

**Section 1**  
**Introduction**  
Second Edition 2004

# 1. INTRODUCTION

## 1.1 Scope

Natural stone materials are generally used as surfacing in conservation areas and prestigious streetscape projects. Roads and footways paved with stone can enhance the townscape by providing a traditional, high quality appearance. Stone can also offer sustainable construction and provide a more environmentally sensitive approach to the design of traffic calming measures.

Today, town and city roads are required to provide access to vehicles, public transport and retail service deliveries, often within restricted road widths. The stresses imposed on these roads and shared areas have increased owing to traffic growth, higher vehicle weights and new vehicle configurations. Appropriate design procedures are therefore essential to ensure the finished product is functional as well as looking good. Engineered construction that integrates maintenance regimes and future statutory undertakers' requirements is also critical.

However, a gap exists in engineering knowledge of how natural stone units behave as surfacing in pavements subjected to heavy loading. Throughout Europe, most of the constructions used are based on semi-empirical principles or tried and tested local specifications. These constructions vary from place to place, and there is no consensus on how to design a durable stone surface.

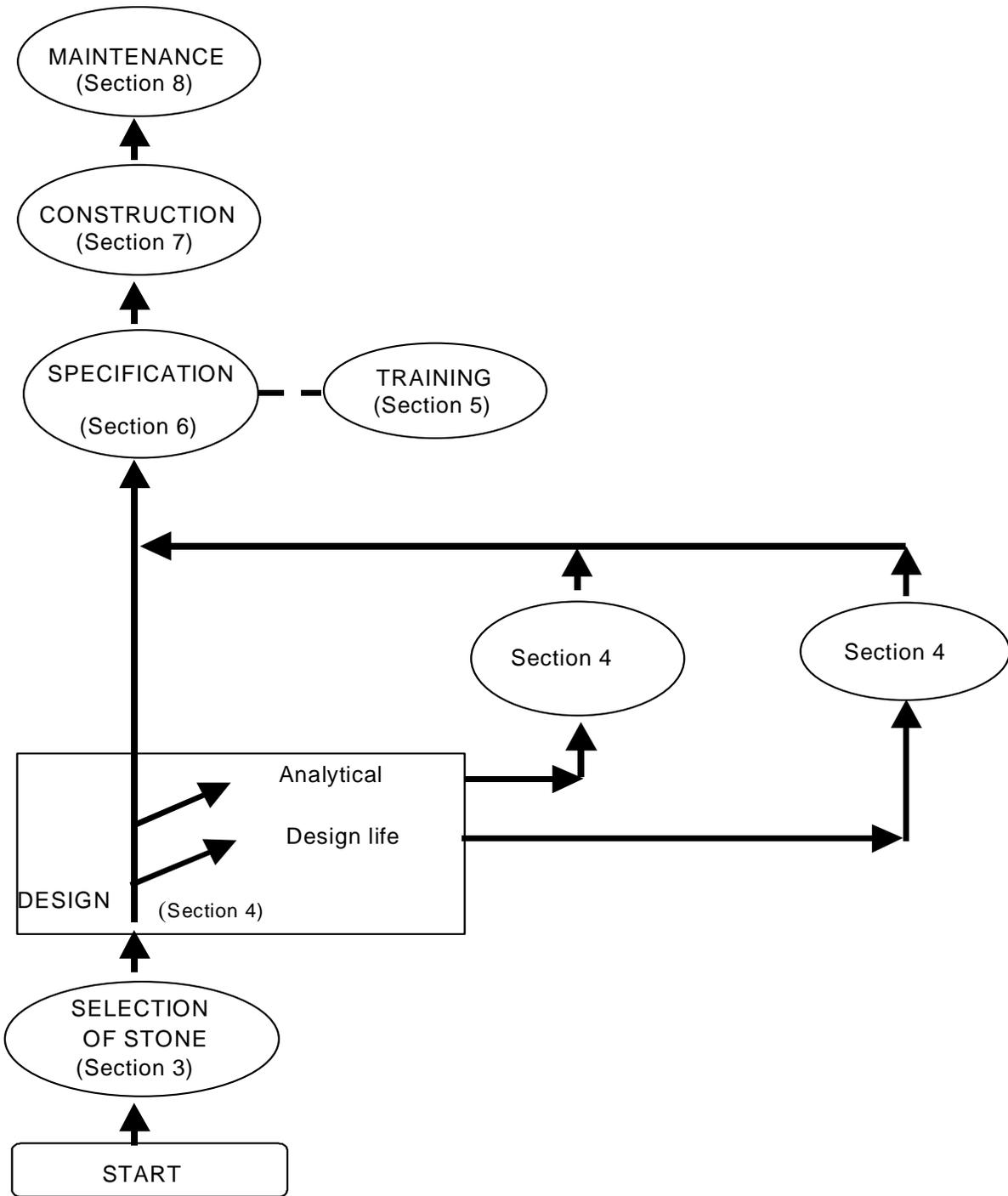
This guide is the result of a major research and testing programme, which investigated the fundamental engineering principles of the behaviour of stone unit surfaces, developed possible constructions and tested these at both small and full scale to establish loading capabilities.

