Selecting the Correct Stone

Federation Stone Great Britain





Contents **page**

Stone consultants: Throughout this document we have referred to stone consultants as experts who will be able to assist you in the selection of the stone. It is vital that the person/ company selected has the appropriate level of experience to assist you with the selection of the stone and that you give clear scope of requirements to the consultant, explaining exactly what you want done.

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This Stone Federation Great Britain guide is based on relevant sections of a number of British Standards, Codes of Practice and trade documents. It sets out the current best practice for the selection of natural stone for larger cladding, flooring, paving and masonry projects. It considers the important issues relating to the interpretation of samples, the role of the quarry/mine/factory visit in the assessment of the stone selection and the relevant factors appropriate to the evaluation of the technical properties of the stone, and if necessary, to a successful testing regime. It aims to identify the common misunderstandings and is designed to help the specifier to make an informed selection of a suitable stone for their project.

1. **Samples:** All samples should be labelled in accordance with BS EN 12440 Natural Stone – Denomination Criteria, ie. they should have their traditional name, quarry location and country of origin and the petrological family declared, together with a sample reference number. This information will allow you to compare this sample with previous samples and with buildings using these stones and will also allow you to access previous technical information which will give you an indication whether the stone is suitable in your proposed application.

   Some stones are given commercial names but it is vital that the traditional name of the stone is established so that all appropriate historical information can be found. If the supplier is unable or unwilling to provide information we advise that an alternative stone is selected. All samples should be marked with the surface finish that has been applied to the sample, ie. if fine rubbed or honed, it should have the grit size used so that the specifier can accurately specify the finish of the stone. The wording should also reflect the requirements of the relevant product BS EN Standards.

   a. **Indicative Samples:** An indicative sample shows the general colour, tone and texture of the stone, but cannot and should not attempt to show the range of geological characteristics that will be naturally present in all stones. These indicative samples are typically small stones, say 150mm x 150mm, so that they can be posted to various members of the project team for presentation to the planners (if appropriate). A short list of acceptable stones is normally made from viewing the indicative samples.

   b. **Range/Control Samples:** The range/control samples may be specifically prepared for the project, or there may be panels of current production already established at the quarry/mine showing the typical range of features normally found in the bed of stone. The range/control samples should be of sufficient size to indicate the general appearance of the finished work. Normally about 10 large stones at least 600mm x 400mm or the sizes of the common stones on the project. These samples should include the typical variations in colour, texture, veining, shell content, grain size and the distribution, character and frequency of these, and all other features that are deemed to be part of the geological characteristics of the stone.

If processing of the stones typically involves the use of patching, fillers or other similar products for natural holes, faults or cracks, then they should be declared by the quarry/mine or the production facility completing this operation and the reference samples should include any such feature. It is ultimately the quarry or mine's responsibility to select a suitable number of samples from various blocks from the chosen bed to show the typical range of geological variations that are present in the stone or the bed of stone. Invariably this inspection should take place at the extraction site but if in exceptional circumstances this is not possible, then confirmation that the source of the stone has been closely consulted in the sample selection must be sought.

You should view these samples and agree an acceptable range of samples for the project, remembering that rejection of characteristics typically found in the stone will potentially result in abortive cutting, prolonged procurement and possibly increased costs. All characteristics accepted in these samples should be considered to be typical of the normal production and not as flaws and therefore should not become a reason for rejection, unless their concentration becomes excessive and the typical character of the stone is lost.

Any comparison between the range/control samples and the actual production should be conducted in normal daylight for external stone work. For internal stone work the samples should wherever possible, be viewed in light conditions similar to those anticipated for the project. Wherever possible, samples should be viewed from a distance of 2m as stated in all the relevant British Standards and in the orientation in which the stone will be used. This will allow for an accurate comparison similar to the conditions on site.

c. Building Inspections: It is advisable, if possible, to confirm the selection of the stone by viewing a number of buildings built in the vicinity or in a similar environment of the proposed project using the same stone or bed of stone and in the same application and exposure conditions. The stones on these buildings should be examined closely, noting the geological characteristics in the individual stones compared to the samples provided. It is important to remember that some of these characteristics may dull as part of the weathering process, so it may be advisable to retain the services of a stone consultant/experienced geologist to explain the process. After examining the stone in detail it is suggested the entire façade is viewed from a reasonable distance, perhaps from across the street, to see the stone as part of the overall building structure and to note the characteristics that are still visible or dominant.

