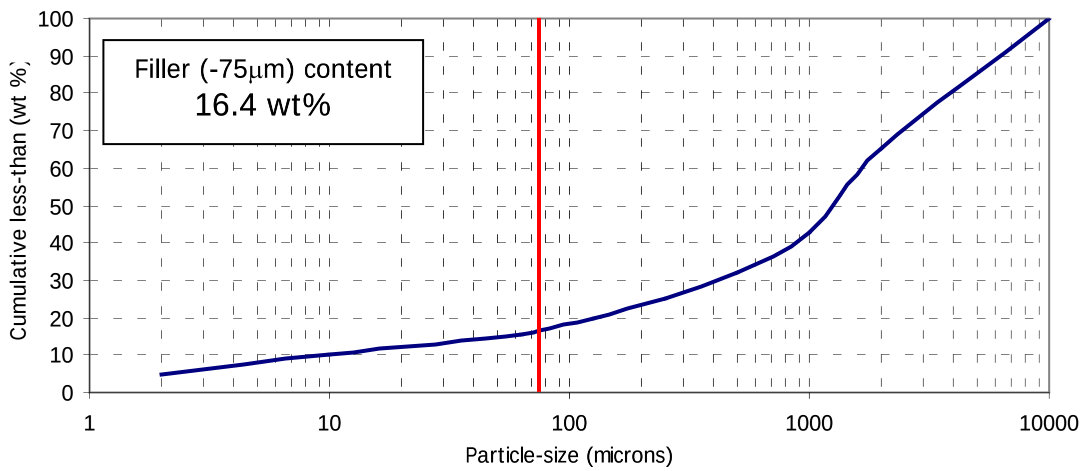
Sample code: LHF3 / CJM506 **Date:** 11/8/98

Mineralogy

Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines produced during aggregate production (mobile tertiary crusher). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, mica and chlorite and trace amounts of calcite. The sample has a low filler content, 16% <75 μm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines ('Historic' plant fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHF4 / CJM507

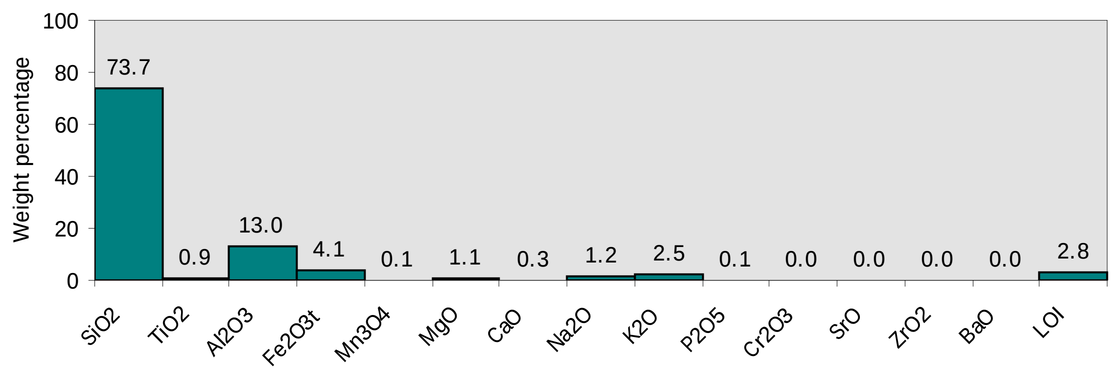
Date: 11/8/98

Mineralogy

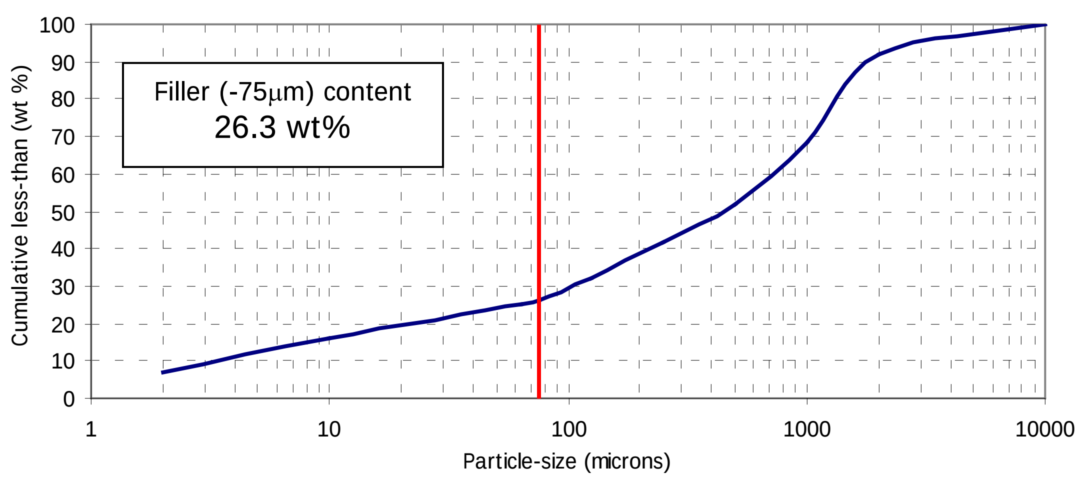
Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during former aggregate production ('historic' plant fines). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, mica and chlorite. Chemical analysis determined that the sample contains 74% SiO_2, 13% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 4% Fe_2O_3. The sample has a moderately low filler content, 26% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
('Historic' green, adj. site entrance))

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

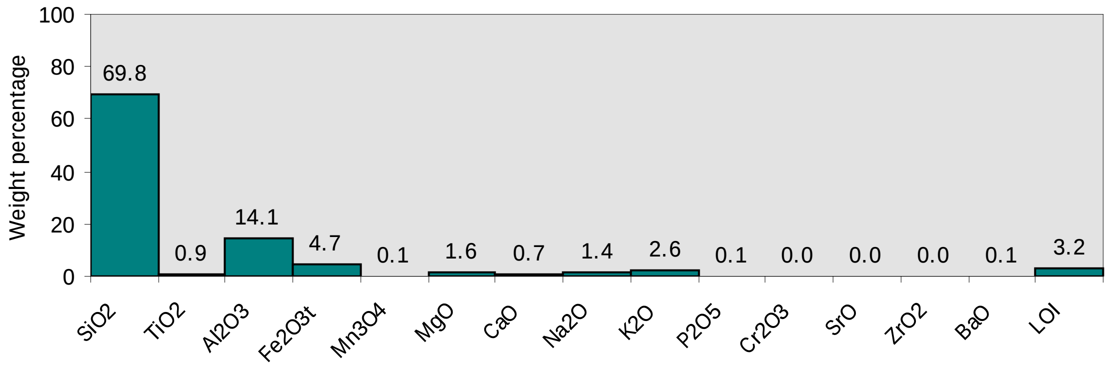
Sample code: LHF5 / CJM508 **Date:** 11/8/98

Mineralogy

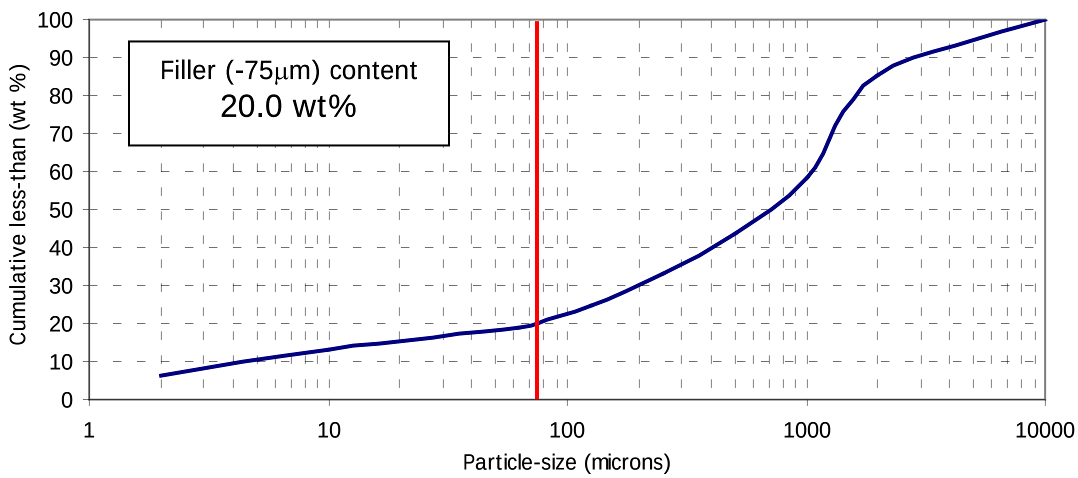
Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	Calcite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during former aggregate production ('historic' plant fines). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- &K-) feldspar and mica, and trace amounts of calcite. Chemical analysis determined that the sample contains 70% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 20% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
('Historic' black, E of Merchants Lough)

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

Sample code: LHF6 / CJM509

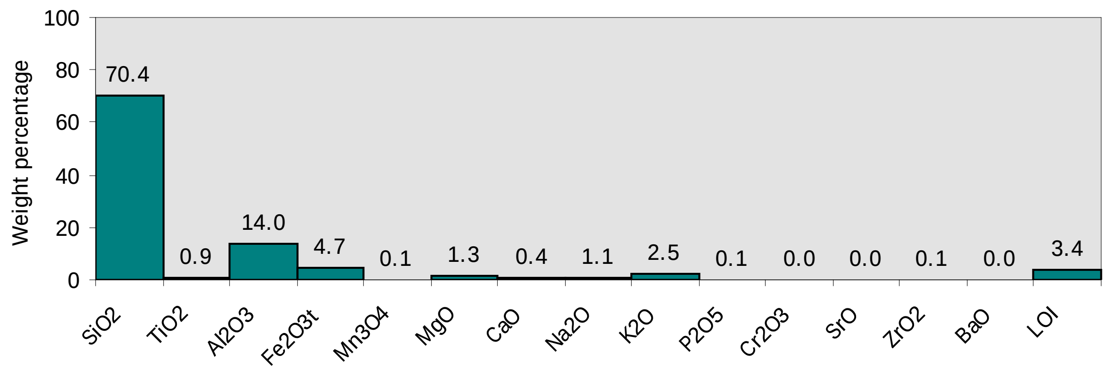
Date: 11/8/98

Mineralogy

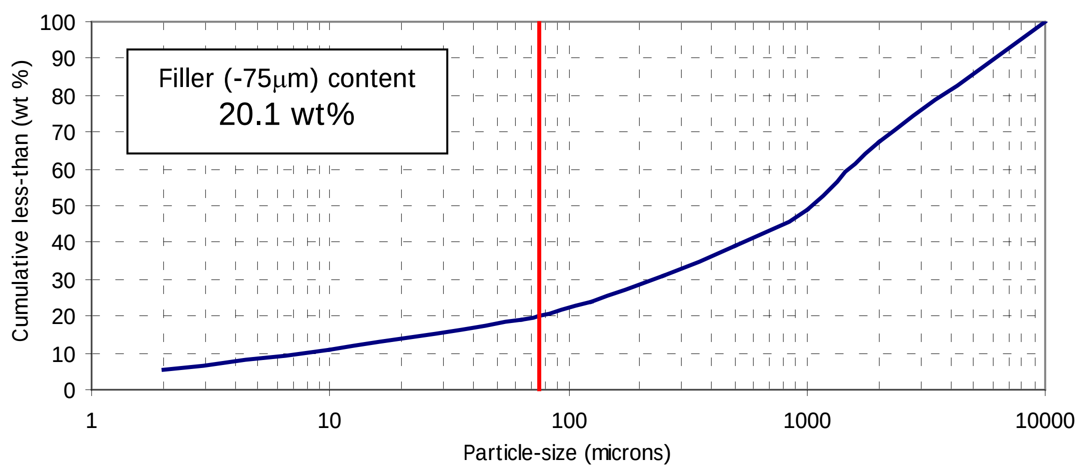
Dominant	Quartz
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during former aggregate production ('historic' plant fines). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- &K-) feldspar and mica. Chemical analysis determined that the sample contains 70% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 20% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines ('Historic' green, E of Merchants Lough)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHF7 / CJM510

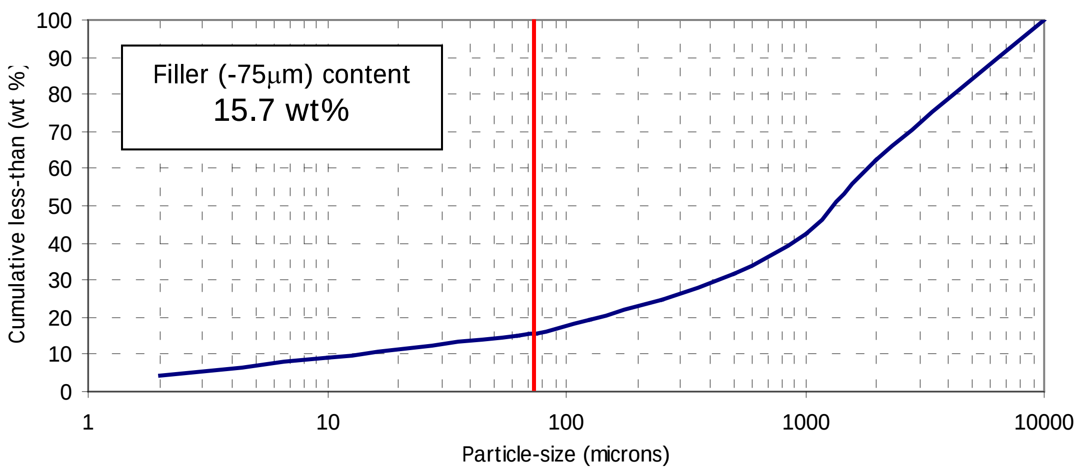
Date: 11/8/98

Mineralogy

Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines produced during former aggregate production ('historic' plant fines). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, mica and chlorite, and trace amounts of calcite. The sample has a low filler content, 16% <75 µm.

LEAHILL QUARRY **(Tarmac Fleming (Quarries) Limited)**

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines (Black + green, E of Merchants Lough)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHF8 / CJM511

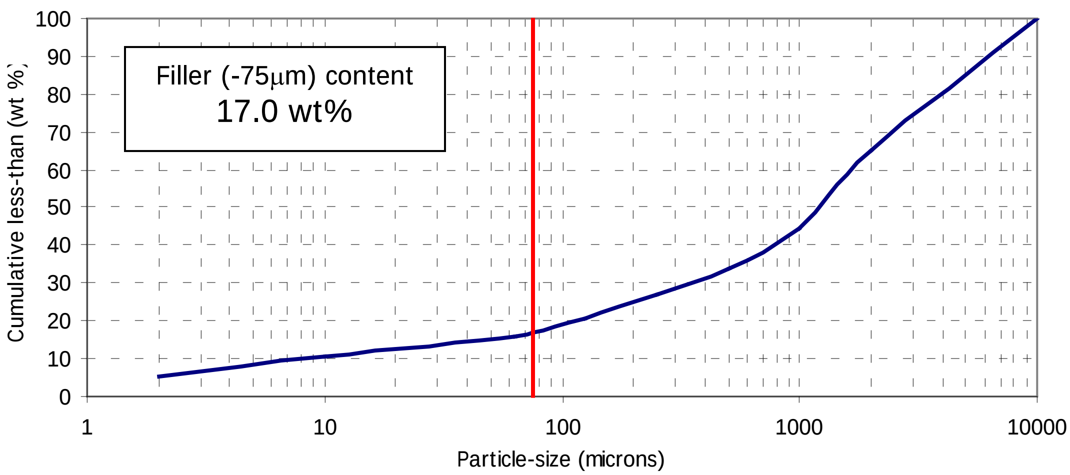
Date: 11/8/98

Mineralogy

Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines produced during former aggregate production ('historic' plant fines). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- &K-) feldspar and mica. The sample has a low filler content, 17% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines ('Historic' green, far E of site)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHF9 / CJM512

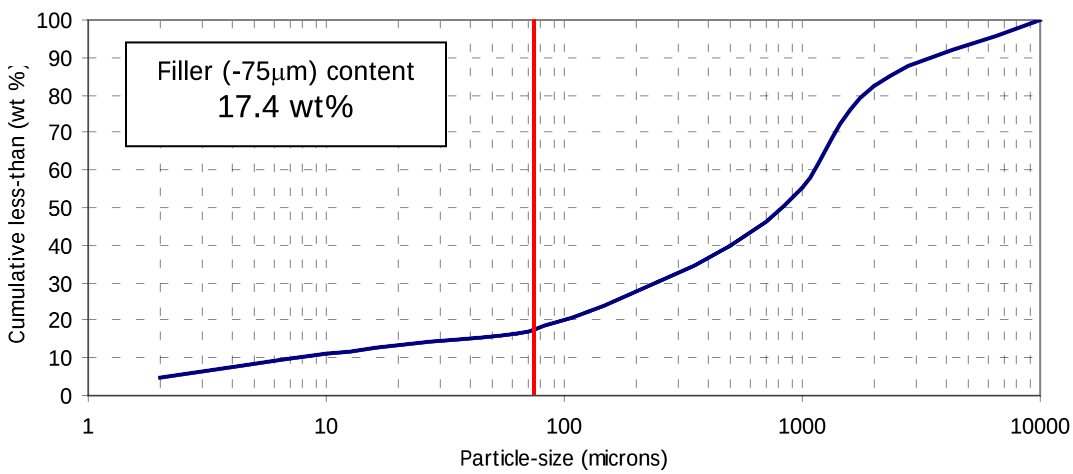
Date: 11/8/98

Mineralogy

Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines produced during former aggregate production ('historic' plant fines). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, mica and chlorite, and trace amounts of calcite. The sample has a low filler content, 17% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
('Historic' black, N of site office)

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

Sample code: LHF10 / CJM513

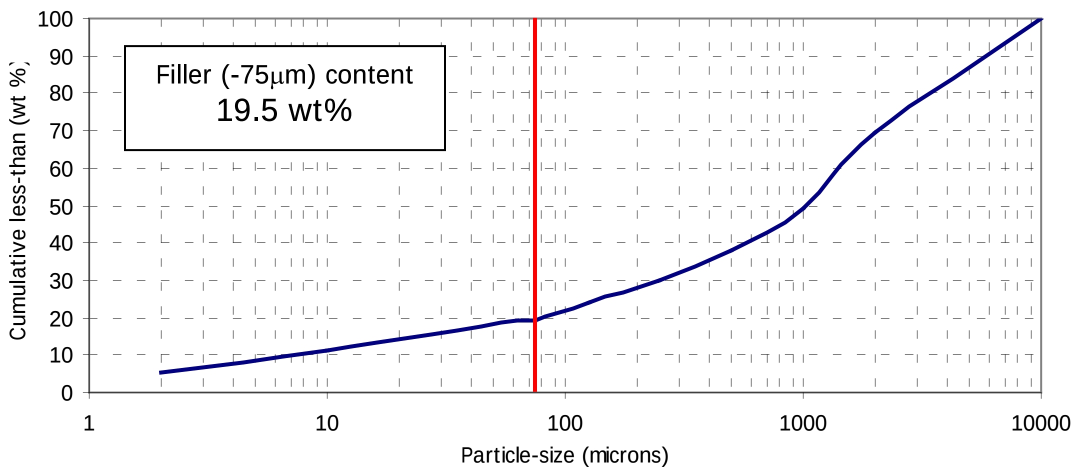
Date: 11/8/98

Mineralogy

Dominant	Quartz.
Major	Chlorite.
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines produced during former aggregate production ('historic' plant fines). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- &K-) feldspar and mica. The sample has a low filler content, 20% <75 μm.