Concurrently with the research programme, BS 7533 "Pavements Constructed with Clay, Natural Stone and Concrete Pavers" was being drafted and the initial results of the programme published in the first edition of this document were used to inform the drafting of the British Standard.

Feedback and comment on the First Edition and responses during the consultation process for the British Standard have lead to this second edition of the guide being produced. This incorporates the recent thinking on design, specification and construction techniques.

It provides updated advice on good practice associated with sourcing materials and maintenance.

Figure 1.1 gives a simplified flow diagram concerning the steps a designer should take when designing a stone element pavement.



**Figure 1.1 Steps in Design of Stone pavements**

## 1.2 Background

Stone block pavements were in use long before modern asphalt or concrete roads became the preferred form of road construction. According to Egyptian records, the oldest stone paved road was constructed in about 3000 BC, to assist the movement of huge limestone blocks for the building of the great pyramid. From medieval times, stone surfacings were the most widely used form of road construction in European cities and important towns. They have contributed to the built heritage that distinguishes many cities on the world stage. For example, the general type of road construction in use in London at the beginning of the nineteenth century employed granite setts from 8 in. to 14 in. long, 6 in. to 9 in wide and 9 in. deep. The method involved “laying the setts in rows upon the subsoil and grouting and ramming with a wooden rammer. The traffic was then expected to perform the last duty for the paviour by settling each stone upon its bed” (Taylor, 1850).

In the 1950s, between 15% and 30% of Scottish city streets were paved with setts (Wright, 1953). Main advantages of stone paved roads were seen as their long life (>100 years) and ease of lifting and replacing them for access to services, or in the event of settlement. Low maintenance need in busy streets was also seen as an important benefit. Disadvantages were quoted as a high initial cost, a tendency to become slippery and a tendency to develop a poor riding quality. Although techniques were available to improve skidding resistance and improve surface profile, sett paving appeared to have peaked in terms of production by the end of that decade and was beginning to be replaced by other forms of construction. Asphaltic surfacings laid on the setts as they existed, or after relaying on their sides was the most common practice.

Today, because of the introduction of other forms of road construction, much of the traditional skills and knowledge associated with stone laying have been lost. These skills were generally handed down from generation-to-generation by word of mouth, and little documented information exists. Currently there is a range of specifications and installation techniques, but no unified standard exists for the design and specification of roads paved with stone. As a result, many professionals have commented that design teams can draw on little or no guidance. Others highlight the need for detailed analysis of the performance of stone paving in both successful and failed modern schemes.