2. Quarry/Mine/Factory visit: Stone Federation Great Britain strongly advises that a visit is made to the quarry or mine and factory so that the stone proposed for the project can be carefully inspected. The existence of an independent experienced Stone Consultant or ideally, a qualified independent experienced geologist, is recommended, particularly if you are not familiar with stone and it is even more important if you are looking at a stone that is not regularly used in the UK. These visits provide an opportunity to examine the stone faces and the stock to familiarise yourself with the geological variations between the different beds or types of stone.

The range/contract samples are normally inspected as part of the visit. Information about the quantity and programme should be provided to the stone supplier so that the availability of the stone can be considered. Many project teams are now more concerned by the environmental and ethical impacts of the extraction operations and whilst documentation can give an indication, first-hand experience of the site is invaluable in assessing the merits of different operations and operators.

a. Geological features: An important part of any visit to the extraction site is to look at the exposed faces in the quarry or mine and note the differing geological features. Remember that in a rough cut face and particularly in a natural or split face, the features may not be immediately obvious, but the face should be examined very closely. Look for variation in different parts of the face; compare the top of the face to the bottom and look along the length of the face and different exposures of the same face to see if there are differences.

Some stones with a low natural bed height may be used and have a proven track record of being used face bedded so the details on the actual bedding planes should be more closely examined. Also examine any other data that may be available such as cores, core logs, trial pits and cuts as well as adjacent outcrops and exposed faces.

Ask where the production teams are heading and where they will be extracting when the stone for your project will be required. Carefully compare the features seen in the faces to the stocks. Examine the size of blocks in stock and the total quantity. Ask what proportion of your project will come from stock and consider whether you want to make a pre-purchase of the stone to secure the supply of a particular stone or block size for your project.

b. Rates of Extraction: It is important to establish the rate of extraction from the quarry/mine and the quantity of blocks in stock and compare this to the stone required and programme for your project. If your requirement for the project is a large percentage of the overall stock or the production from the site, then alterations to the programme could have a big impact on the company's ability to supply the stone and perhaps a block pre-purchase should be considered.

It is also worth noting the size of the blocks compared to the stone sizes required for the project. Obviously the finished stone sizes cannot be bigger than the quarried block but if the stone sizes are larger than the average size of the blocks, then this will impact on the amount of block that the site produces and that can be used for the project. Again, to ensure there is sufficient block, a block pre-purchase should be considered. Also consider the longer term viability of the stone for the project if the stone is required over an extended programme and the future viability of the stone over the life of the building.

c. Environmental Impacts: Environmental Management Systems (EMS) can be prepared for all of the extraction processes and certificated to either ISO 14001 or EU Eco-Management and Audit Scheme (EMAS). However, in practice most dimension stone operations are relatively small when compared with aggregate extraction sites and few, if any, are certificated. It becomes even more difficult to complete a comparison of the environmental impacts from pure documentation when the quarry or mine is outside the EU.

In the absence of a documentary comparison, we suggest that you look at the operations and ask questions about the environmental impact of the operations. All UK sites will have strict environmental planning requirements and even the old permissions will have been reassessed under the 1995 Environmental Act.