REFILL characterisation factsheets:

Leahill Quarry waste: Plant fines

(current production)

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
(Current production from new plant)

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

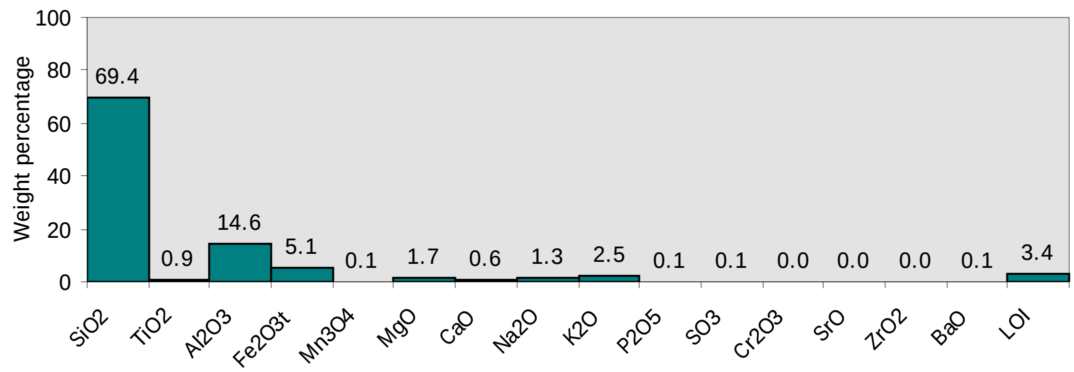
Sample code: LHF11 / CJM514 **Date:** 12/11/98

Mineralogy

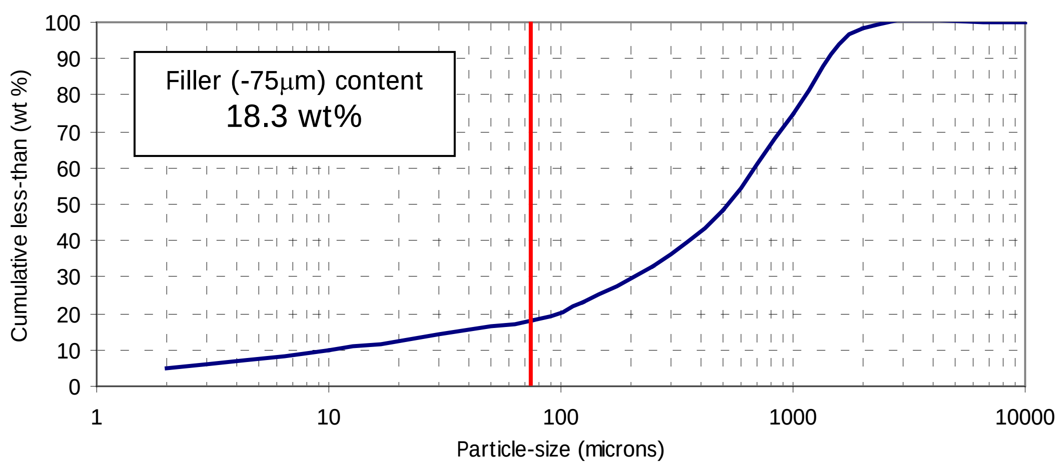
Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar and chlorite.
Trace	?Calcite and ?rutile.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during current aggregate production. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, mica and chlorite, and trace amounts of calcite and rutile. Chemical analysis determined that the sample contains 69% SiO_2, 15% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 18% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
(Current production from new plant)

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

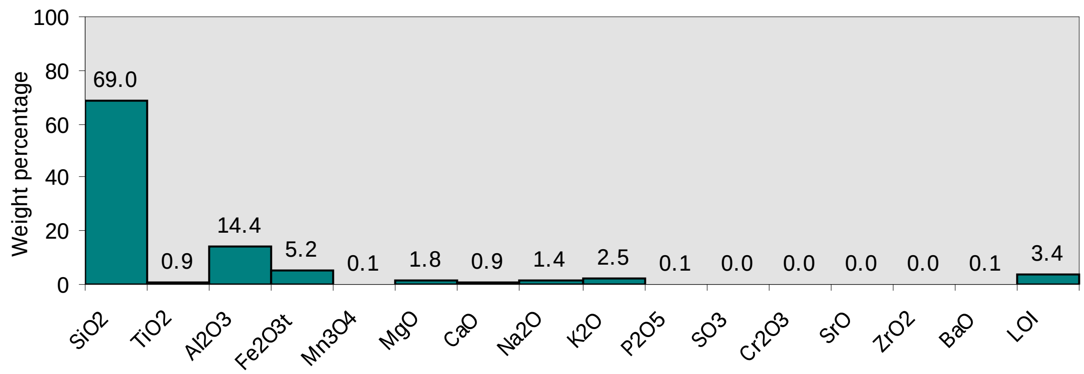
Sample code: LHF13 / CJM516 **Date:** 12/11/98

Mineralogy

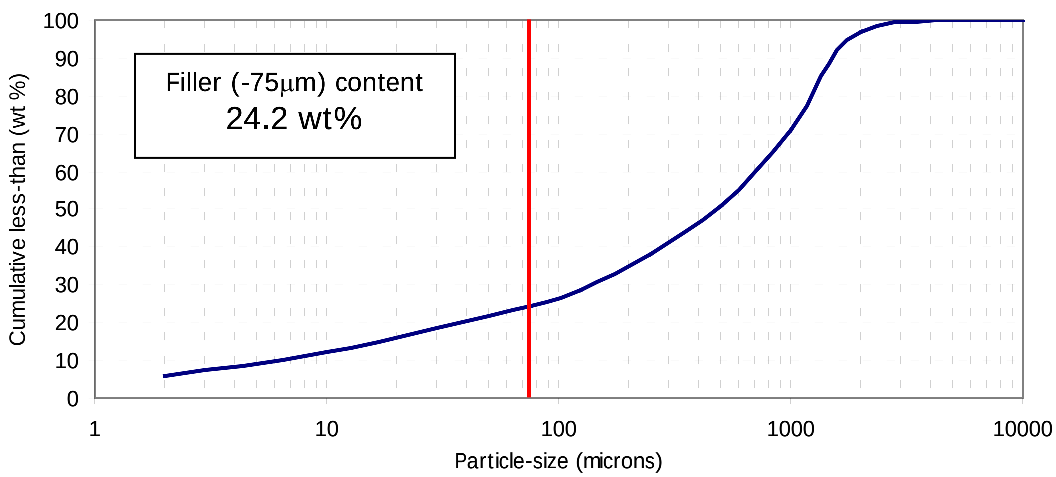
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar and chlorite.
Trace	Mica, calcite and ?rutile.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during current aggregate production. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar and chlorite, and trace amounts of mica, calcite and rutile. Chemical analysis determined that the sample contains 69% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 24% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
(Current production from new plant)

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

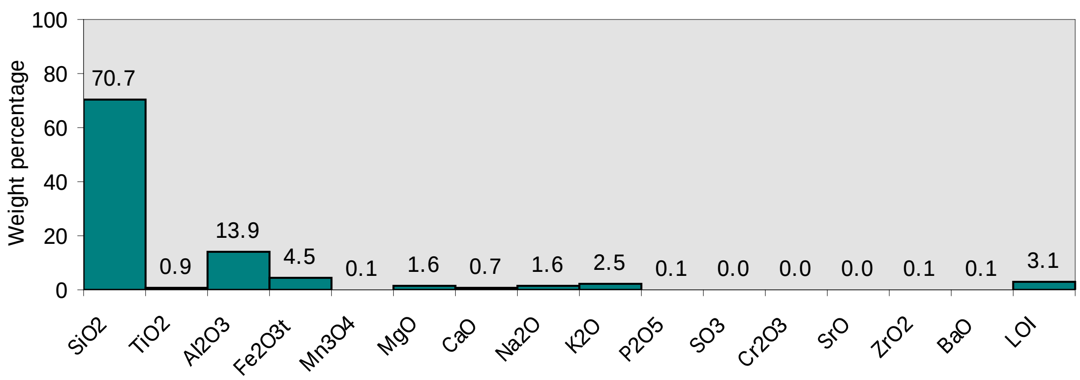
Sample code: LHF15 / CJM518 **Date:** 12/11/98

Mineralogy

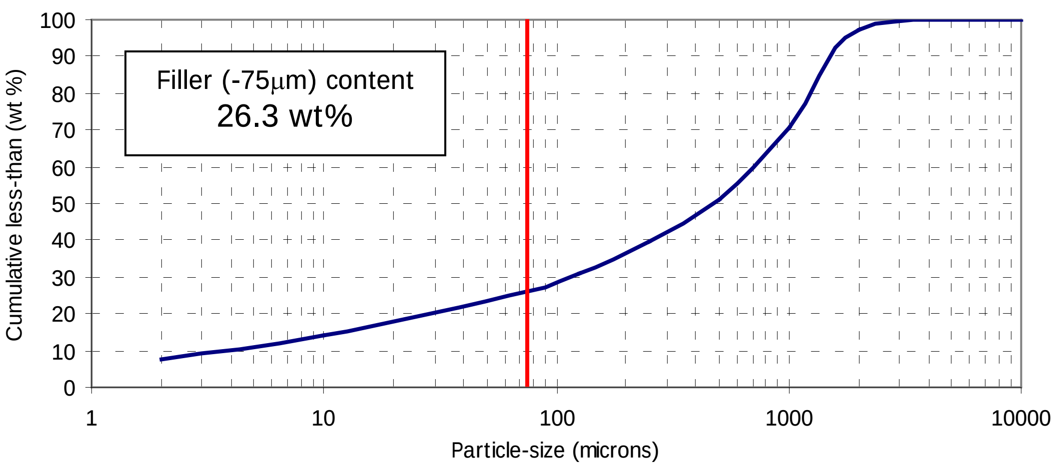
Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar.
Trace	Mica, chlorite, ?rutile and ?calcite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during current aggregate production. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, and trace amounts of mica, chlorite, rutile and calcite. Chemical analysis determined that the sample contains 70% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a moderately low filler content, 26% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
(Current production from new plant)

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

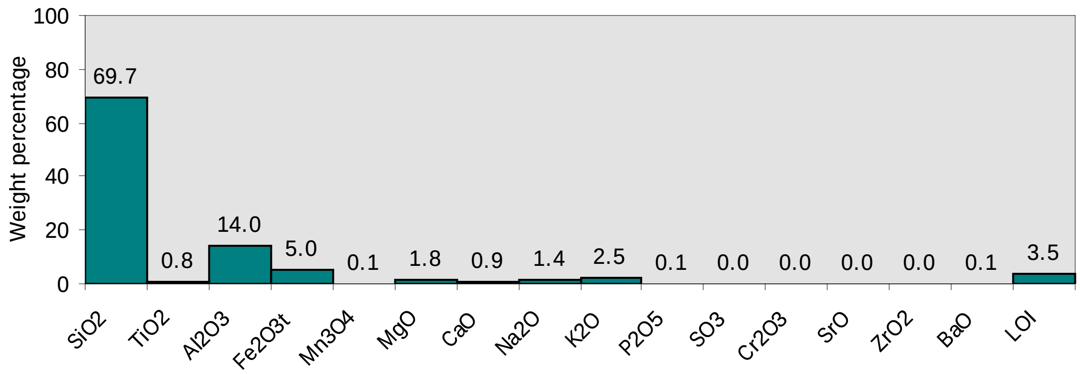
Sample code: LHF17 / CJM520 **Date:** 12/11/98

Mineralogy

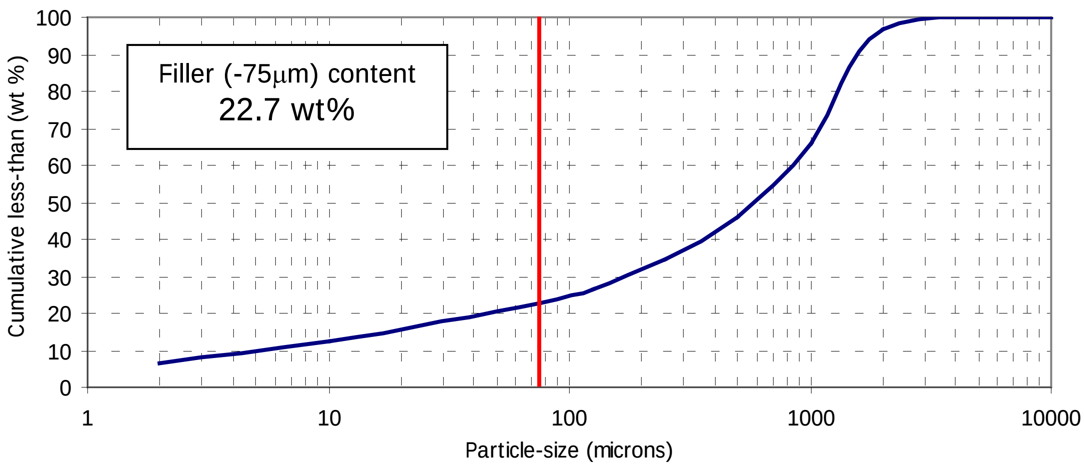
Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar.
Trace	Mica, chlorite and ?rutile.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during current aggregate production. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, and trace amounts of mica, chlorite and rutile. Chemical analysis determined that the sample contains 70% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 23% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines
(Current production from new plant)

Rock type: Medium siltstone – fine sandstone
(Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1
(Draft European Standard)

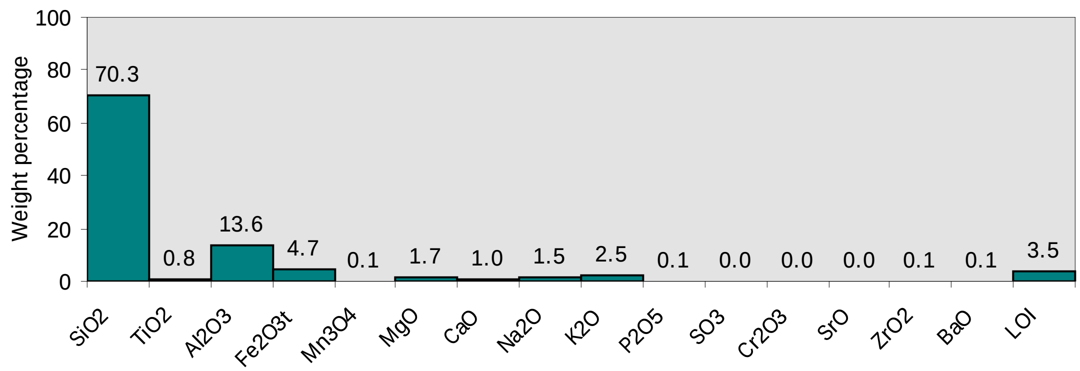
Sample code: LHF19 / CJM522 **Date:** 12/11/98

Mineralogy

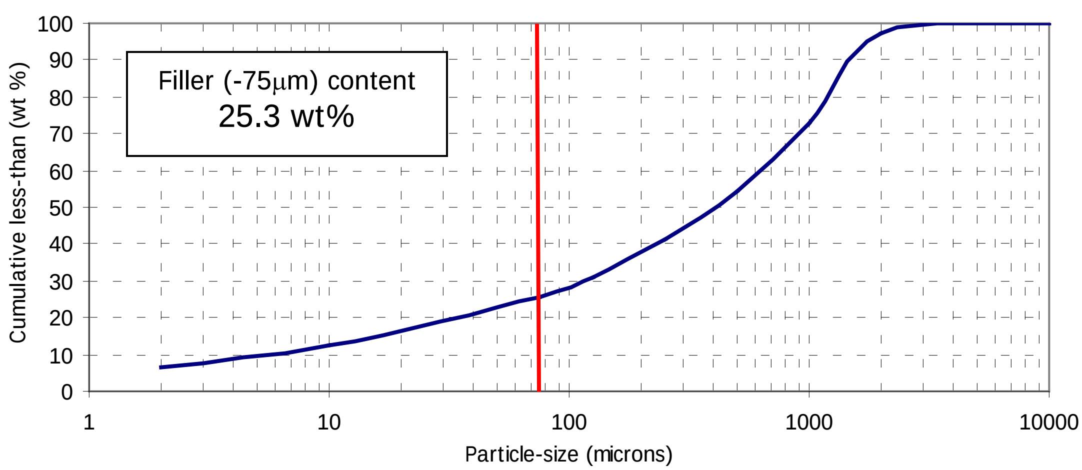
Dominant	Quartz.
Major	
Minor	Alkali (Na- & K-) feldspar.
Trace	Mica and chlorite.