As part of the research for the guide a review of the use of natural stone as a road surfacing throughout Europe was undertaken (McHale and Fordyce, 1999) the findings are that design guidelines in central and Western Europe are based primarily on German experience. The French have developed notional national specifications and design guidelines (Norme P, 1993). In Italy and Spain, there are a number of regional practices. However, throughout Europe there is no common guidance for design, specification or construction of surfaces constructed in stone materials. A wide range of organisations are involved in the preparation of design guidelines and pavement specifications, including research establishments and government bodies, but this research is as yet un-coordinated and tends to be specific to individual regions or countries.

This review found many examples of stone surfaces which appeared to sustain heavy loading, however it also discovered many instances where similar constructions to these successful surfaces had failed or where additional maintenance work was required to keep the surfacing intact. It was also evident that good practice was not transferable from one place to another, which again emphasized the lack of real understanding of how pavements performed. This mirrors the situation in this country.

Although national guidelines vary, important concepts on the design, specification and construction of successful pavements are shared. They include the following:

- **Traffic load limit**
- **Maximum service life**
- **An increase in depth of stone element with an increase in traffic loading**
- **Compatibility between the elastic response of the upper and lower layers under load**
- **The use of skilled and properly trained personnel**
- **Predetermined maintenance regimes**

Again, the influence of these factors was uncertain and much of the guidance was still semi empirical in nature. Whilst many of the above have been incorporated, this guide is based on a programme of tests and trials of various theories to establish the fundamental engineering principles of the behaviour of natural stone surfaces and develop specific guidance on construction techniques

## **Guidance**

*The techniques used in installing stone surfaces which perform well, vary throughout Europe. They are based on semi empirical, traditional, guidance borne of experience rather than engineering knowledge. No unified guidance exists.*

*This Guide has been developed to address this lack of engineering understanding and is based on a programme of research, tests and trials from which practical guidance based on engineering principles has been developed.*

### **1.3 Decision to use stone**

Government and planning policy favours the use of stone, as it assists in the achievement of targets on sustainability, environmental protection and employment (Historic Scotland, 1999). The availability of funding from the European Union, Heritage Lottery fund, together with other private and public funding has meant that new, high quality streetscapes incorporating natural stone can be considered.

Funding for schemes frequently comes through partnership arrangements between local authorities and central government, typically in inner city regeneration and townscape improvement programmes where the perceived advantages can justify the higher capital costs.

Stone can be used in many situations where traffic speeds are low or moderate i.e. below 30mph – stone surfaces are not appropriate for higher speed roads. If designed and maintained correctly stone surfaces can sustain moderately heavy vehicles and high volumes of traffic. It is not recommended that stone surfacing be used where there is a demand for high friction to permit rapid, controlled braking or manoeuvring, e.g. approaches to pedestrian crossings and traffic lights.

Many considerations will influence the decision to use natural stone. Financial considerations are invariably one of these. Often not just unit cost is used to evaluate a scheme since there are many elements that influence costs including initial capital outlay, maintenance commitments and operational costs, which are relatively easy to measure.

Figure 1.2 gives relative indices for the costs of various surfacing materials at typical prices in 2000.

<i>Material</i>	<i>1.3.1 Cost index</i>
Asphalt	1
Concrete pavements	4
Stone cubes	8
Stone setts	12 to 20
Stone slabs	10 to 30
Embellishments e.g. carving, sculpture	20 to 90

**Figure 1.2 Relative Costs**

In considering financial value it is important to take account of direct financial benefits that accrue from natural stone streetscapes including improved retail environment and enhanced appeal as a business location. In addition to these there are other quality issues that need to be considered that are less readily quantified in pure financial terms but should nevertheless be part of the evaluation process. These include enhanced amenity value, historical character and improved profile and image.

It is generally accepted that the many benefits that accrue from a high quality, natural stone streetscape environment more than offset the initial high investment. However, because of the high initial cost it is important that a fuller whole life cost model is considered in which, the benefits are properly investigated and understood.