Most companies will have an Environmental Policy and a phased restoration plan that can be compared with the actual operation. Some sites will have measured the carbon footprint of their operation and also have a written plan showing the policies in place to reduce the emission of greenhouse gases. Similar policies may be in place to reduce the water extraction and avoid unnecessary waste. The location of the quarry/mine in comparison to the manufacturing works and the final destination of the stone will have a major impact on the carbon footprint on the stone, but it is difficult to be specific about the actual figures, as a large number of factors come into play and accurate comparisons are difficult.

d. Ethical/Social Issues: The quarry/mine should have consultation with the local communities about the impact of their operations and may have objectives and targets to reduce these impacts and any resulting complaints. For the employees there should be encouragement for learning and development. Most UK and EU sites will have these in place, but it becomes more important when stones are being considered from developing countries.

Whilst it is tempting to look at more competitively priced stones it should be equally important to ensure that the company extracting the chosen stone is conducting its operation in an ethical manner. Child labour and bonded labour is still used in quarry sites in the developing world and companies that have been encouraged to abandon these practises should not find themselves penalised by the price being the only factor of consideration. It is vitally important that the extraction site is visited and appropriate questions asked. The health and safety of these operations should also be assessed and health and safety policies can be requested and these can be compared to the actual operating conditions.

Photograph courtesy of Marshalls Plc

e. Processing Works: It is advisable to visit the processing works for the fabrication of the stonework for your project. You should ask about the quality control system and examine the quality control in progress as you tour the factory site. It is normal practice in a masonry works for the sawyers to inspect every slab cut from the blocks and you should see evidence of this and the accurate checking of tolerances either manually or through an automated system.

You should see stones similar to the ones required for your project being produced and you should also be able to carry out a few spot checks on aesthetics and tolerances. Look at the quantities being produced and compare the capacity with the quantities required for your own project. Get a general impression of the site and the competence of the management.

3. Technical Assessment of the Stone: All natural stones will weather and some will suffer from reductions in their strength, but it is important to be able to make an initial assessment of a stone's technical properties before it is added to a project short list. There are various tests that help to build a picture of a stone's potential suitability for a particular application and whilst past projects are a good indicator, recent test data should be examined. You may need a stone consultant to assist with this interpretation, particularly when you are using a stone that is not widely used in this market or for your intended application.

CE certificates provide a useful starting point but currently they are not mandatory in most EU Countries. It is vital that the chosen stone's technical properties are truly adequate for the intended use and any production testing should simply be confirming this adequacy rather than attempting to select the 'best' stones for the entire project. It may be appropriate to have an intensive testing regime for a limited number of stones where, for example, a particular performance is required.

If production testing is carried out, then it is imperative that you have a plan in case the stone fails to meet minimum performance criteria (this/these figures may be set by the British Standard and should reflect the specific project requirement or necessity, rather than an arbitrary figure relating to typical previous results). The factor of safety will also need to be established using guidance in the relevant British Standard.

All project testing should be supported by sampling plans so that you can be confident that the stone tested is representative of the variation that you are likely to be using for the project. Once you have established the technical properties it is important that you use this information to design the project in a cost effective way.

a. Existing Technical Data: There are various independent publications that will give you some preliminary technical information on stone; these include the BRE limestone and sandstone books (please note that these were written in the late 1980s and some of the grading of the durabilty results have been superseded by new Standards), BRE stone list (compiled in 2002) on the web site *http://projects.bre.co.uk/condiv/stonelist/stonelist.html* and the Natural Stone Directory. Many extraction companies will provide technical data about their stone and some will be able to provide it in the CE certificate format.

The CE certificate will ensure that the data is presented in a format common throughout Europe, which will allow for an accurate comparison between differing stones. The stones will have the mean and a statistically Highest Expected Value (HEV) and/or the Lowest Expected Value (LEV) calculated based on a 75% confidence level**.** Care must be taken if data is not tested in accordance with British Standard testing methods or is not supported with a CE Certificate. A single mean figure could be very misleading. Similarly a simple range of the results can also be misleading as it could be a range of actual results, average results or lowest/highest expected values.