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines produced during current aggregate production. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- &K-) feldspar, and trace amounts of mica and chlorite. Chemical analysis determined that the sample contains 70% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), <1% TiO_2 and 5% Fe_2O_3. The sample has a moderately low filler content, 25% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Plant fines

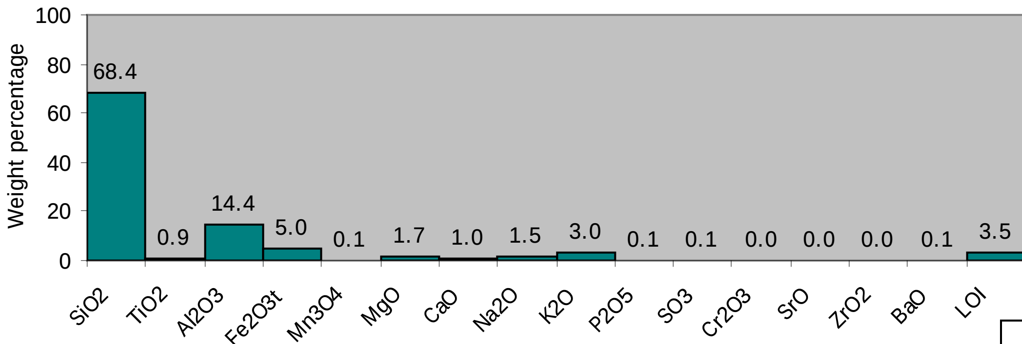
Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: unknown (Concrete testing sample)

Sample code: LHF52 / G160 **Date:** unknown (Tarmac reference 2/0: submitted December 2000)

Mineralogy

Dominant	Quartz.
Major	
Minor	Na-feldspar, chlorite, mica and ?calcite.
Trace	



Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

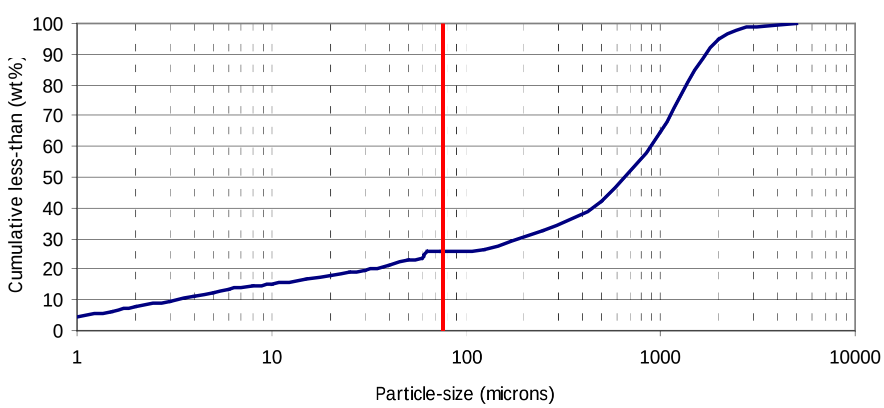
Chemistry

Filler (-75µm) content
26.0 wt%

Summary of data

This sample represents the fines produced during current aggregate production (as used in concrete testing by Tarmac). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of Na-feldspar, chlorite, mica and ? calcite. Chemical analysis determined that the sample contains 68% SiO_2, 14% Al_2O_3, 5% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 26% <75 µm.

Particle-size distribution



REFILL characterisation factsheets:

Leahill Quarry waste: Filler fines

(Fluidised bed product)

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

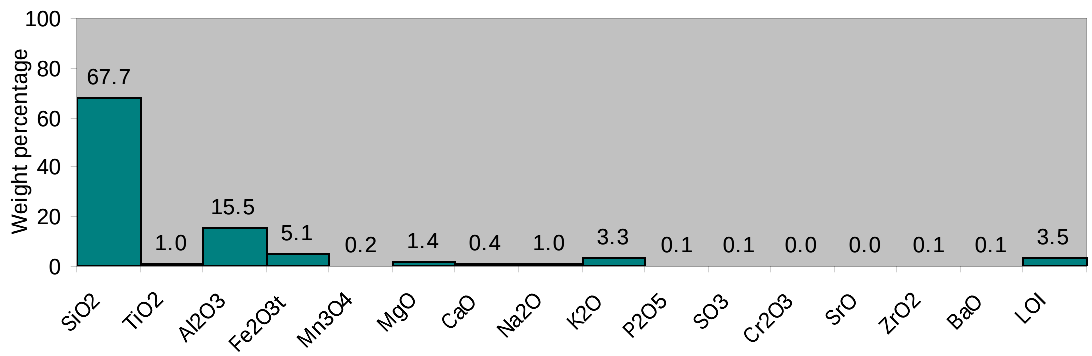
Sample code: LHF31 / E724 **Date:** 4/2/99

Mineralogy

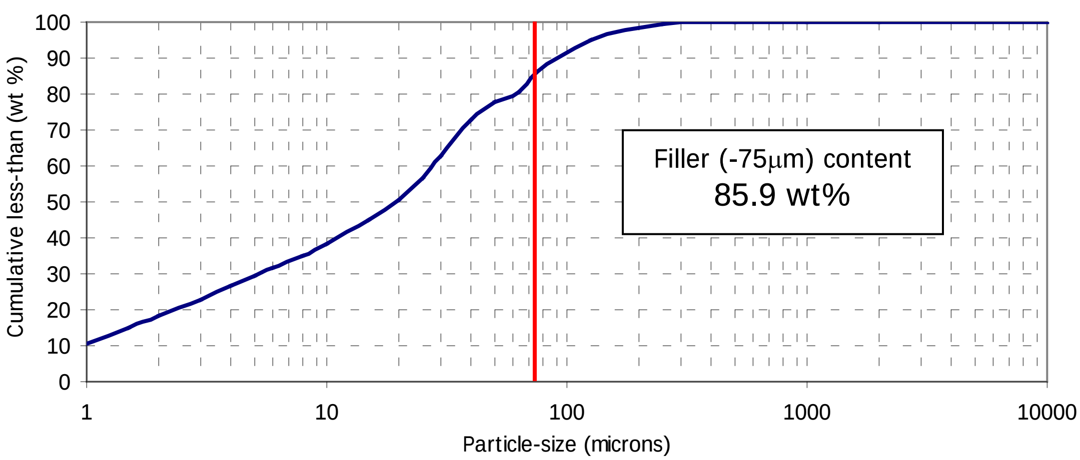
Dominant	Quartz
Major	Chlorite
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 86% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- & K-) feldspar and mica and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

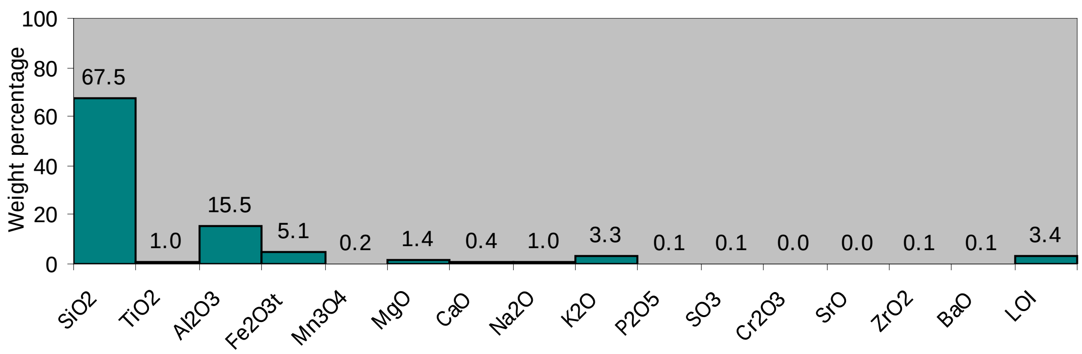
Sample code: LHF32 / E725 **Date:** 11/2/99

Mineralogy

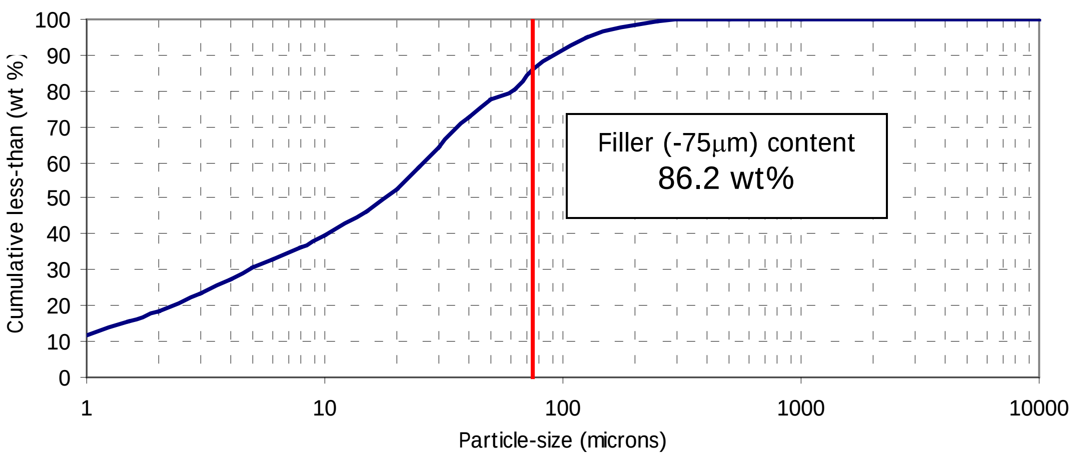
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 86% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 16% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

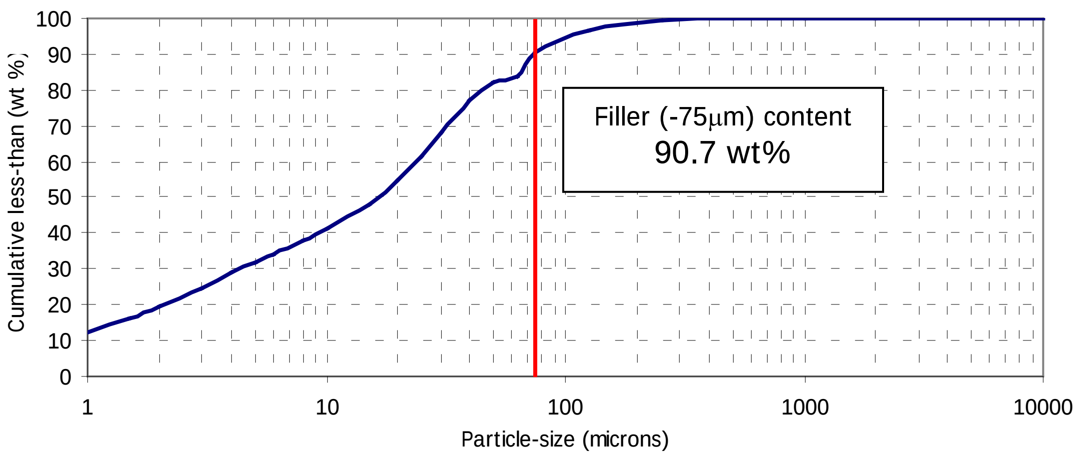
Sample code: LHF33 / E726 **Date:** 16/2/99

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 91% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

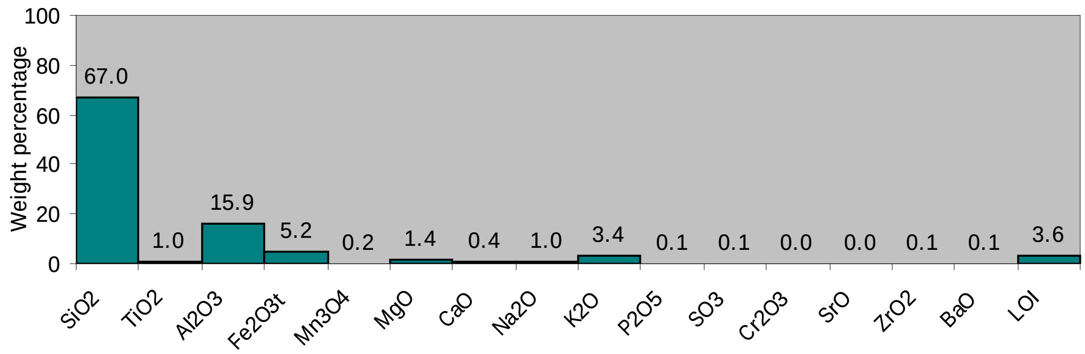
Sample code: LHF34 / E727 **Date:** 18/2/99

Mineralogy

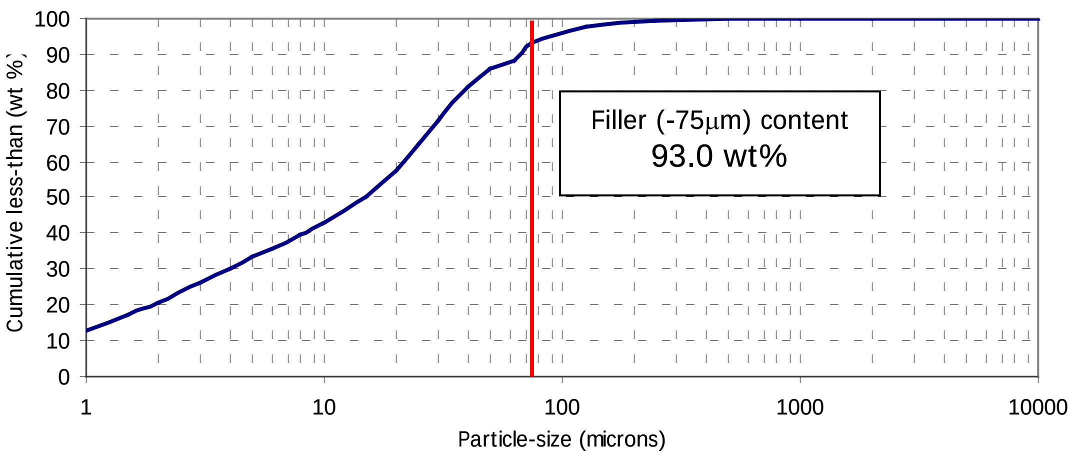
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 93% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 67% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

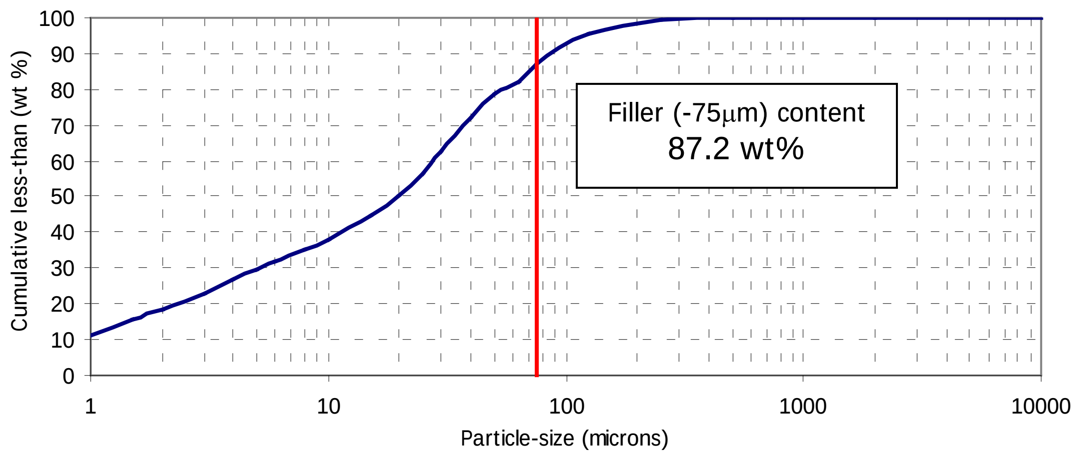
Sample code: LHF35 / E728 **Date:** 24/2/99

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 87% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

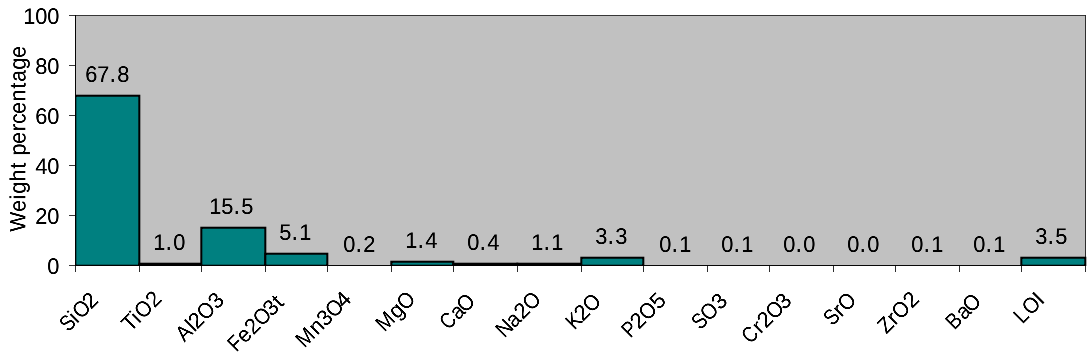
Sample code: LHF36 / E729 **Date:** 26/2/99

Mineralogy

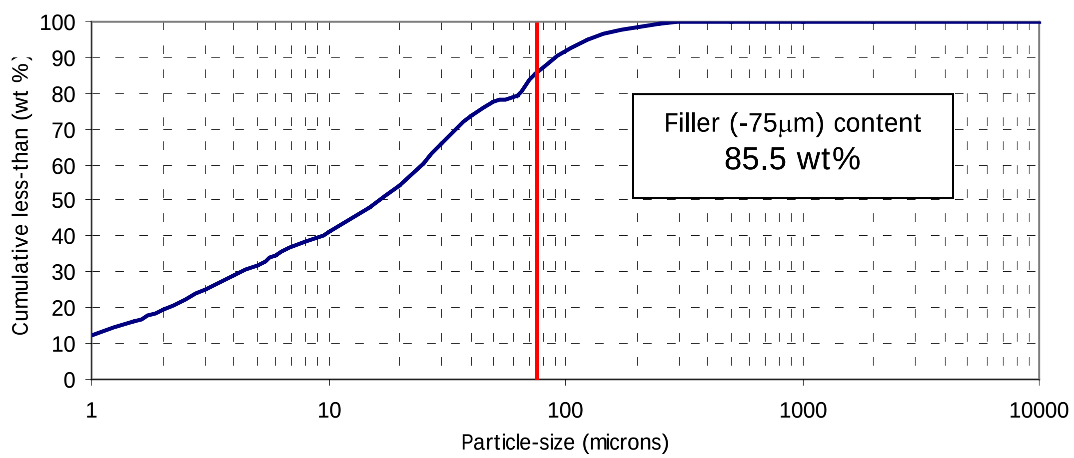
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 86% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 16% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

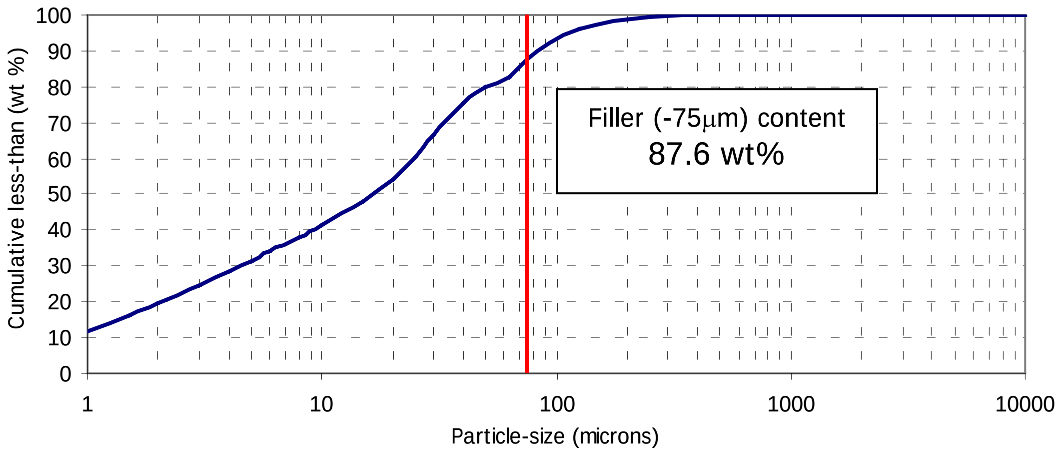
Sample code: LHF37 / E730 **Date:** 27/2/99

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 88% <75 μm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

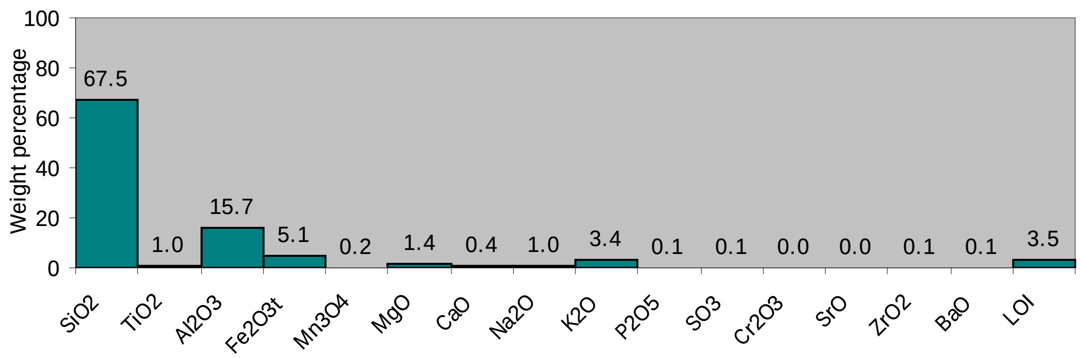
Sample code: LHF38 / E731 **Date:** 3/3/99

Mineralogy

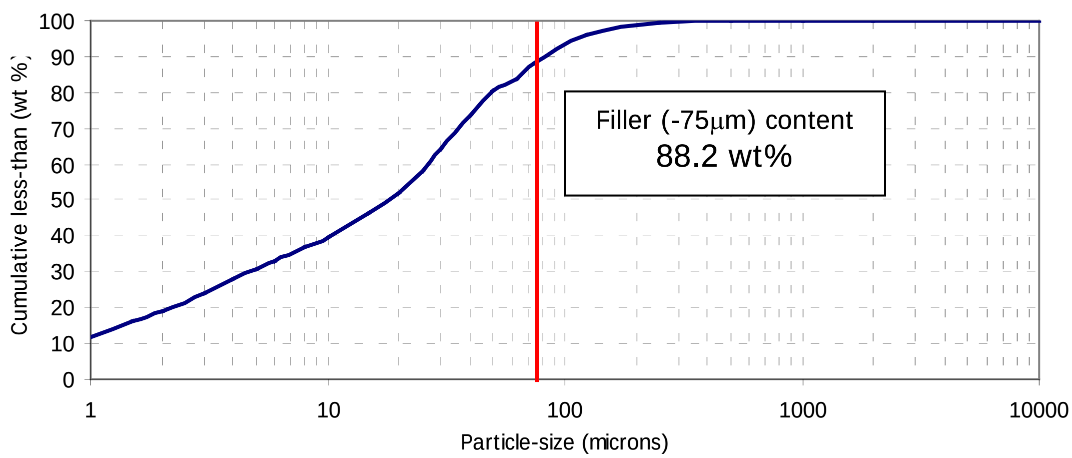
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 88% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

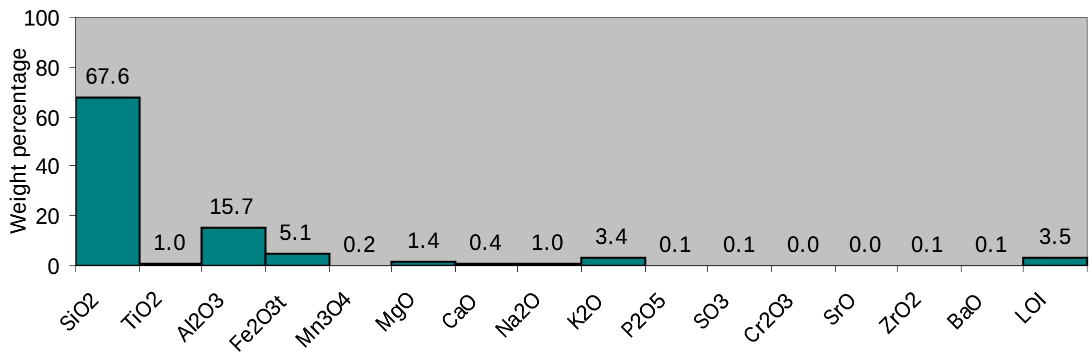
Sample code: LHF39 / E732 **Date:** 12/3/99

Mineralogy

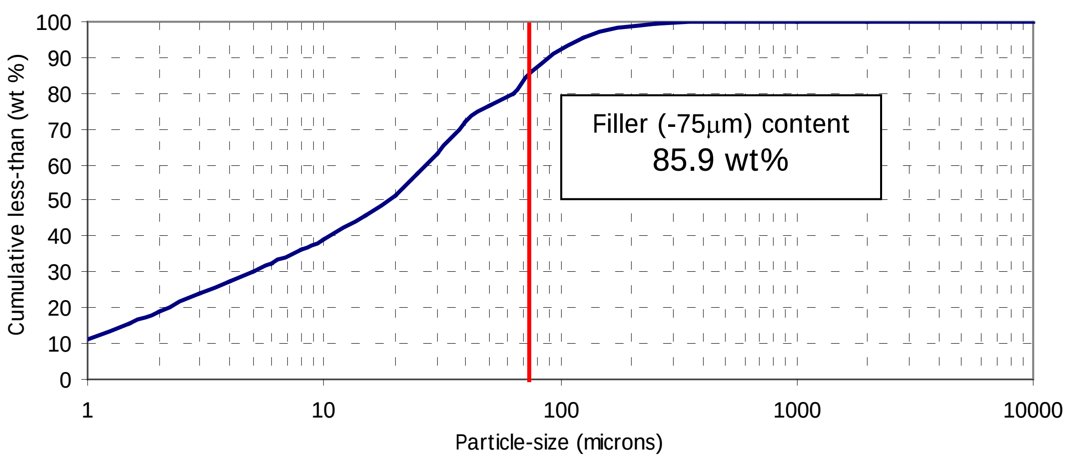
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 86% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

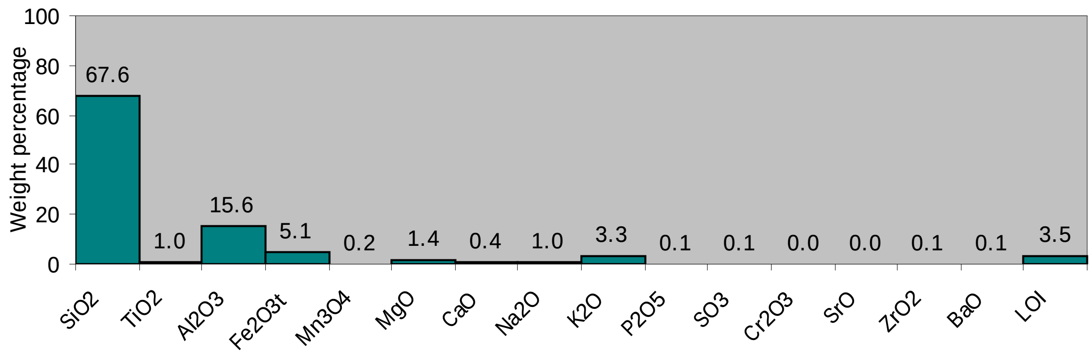
Sample code: LHF40 / E733 **Date:** 15/3/99

Mineralogy

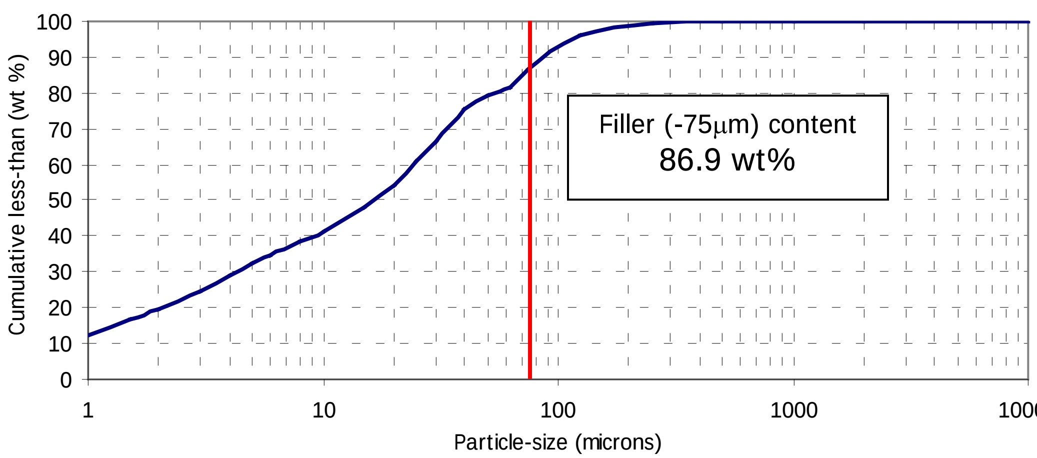
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 87% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

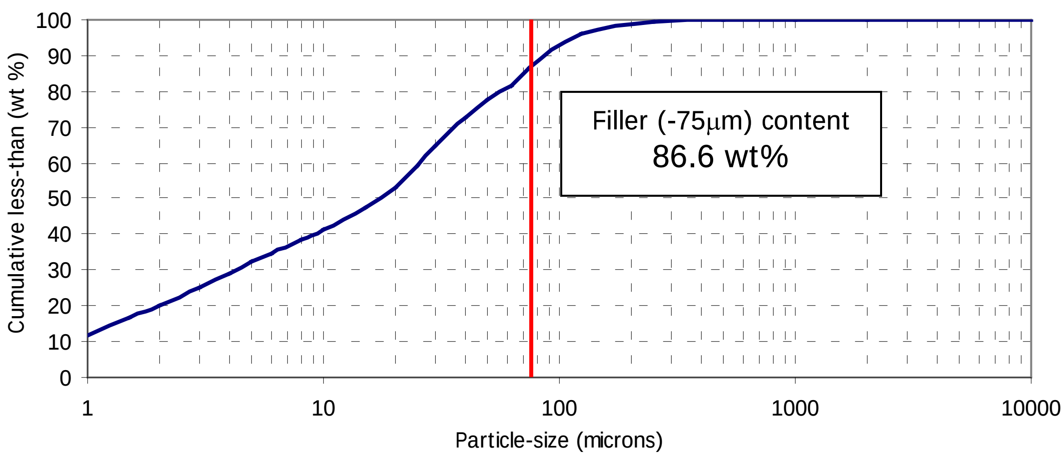
Sample code: LHF41 / E734 **Date:** 23/3/99

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 87% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains % SiO_2, % Al_2O_3, % alkalis (Na_2O & K_2O), % TiO_2 and % Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

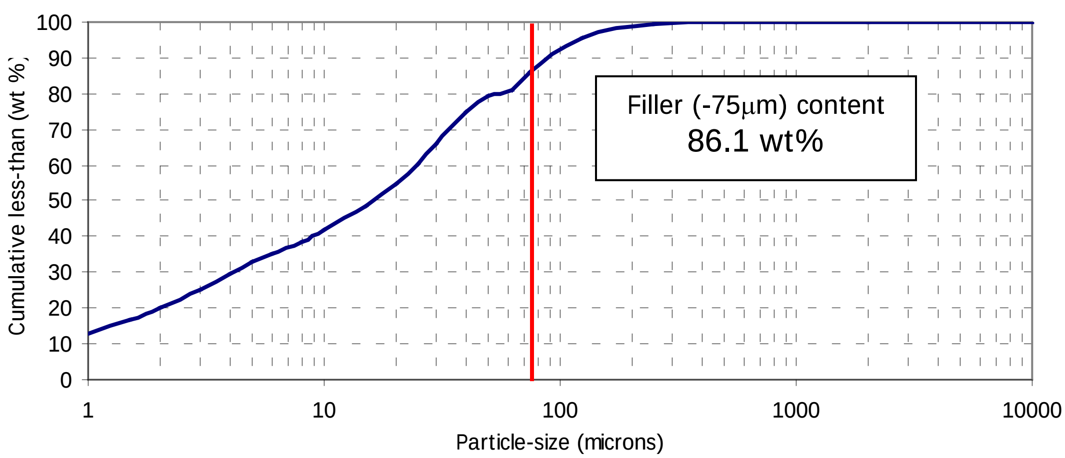
Sample code: LHF42 / E735 **Date:** 24/3/99

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 86% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains % SiO_2, % Al_2O_3, % alkalis (Na_2O & K_2O), % TiO_2 and % Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