It is important to be able to check the dates that the tests were conducted. Ideally the tests will had been performed over a long period of time, including some recent results. Unless there have been significant changes in the geological character of the stone in recent production (this can be assessed by looking at past projects) tests up to 10 years old are still valid as demonstrating current technical properties.

CE Year: 01/2010	Reference Standard: **EN 1469** Product: **Slabs of Natural Stone for Cladding** Denomination: **Portland Basebed**, Limestone *Jordans Quarry, Easton Street, Portland, Dorset, England* End Uses: **External Wall and Ceiling Finishes**	
Name and address of the producer: **Albion Stone plc**		
Characteristics	**Declared values**	**Test method**
Reaction to Fire	Class A1	Without testing (see decision 96/603/EC, as amended)
Flexural Strength	LEV: 3.68 MPa Mean Value: 6.78 MPa Standard Deviation: 0.89	EN 13161
Resistance to Fixings at 75mm thick	LEV: 3,795 N Mean Value: 4,329 N Standard Deviation: 464	EN 13364
Frost Resistance	Passed	EN 12371
Water Vapour Permeability	NPD	EN ISO 12573 or EN 12524
Thermal Shock Resistance	NPD (No Performance Determined)	EN 14066
Apparent Density	LEV: 2,122 kg/m³ HEV: 2,236 kg/m³	EN 1936

b. **Existing Buildings:** The purpose of all testing and technical data is to help predict the ongoing performance of the stone. Evaluation of existing buildings will be useful in the assessment of stones, particularly its durability. Stones that have a proven track record in the same environment and in a similar application will require a less rigorous testing regime; therefore differing testing regimes are likely for different stones, with cost and programming implications. A stone consultant would also be able to advise you on these issues.

c. **Initial Testing:** After collating the available existing data it may be necessary to conduct some preliminary testing to confirm the suitability of a stone on the shortlist; a stone consultant will be able to help interpret the data. It is important that these tests are completed in plenty of time to react to any unexpected results that may involve elements of a redesign on the stone thickness for example, or even the replacement of this stone on the project.

All tests should be to the British Standards and tests should be completed at an independent accredited testing laboratory. Depending on the test selected, please be aware that some tests can take up to 10 weeks to complete and additional time will need to be set aside to complete the sampling plan and for the physical cutting of the stone. Further testing a stone that complies with the relevant BS EN Standards is frequently unnecessary. Additional testing should only be at the instruction of the stone consultant or to confirm the stone properties for a unique application or fixing system.

d. Relevant Tests: The British Standard sets the test requirements for the various product types. Where additional testing is required these tests should be related to the actual project requirements rather than just a list of all the available tests. A stone consultant will be able to assist you with the selection of a testing regime specifically designed for your project. The testing regime must also consider the use of the stone. Stones that have a good history of use on similar projects in the location of the project, will obviously require significantly less evaluation than a new stone to the project's location. The testing should also reflect whether some of the data is near to the unsatisfactory or marginal requirement for the project or if the stone is being used in an application that puts additional stress on the stone.

e. Production Testing: Production testing should be carried out to confirm the ongoing consistent quality of the stone as it is produced, NOT to select the best stone for the project. The initial testing should have already confirmed that the stone is suitable for the project. It is important to remember that the samples for production testing are taken as the stones are processed, so by the time the results are known the stones from the block will have been produced and in some instances, fixed onto the building. An appropriate factor of safety for stone will allow for the typical variations of the natural product; however, the production testing may indicate a trend in the physical properties of a stone that needs further investigation.

f. Testing Sample Plan and Report: It is important that any sample submitted for testing is representative of the typical properties of the stone. A sample plan should be prepared in compliance with the requirement set out in the relevant Euro-code, such as BS EN 1469 Natural Stone Products – Slabs for Cladding - Requirements.