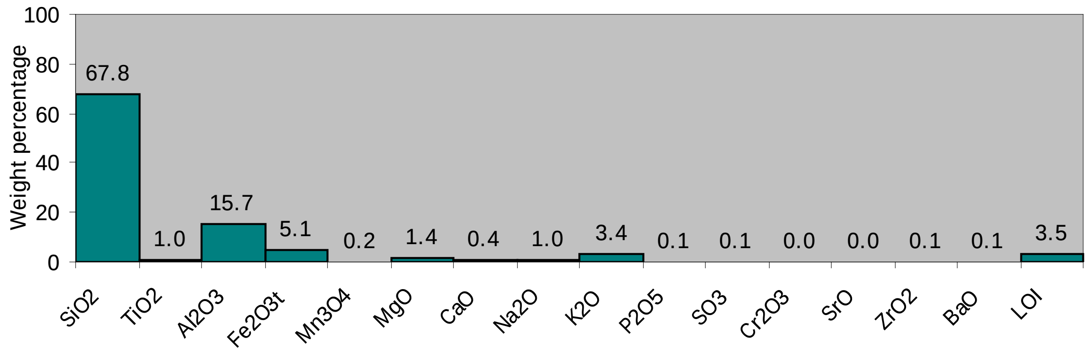
Sample code: LHF43 / E736 **Date:** 26/3/99

Mineralogy

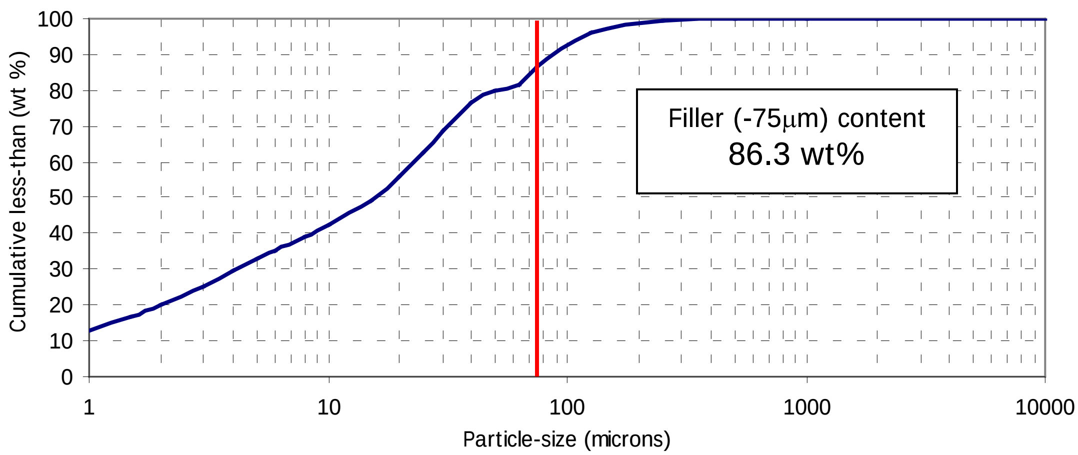
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 86% <75 μm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

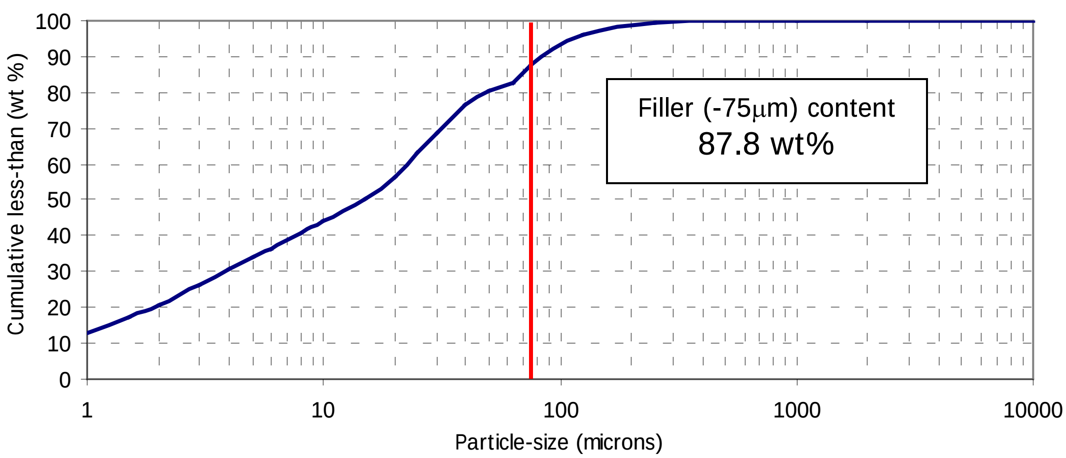
Sample code: LHF44 / E737 **Date:** 29/3/99

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 88% <75 μm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

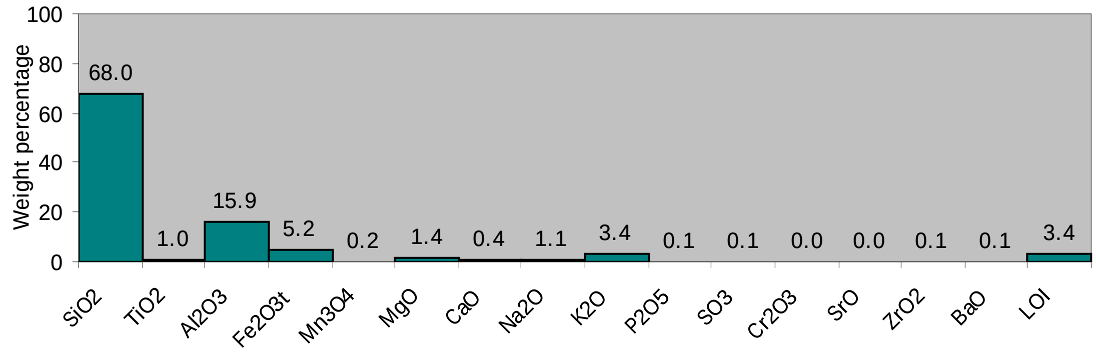
Sample code: LHF45 / E738 **Date:** 30/3/99

Mineralogy

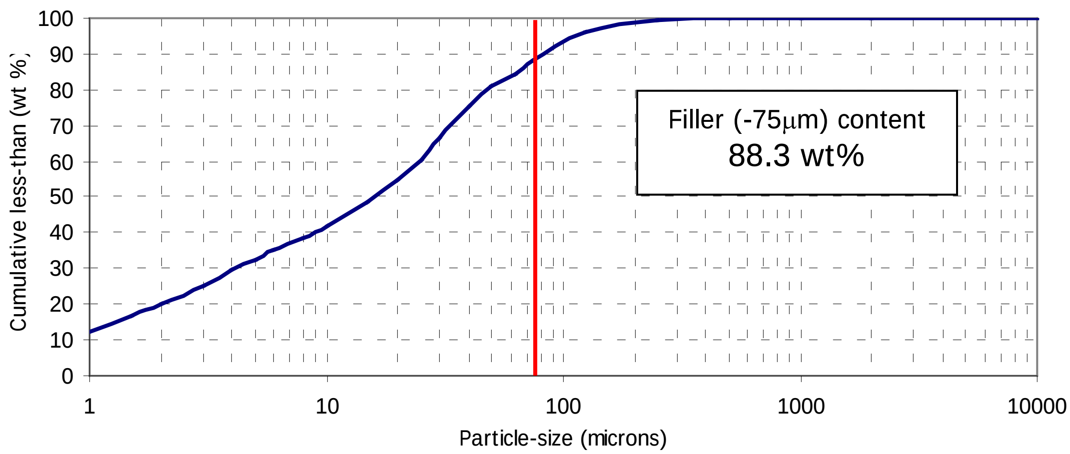
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 88% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

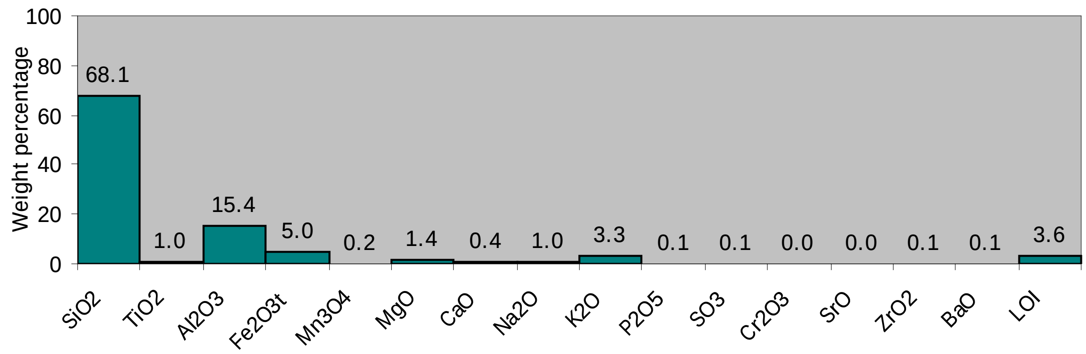
Sample code: LHF46 / E739 **Date:** 13/4/99

Mineralogy

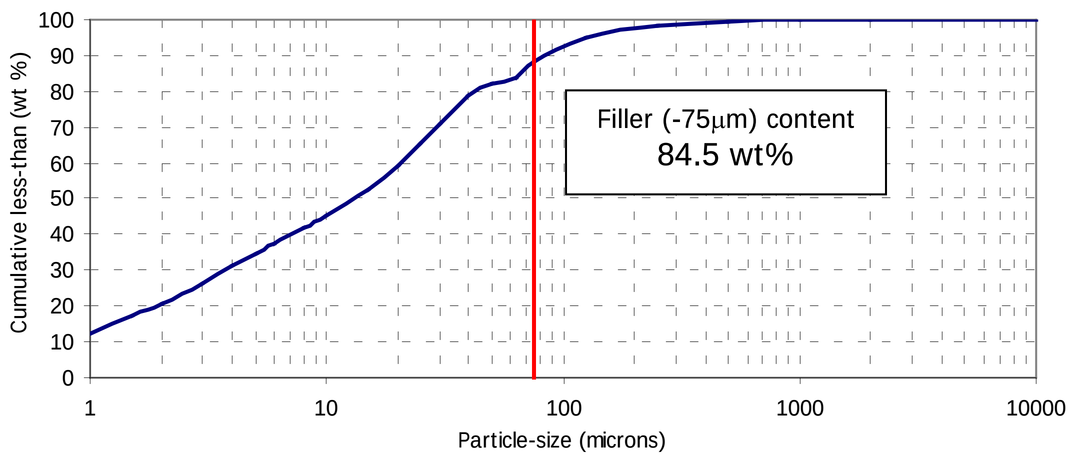
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 85% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 15% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY **(Tarmac Fleming (Quarries) Ltd)**

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (conditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

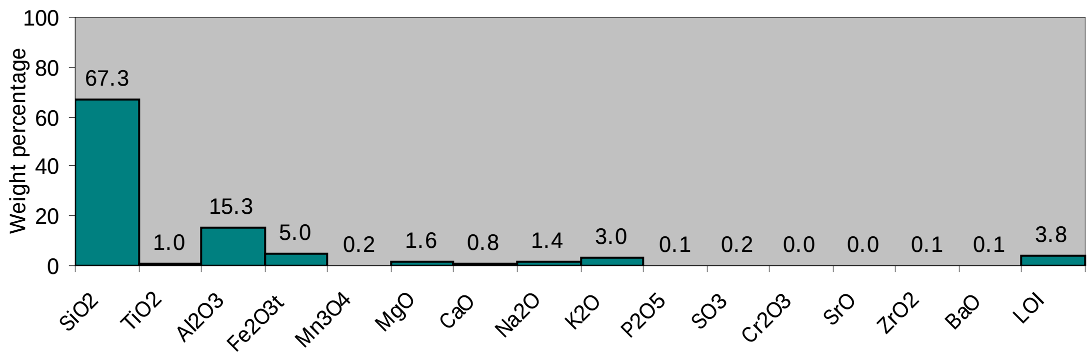
Sample code: LHF47 / E740 **Date:** 26/2/99

Mineralogy

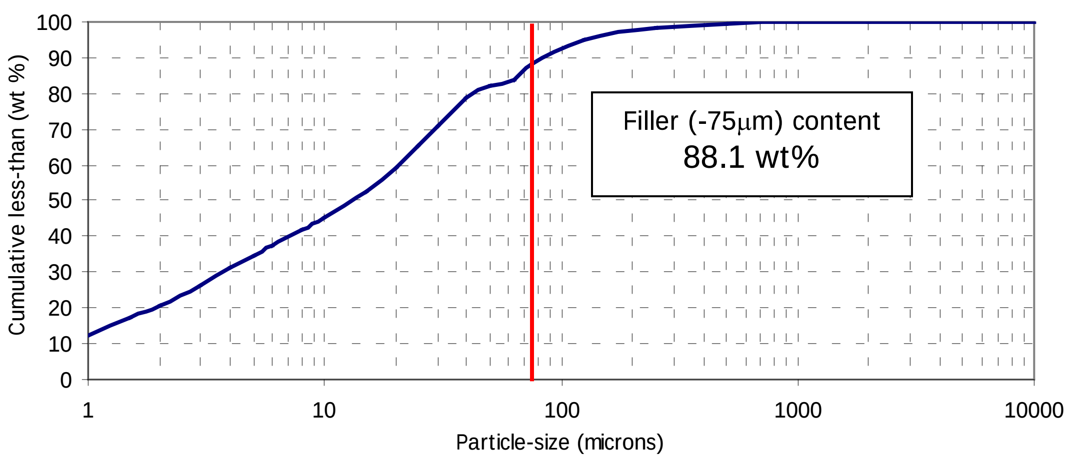
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 88% <75 μm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 67% SiO_2, 15% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (conditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

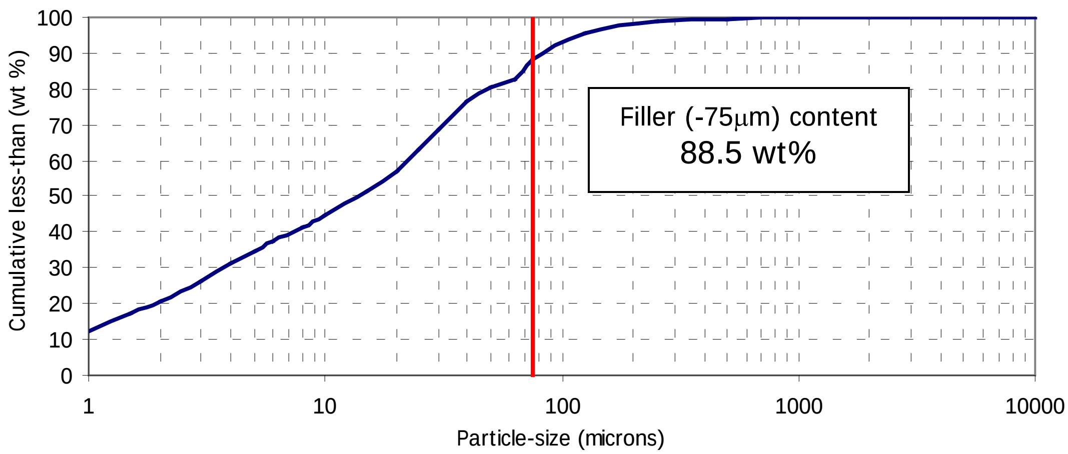
Sample code: LHF48 / E741 **Date:** 5/3/99

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 89% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (conditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

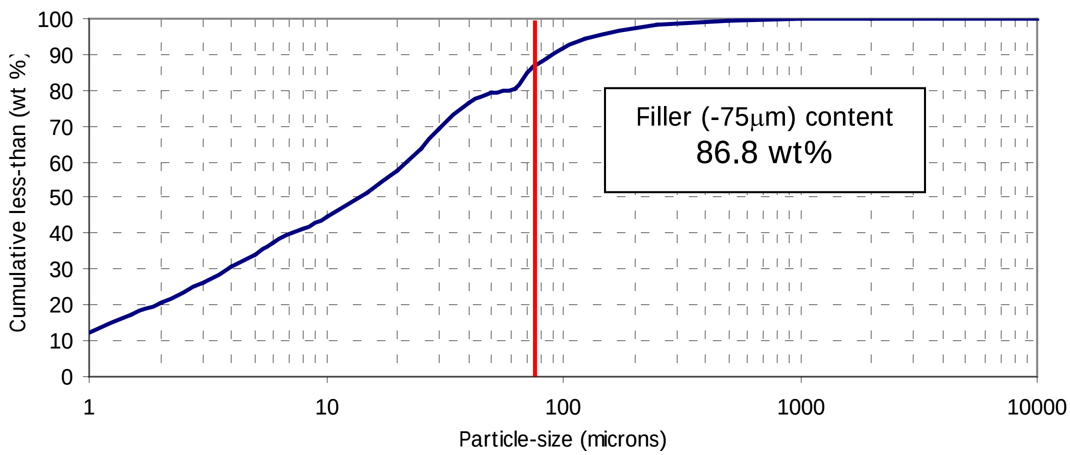
Sample code: LHF49 / E742 **Date:** 19/3/99

Mineralogy

Dominant	Quartz
Major	Chlorite
Minor	Alkali (Na- & K-) feldspar and mica.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 87% <75 µm. Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- & K-) feldspar and mica and trace amounts of calcite and anatase.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (conditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

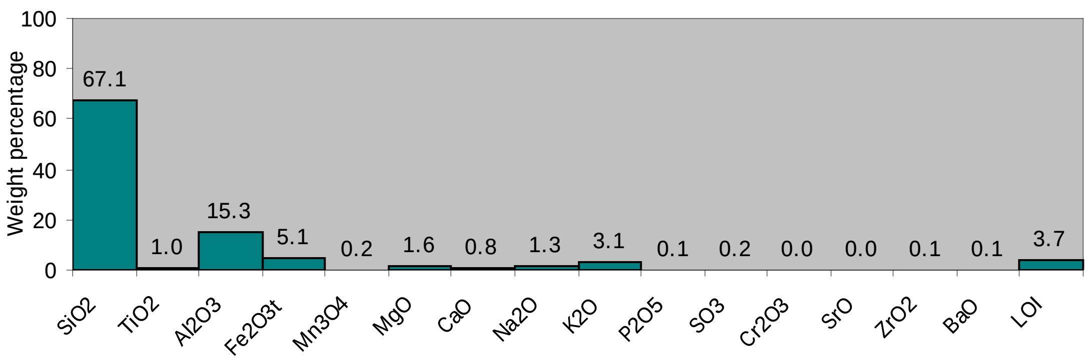
Sample code: LHF50 / E743 **Date:** 26/3/99

Mineralogy

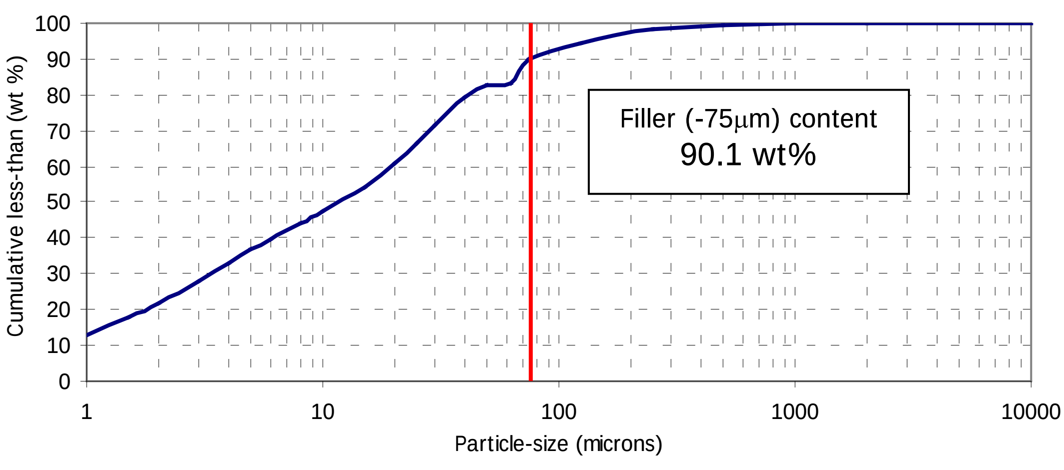
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite.
Trace	Calcite and anatase (TiO_2).

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 90% <75 μm. Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 67% SiO_2, 15% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Ltd)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Fluidised bed fines (unconditioned filler)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHF51 / F740 **Date:** 2000
NB Sample taken for asphalt testing

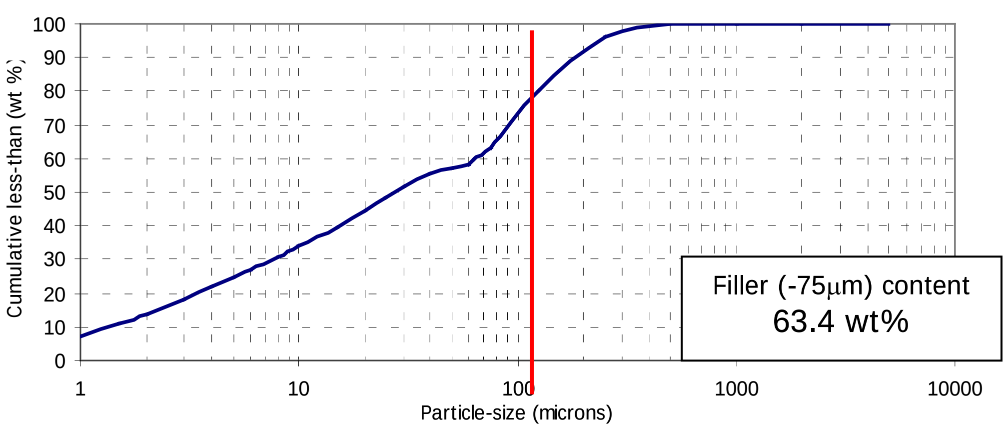
Mineralogy

Dominant	Quartz
Major	Chlorite
Minor	Alkali (Na- & K-) feldspar and mica
Trace	
Clay Mineralogy	Chlorite (iron-rich var.) & illite (muscovite var.)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry

Particle-size distribution



Summary of data

This sample is taken from the fluidised bed plant at Leahill Quarry. It has a high filler content, 63% <75 µm. Mineralogical analysis (by X-ray diffraction) indicated that it is composed of dominant quartz, major amounts of chlorite and minor amounts of alkali (Na- & K-) feldspar and mica. The clay fraction (<2 µm) is composed of chlorite (iron-rich variety) and illite (muscovite mica variety). Chemical analysis determined that the sample contains 64% SiO_2, 17% Al_2O_3, 3% alkali earths (MgO & CaO), 5% alkalis (Na_2O & K_2O), 1% TiO_2 and 6% Fe_2O_3.

REFILL characterisation factsheets:

Leahill Quarry raw material:

Borehole core (fines from aggregate testing by Tarmac)

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC1 / E985 **Date:** 8/7/99

Borehole: LH1A **Depth:** 0 – 40.88 m

Summary of borehole core lithology:

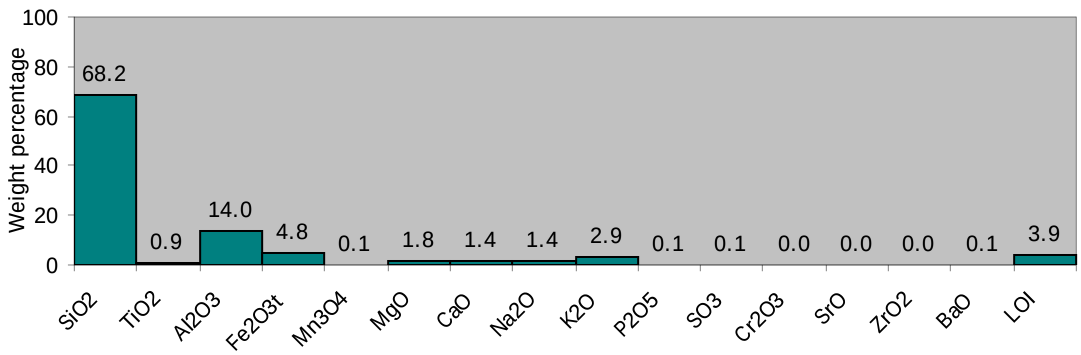
Sandstone	Siltstone	Mudstone
55%	45%	0%

Mineralogy

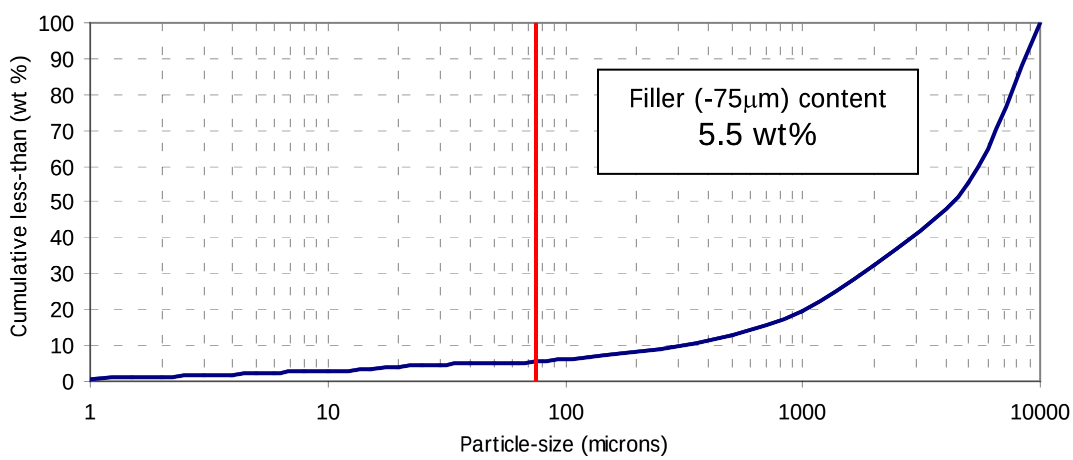
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH1A). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 6% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC2 / E986 **Date:** 8/7/99

Borehole: LH1B **Depth:** 40.88 – 85.70 m

Summary of borehole core lithology:

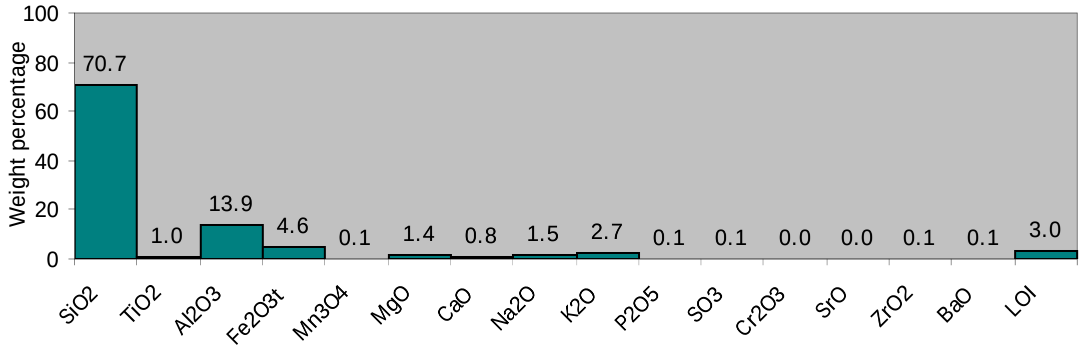
Sandstone	Siltstone	Mudstone
84%	16%	0%

Mineralogy

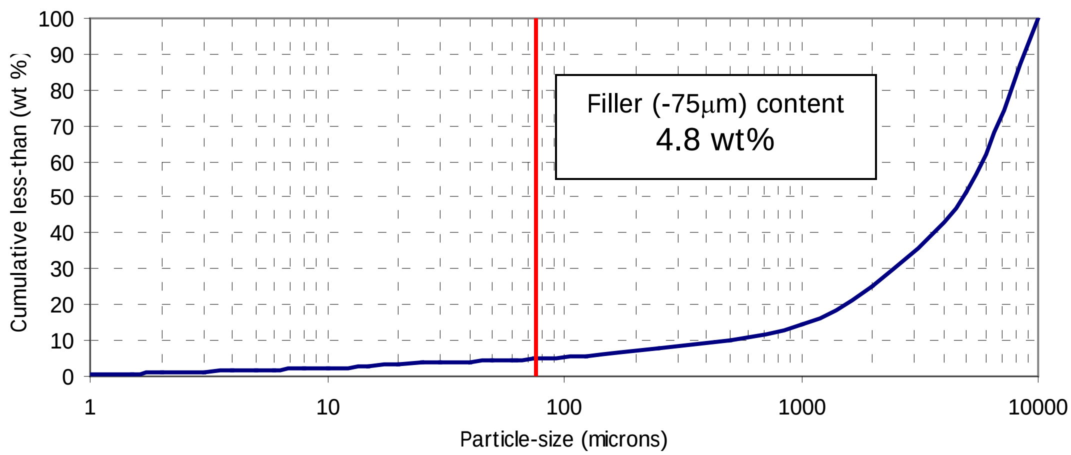
Dominant	Quartz
Major	Na-feldspar
Minor	K-feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH1B). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of Na-feldspar, minor amounts of K-feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 71% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 5% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC3 / E987 **Date:** 8/7/99

Borehole: LH2A **Depth:** 0 – 63.81 m

Summary of borehole core lithology:

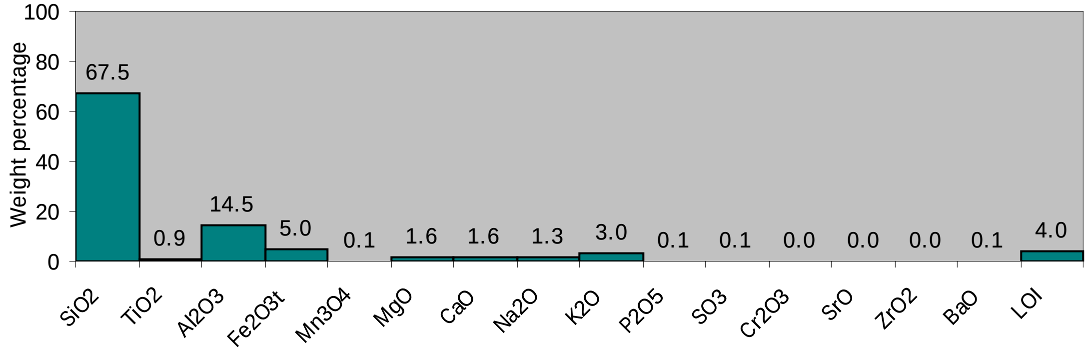
Sandstone	Siltstone	Mudstone
95%	5%	0%

Mineralogy

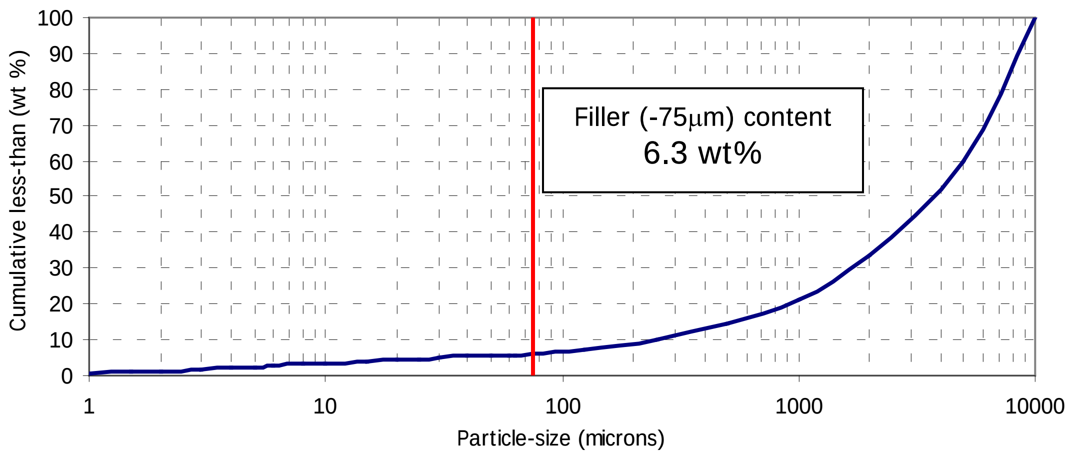
Dominant	Quartz
Major	Chlorite
Minor	Alkali (Na- & K-) feldspar and mica
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH2A). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- & K-) feldspar and mica and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 15% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 6% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC4 / E988 **Date:** 8/7/99

Borehole: LH2B **Depth:** 63.81 – 125.32 m

Summary of borehole core lithology:

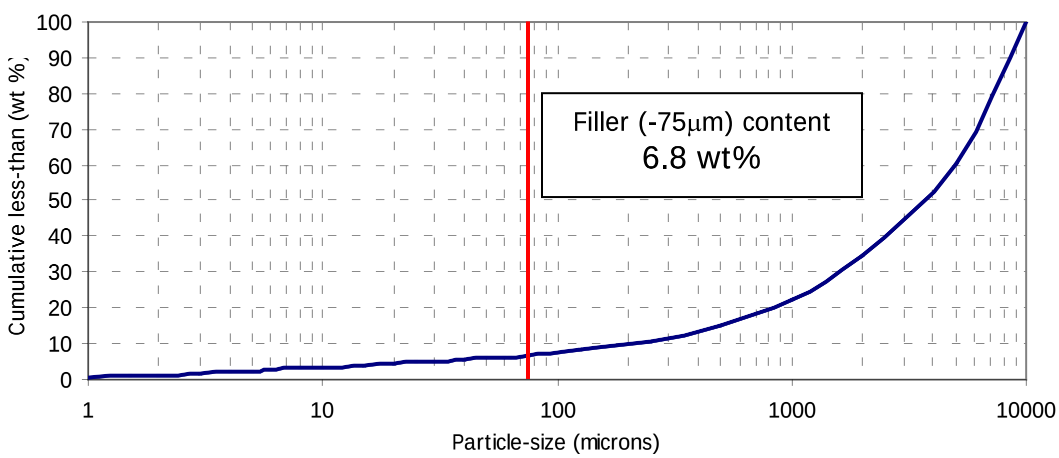
Sandstone	Siltstone	Mudstone
70%	25%	5%

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH2B). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. The sample has a low filler content, 7% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC5 / E989 **Date:** 8/7/99