The sampling plan should define the extraction, cutting and working of the samples for testing. It should show the proposed locations in the quarry or mine that the block will be/have been extracted from on a plan, as well as the number of samples for the various tests. The sampling plan will either be prepared by the quarry/mine or a stone consultant for approval by the client/design team. As the samples are cut, a sampling report should be completed. This provides traceability of the physical samples through to the testing laboratory.

g. Factor of Safety: It is important that the factor of safety for the type of stone being used is established at an early stage of the project design and it may be different for the various stones on the shortlist. The factor of safety for stone tends to be higher than for some other materials for several reasons;

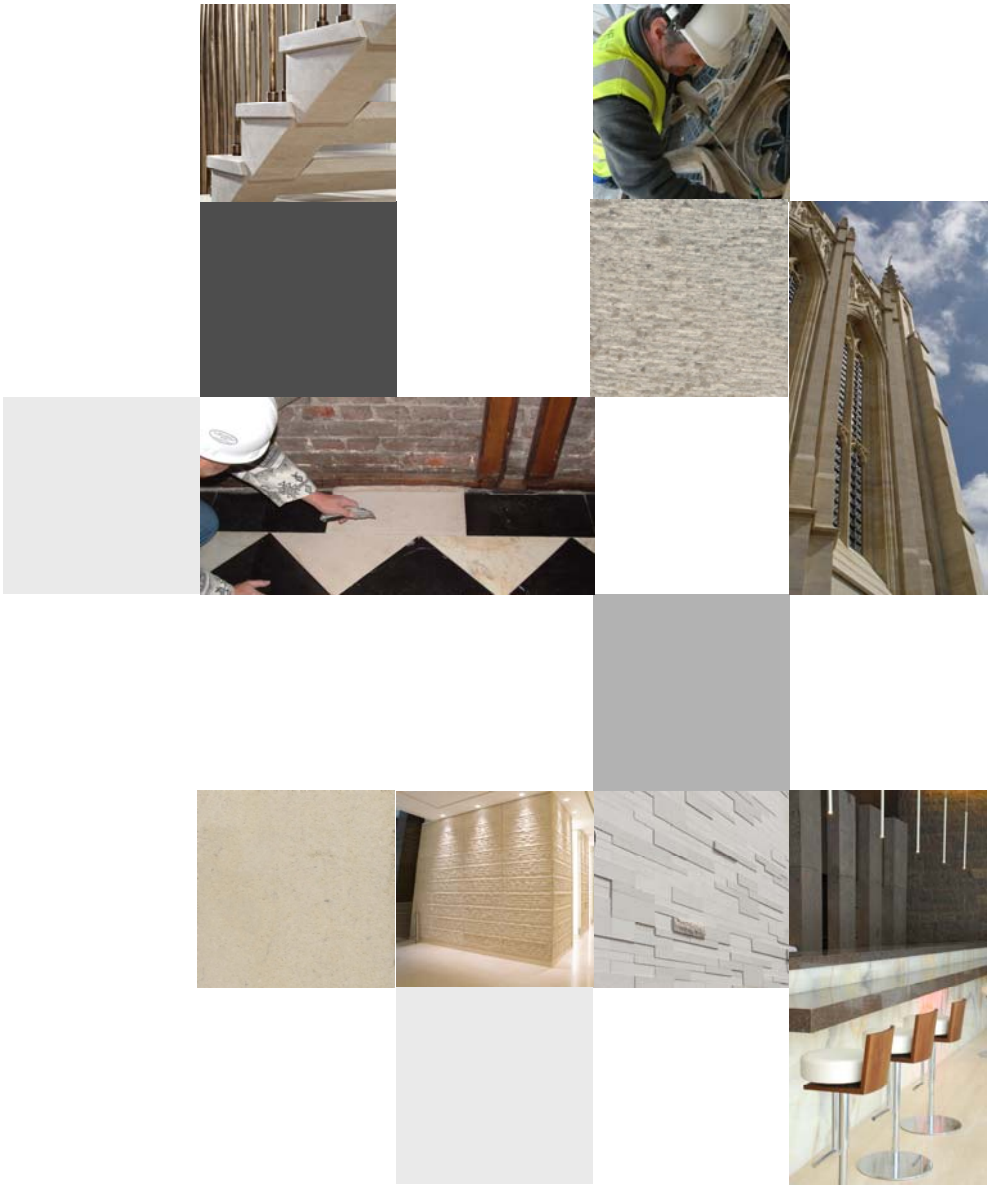
i. Stone is a natural material.
ii. Stone is brittle.
iii. Some stones weaken over time as a result of atmospheric attack or from microcracking as a result of thermal/moisture or wind stresses.
iv. Some stones may contain unseen flaws or inclusion that may have not been in the tested samples.

h. Thickness of Cladding: The BS 8298 has recently undergone a major revision and now encourages the designer to calculate the required thickness of stone cladding. The calculation requires knowledge of the expected imposed load, the required factor of safety, the details of the stone units and the type of stone. Once this information is established, the calculation to determine the thickness of the stone can be completed using the properties of the stone (particularly the flexural strength and breakout load at fixing), the panel size, the imposed loads and the fixing system. It is necessary to consider both the flexural strength of the panel and the potential failure of the fixing points, so there are two separate calculations that need to be completed. Further information relating to the detailed calculations is available in the new BS 8298 and a Stone Consultant should be able to help you through the calculation for your project.

i. Thickness of Paving: The BS EN 1341 provides guidance on the calculations required to establish thickness of stone paving units as applicable for various classes of trafficking and applications.

4. List of relevant British Standards, Codes of Practice and relevant publications:

- BS EN 12440 Natural Stone Denomination Criteria
- BS EN 1469 Natural Stone Products-Slabs for cladding – Requirements
- BS EN 12057 Natural Stone Products Modular Tiles – Requirements
- BS EN 12058 Natural Stone Products- Slabs for floors and stairs – Requirements
- BS EN 12059 Natural Stone Products – Dimensional stonework - Requirements
- BS EN 1341: Slabs of Natural Stone for external paving - Requirements and test method
- BS EN 1342: Setts of Natural Stone for external paving - Requirements and test method
- BS EN 1343: Kerbs of Natural Stone for external paving - Requirements and test method
- BS EN 771-6 Specification form masonry units – Part 6 Natural stone masonry Units
- BS 8298: Code of Practice for the Design and Installation of Natural Stone Cladding and lining, will be issued in five parts:
    - Part 1: General:
    - Part 2: Traditional handset external cladding:
    - Part 3: Stone-faced pre-cast concrete cladding systems;
    - Part 4: Rainscreen and stone on metal frame cladding systems;
    - Part 5: Internal linings.
- BS 5385-5 Wall and floor tiling – Design and installation of terrazzo, natural stone and agglomerated stone tile and slab flooring – Code of Practice
- The building limestones of the British Isles – 1983 - Elaine Leary
- The building sandstones of the British Isles – 1986 – Elaine Leary
- The building magnesium limestones of the British Isles -1988 – Diane Hart
- BES 6001 Environmental and Sustainability Standard which incorporates Management, Supply Chain, Environmental and Social Requirements
- BS 5642: Part 1 Sills and Copings; Specification for window sills of precast concrete, cast stone, clayware, slate and natural stone
- BS 5642: Part 2 Specification for copings of precast concrete, cast stone, clayware, slate and natural stone
- Eurocode 6. BS EN 1996 – Design of Masonry structures
    - BSEN 1996-1-1 Design of Masonry structures. General rules for reinforced and unreinforced masonry structures
    - BSEN 1996-1-2 Design of Masonry structures. General rules. Structural fire design
    - BSEN 1996-2 Design of Masonry structures. Design considerations, selection of materials and execution of masonry
    - BSEN 1996-2 Design of Masonry structures. Simplified calculation methods for unreinforced masonry structures
- The Geological Society Engineering Group Working Party Report; Smith, M R 1999, Stone: Building Stone, rock fill and armourstone in construction.
- Stone Federation Code of Practice for the Design and Installation of Internal Flooring.



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