Borehole: LH3A **Depth:** 0.37 – 58.30 m

Summary of borehole core lithology:

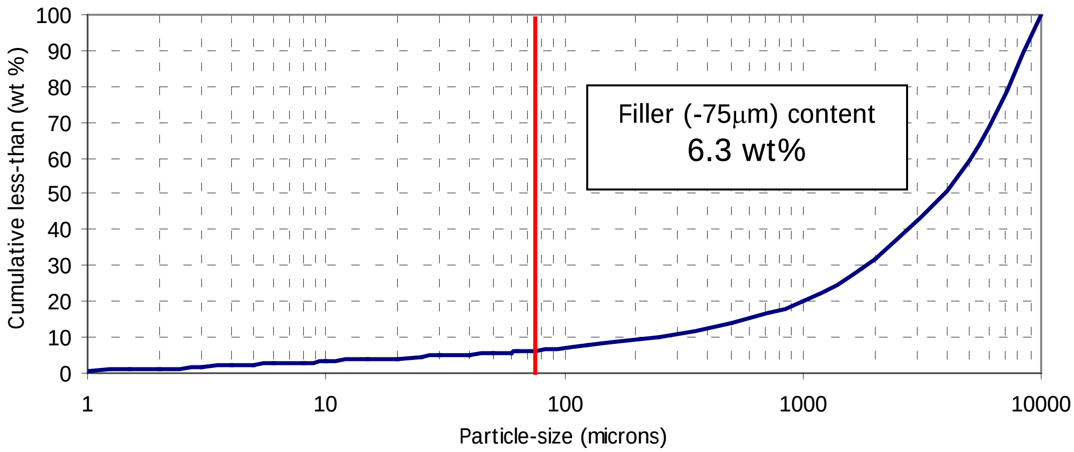
Sandstone	Siltstone	Mudstone
63%	36%	1%

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH3A). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. The sample has a low filler content, 6% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC6 / E990 **Date:** 8/7/99

Borehole: LH3B **Depth:** 58.30 – 123.70 m

Summary of borehole core lithology:

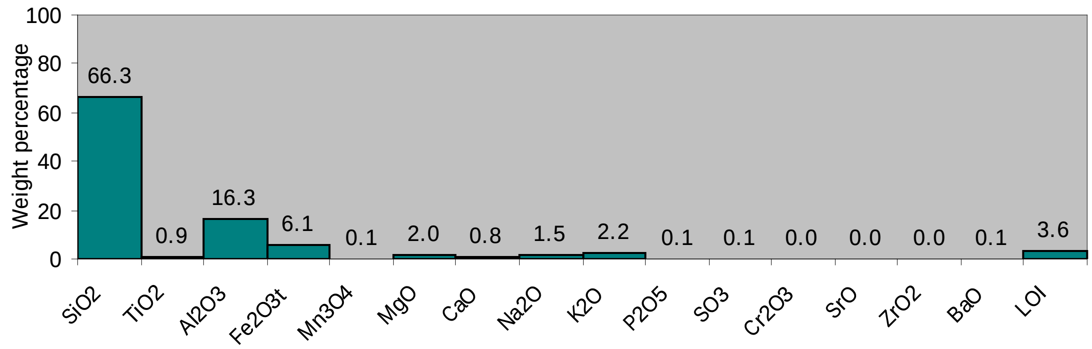
Sandstone	Siltstone	Mudstone
17%	72%	11%

Mineralogy

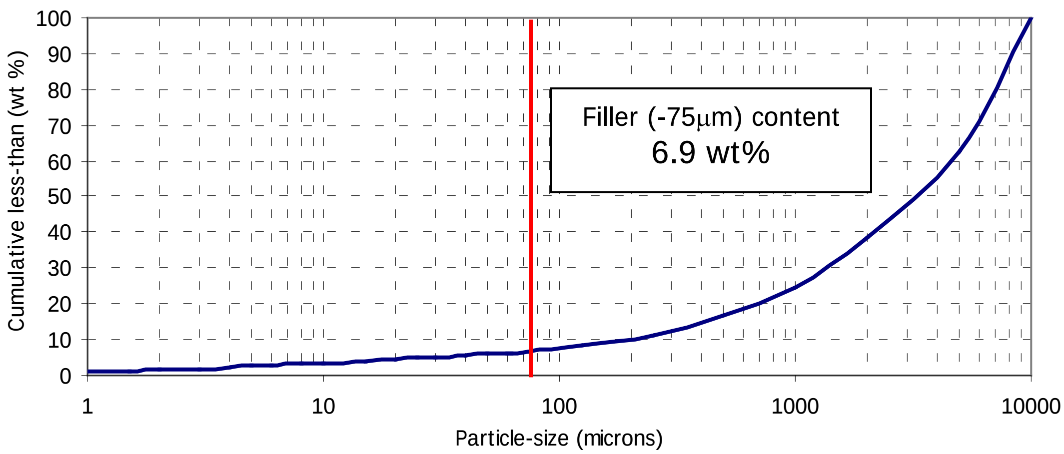
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH3B). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 66% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 6% Fe_2O_3. The sample has a low filler content, 7% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC7 / E991 **Date:** 8/7/99

Borehole: LH3C **Depth:** 123.70 – 149.45 m

Summary of borehole core lithology:

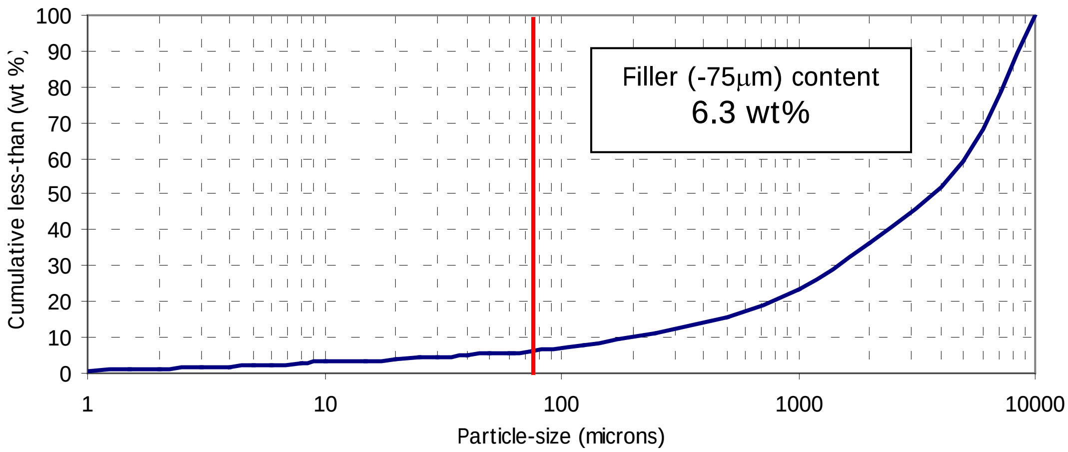
Sandstone	Siltstone	Mudstone
31%	67%	2%

Mineralogy

Dominant	Quartz
Major	Chlorite
Minor	Alkali (Na- & K-) feldspar and mica
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH3C). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- & K-) feldspar and mica and trace amounts of calcite and anatase. The sample has a low filler content, 6% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC8 / E992 **Date:** 8/7/99

Borehole: LH4A **Depth:** 0 – 50.50 m

Summary of borehole core lithology:

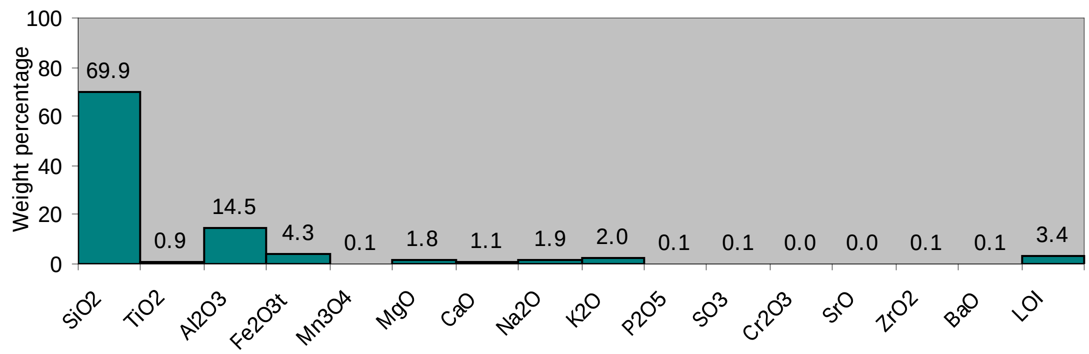
Sandstone	Siltstone	Mudstone
70%	25%	5%

Mineralogy

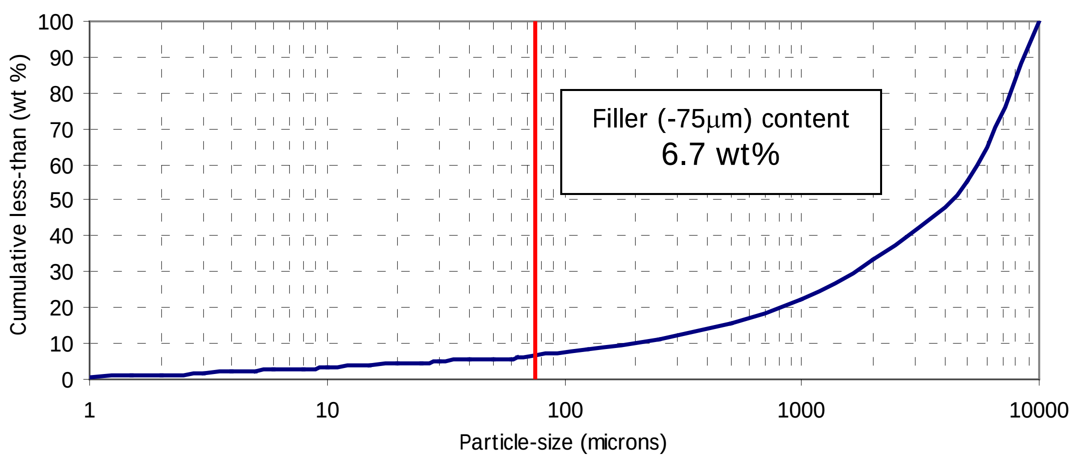
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH4A). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 70% SiO_2, 15% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 4% Fe_2O_3. The sample has a low filler content, 7% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC9 / E993 **Date:** 8/7/99

Borehole: LH4B **Depth:** 50.50 – 100.08 m

Summary of borehole core lithology:

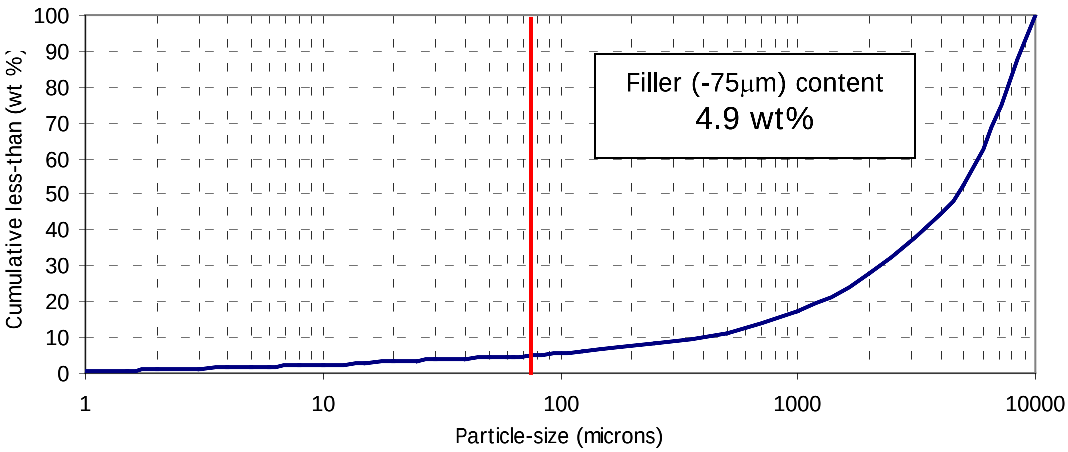
Sandstone	Siltstone	Mudstone
85%	11%	4%

Mineralogy

Dominant	Quartz
Major	Chlorite
Minor	Alkali (Na- & K-) feldspar and mica
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH4B). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- & K-) feldspar and mica and trace amounts of calcite and anatase. The sample has a low filler content, 5% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC10 / E994 **Date:** 8/7/99

Borehole: LH4C **Depth:** 100.08 – 151.04m

Summary of borehole core lithology:

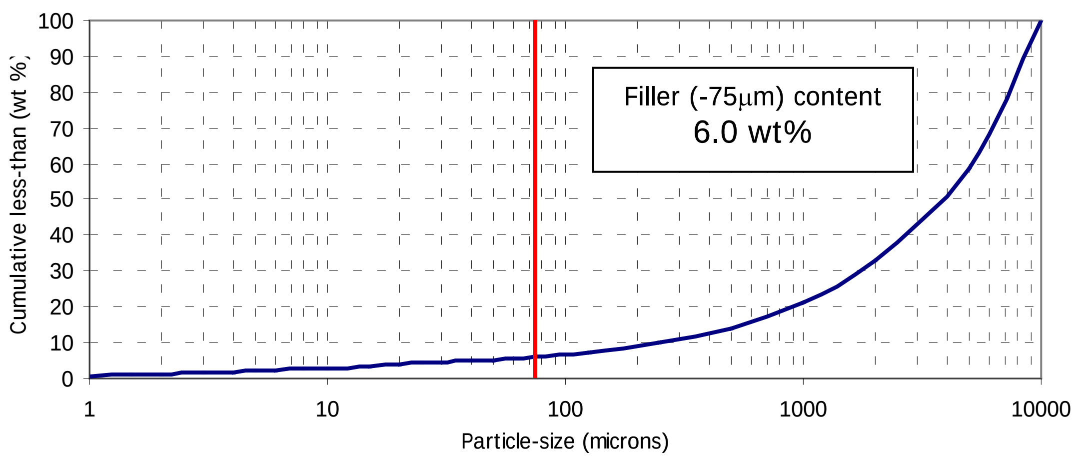
Sandstone	Siltstone	Mudstone
71%	23%	6%

Mineralogy

Dominant	Quartz
Major	Chlorite
Minor	Alkali (Na- & K-) feldspar and mica
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH4C). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of chlorite, minor amounts of alkali (Na- & K-) feldspar and mica and trace amounts of calcite and anatase. The sample has a low filler content, 6% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC11 / E995 **Date:** 8/7/99

Borehole: LH5A **Depth:** 0 – 50.43 m

Summary of borehole core lithology:

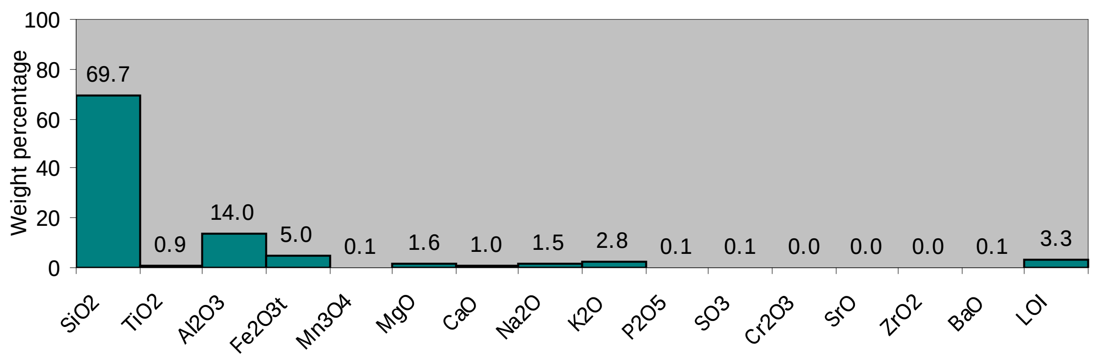
Sandstone	Siltstone	Mudstone
73%	27%	0%

Mineralogy

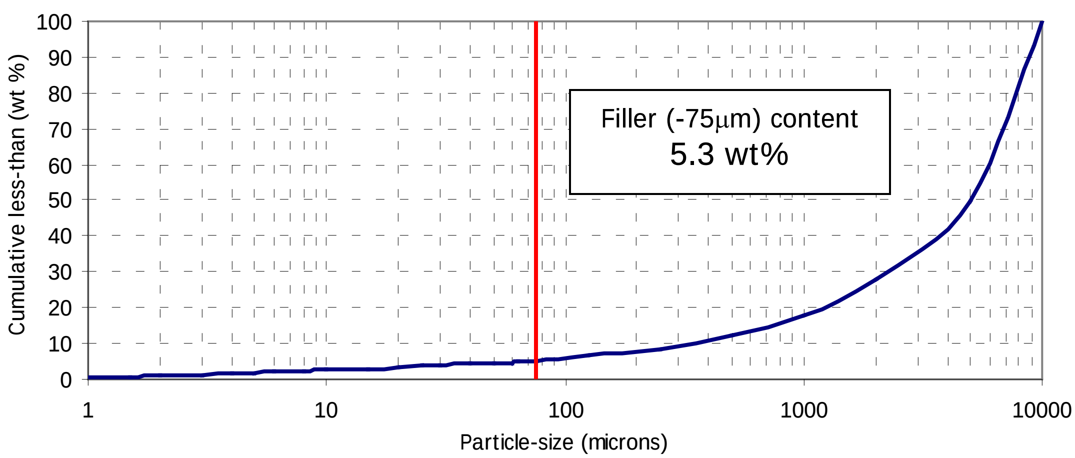
Dominant	Quartz
Major	Na-feldspar
Minor	K-feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH5A). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of Na-feldspar, minor amounts of K-feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 70% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 5% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC12 / E996 **Date:** 8/7/99

Borehole: LH5B **Depth:** 50.43 – 101.69 m

Summary of borehole core lithology:

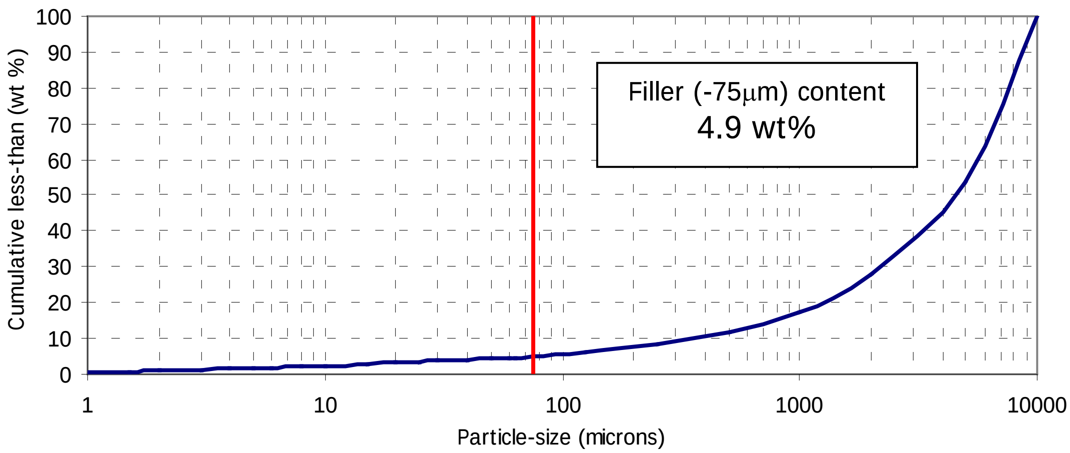
Sandstone	Siltstone	Mudstone
71%	29%	0%

Mineralogy

Dominant	Quartz
Major	Na-feldspar
Minor	K-feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH5B). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of Na-feldspar, minor amounts of K-feldspar, mica and chlorite and trace amounts of calcite and anatase. The sample has a low filler content, 5% <75 μm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC13 / E997 **Date:** 8/7/99

Borehole: LH5C **Depth:** 101.69 – 150.05 m

Summary of borehole core lithology:

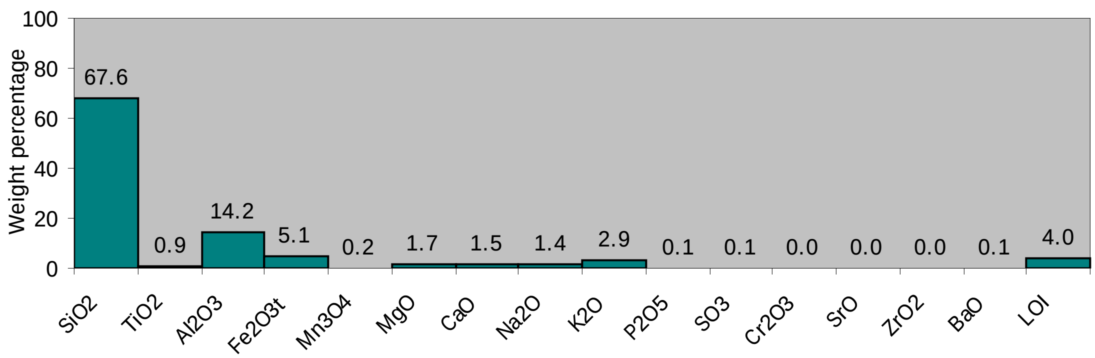
Sandstone	Siltstone	Mudstone
16%	81%	3%

Mineralogy

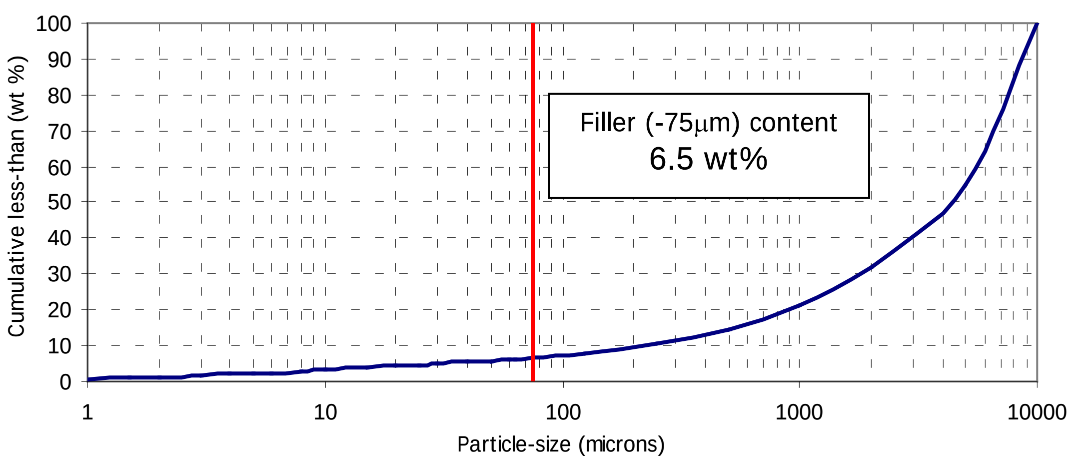
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH5C). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 7% <75 μm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC14 / E998 **Date:** 8/7/99

Borehole: LH6A **Depth:** 0 – 46.49 m

Summary of borehole core lithology:

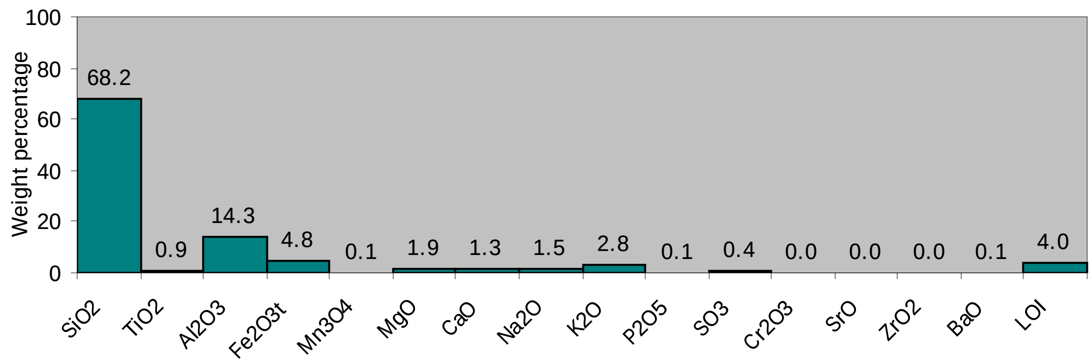
Sandstone	Siltstone	Mudstone
66%	33%	1%

Mineralogy

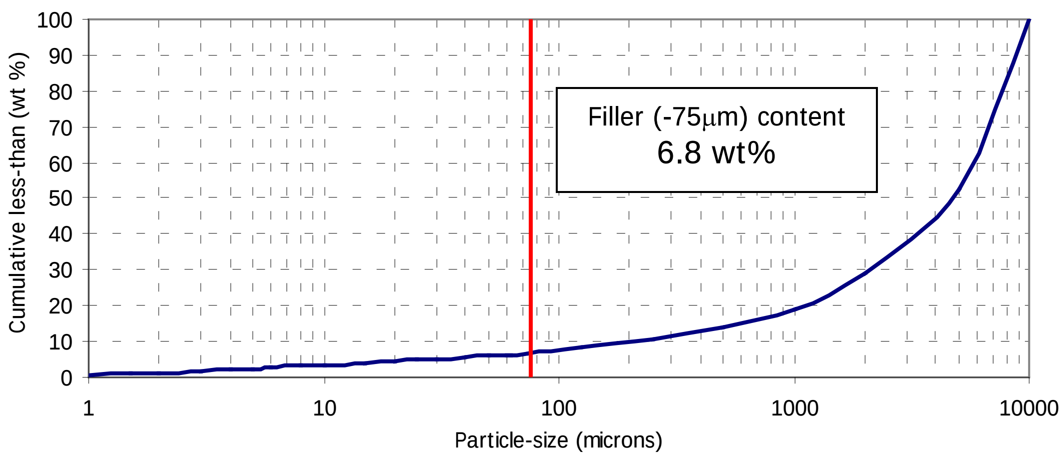
Dominant	Quartz
Major	Na-feldspar
Minor	K-feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH6A). Mineralogical analysis indicated that it is composed of dominant quartz, major amounts of Na-feldspar, minor amounts of K-feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 14% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 7% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC15 / E999 **Date:** 8/7/99

Borehole: LH6B **Depth:** 46.49 – 95.27 m

Summary of borehole core lithology:

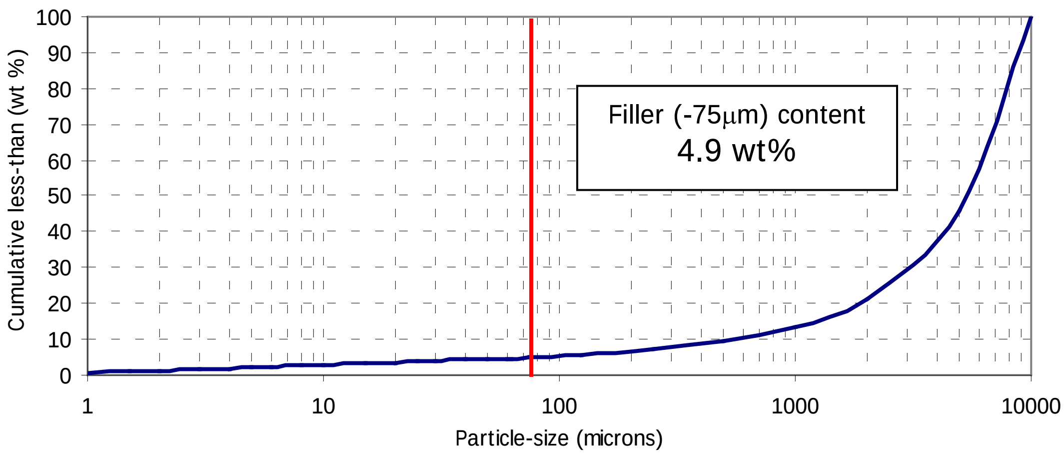
Sandstone	Siltstone	Mudstone
58%	42%	0%

Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH6B). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. The sample has a low filler content, 5% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC16 / F001 **Date:** 8/7/99

Borehole: LH7A **Depth:** 0 – 38.61 m

Summary of borehole core lithology:

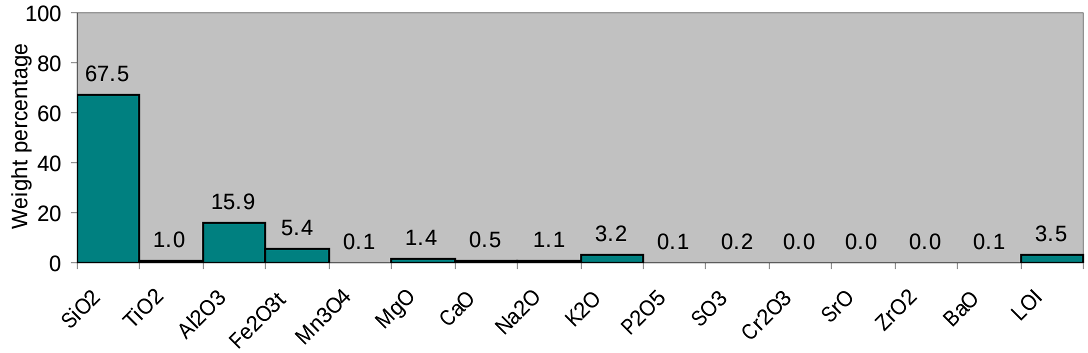
Sandstone	Siltstone	Mudstone
73%	27%	0%

Mineralogy

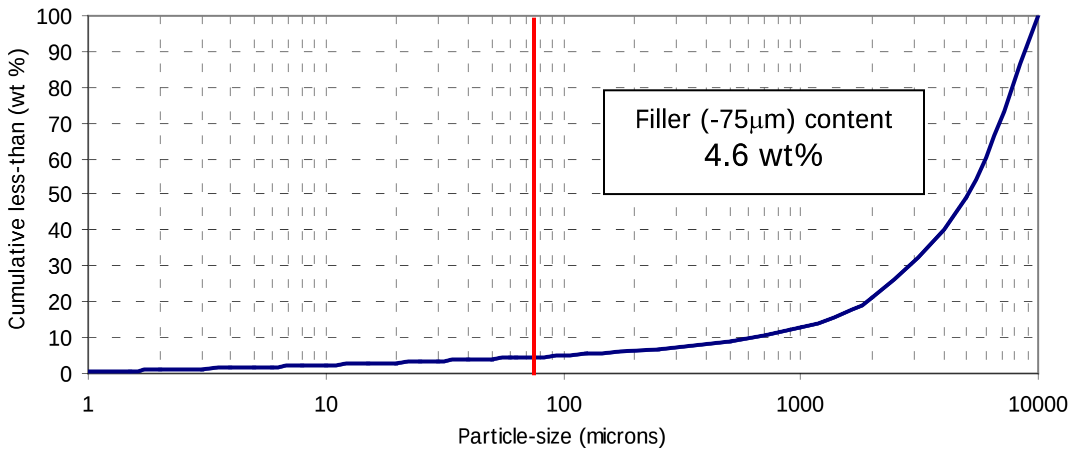
Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Chemistry



Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH7A). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. Chemical analysis determined that the sample contains 68% SiO_2, 16% Al_2O_3, 4% alkalis (Na_2O & K_2O), 1% TiO_2 and 5% Fe_2O_3. The sample has a low filler content, 5% <75 µm.

LEAHILL QUARRY (Tarmac Fleming (Quarries) Limited)

Location: Leahill Quarry, Adrigole, Beara, Co Cork, Ireland

Sample type: Borehole core (aggregate testing fines)

Rock type: Medium siltstone – fine sandstone (Toe Head or Old Head Formation, Upper Devonian)

Sampling: prEN-932-1 (Draft European Standard)

Sample code: LHC17 / F002 **Date:** 8/7/99

Borehole: LH7B **Depth:** 38.61 – 65.20 m

Summary of borehole core lithology:

Sandstone	Siltstone	Mudstone
87%	13%	0%

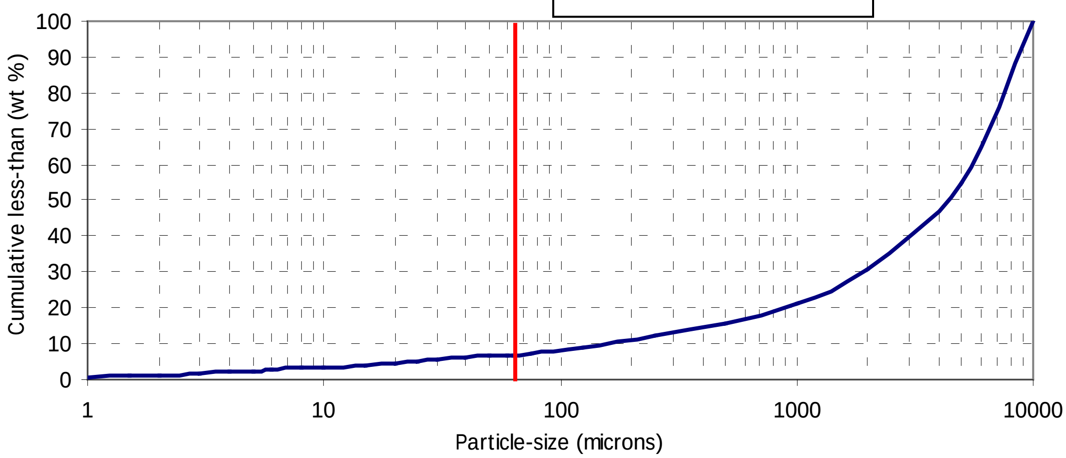
Mineralogy

Dominant	Quartz
Major	
Minor	Alkali (Na- & K-) feldspar, mica and chlorite
Trace	Calcite and anatase (TiO_2)

Dominant = >50 wt%; Major = 20-50 wt%; Minor = 7-20 wt%; Trace = <7 wt%

Filler (-75µm) content
7.4 wt%

Particle-size distribution



Summary of data

This sample represents the fines (<10mm) produced during aggregate testing of borehole core material (LH7B). Mineralogical analysis indicated that it is composed of dominant quartz, minor amounts of alkali (Na- & K-) feldspar, mica and chlorite and trace amounts of calcite and anatase. The sample has a low filler content, 7% <75 µm.