To take account of all of the costs and benefits during the planning and procurement process for a natural stone streetscape it is essential to apply an appropriate evaluation matrix that allows both financial and non financial issues to be considered. A list of the issues that could be considered in such a matrix for project planning are shown in Figure 1.3

Not all of these will be appropriate to all situations and the weighting that should be applied to each factor will vary with the details of each particular scheme. Additional guidance has been prepared in the form of a Whole Life Costing Model that can be found in Section 12.

<i>Costs</i>	<i>Benefits</i>
Initial Capital Cost	Improved retail environment <sup>1</sup>
Financing cost	Improved business environment <sup>1</sup>
Additional operational costs	Improved business appeal <sup>2</sup>
Maintenance costs	Improved amenity value
	Restoring historical character <sup>3</sup>
	Improved profile and image
	Sustainability <sup>4</sup>

1 – Retail outlets or business premises on or immediately adjacent to proposed natural stone streetscape

2 – Business more likely to locate to town or city centre as a result of streetscape development

3 – Weighting will depend on the historical importance of the site and relevance of natural stone to the site

4 – All natural stone surfacing is likely to be more sustainable than asphalt, concrete or block paviour alternatives. If designed and maintained correctly the stone surface should offer longevity in comparison to other surfaces. The stone units can be reclaimed for reuse particularly units from unbound surfacing, which have greatest potential benefit.

**Figure 1.3 Costs and Benefits**

## **Guidance**

*An appropriate whole life cost benefit model should be applied to assess natural stone paving schemes. The model must consider the full range of benefits that accrue from these schemes. (See Section 12)*

## 1.4 Procurement of Construction Process

Natural stone streetscape works involve complex composite structures that are heavily dependent upon skilled labour. It is therefore unlikely that a scheme tender mechanism judged on price alone will lead to a successful project. The need for a highly skilled workforce and appropriate experience and expertise of both designers and contractors must be recognised in the tendering process. An important question for clients is how the balance between quality and price should be struck.

There are several approaches to achieving a desirable quality price balance. Two of the more common approaches include:

- *Quality: Price* balance model
- *Partnering*

The quality price approach involves balancing information on quality and price. Some of the important quality elements that need to be considered in such an evaluation are shown in Figure 1.4; this is a condensed version of work by the Association of Consulting Engineers and by the Local Government Management Board (LGMB). The balance that should be struck between price and quality depends on the nature of the project.

Experience of organisation
Workforce skill and experience
Training policy
Supervisor skill and experience
Availability of workforce

**Figure 1.4 Quality Considerations**

The LGMB has recently produced 'Quality up front' which sets out in detail the approaches which authorities are using to take quality into account in specifying services and awarding contracts, and gives guidance on the quality / price balance for different situations, as shown in Figure 1.5.

<i>Type of work</i>	<i>Quality Weighting (%)</i>	<i>Price Weighting (%)</i>
Complex activity requiring specialist expertise from a number of disciplines	80-90	10-20
Routine activity requiring knowledge from a single professional discipline	50	50
Activity which does not require technical or professional skills	10-20	80-90

**Figure 1.5 Quality and Price weighting**

Stone pavement streetscapes fall into a category somewhere between the top two in Figure 1.5 and accordingly it is suggested that a minimum quality price ratio of 60% / 40% would typically be appropriate although in some case a 75% / 25% would be appropriate. This is a decision for the promoters of the scheme.

The partnering approach seeks to involve all of the parties involved in a construction project as early as possible in the process and to remove the adversarial approach found in more traditional forms of procurement. It can be suited to stone surfacing contracts where the sources and supply of materials may be uncertain; where buildability heavily influences the choices made by the design team and where the quality of the workmanship is vital to the performance of the finished pavement.

### **Guidance**

*Natural Stone streetscapes are complex constructions in a very variable environment. It is therefore essential that appropriate skill and experience is available for their design and construction.*

*To reflect the need for such high levels of quality, procurement strategies should allow for a minimum 60 % / 40 % quality / price ratio.*

*Partnering may be an appropriate form of procurement and brings benefits of involving the Contractor in the design and specification of the project.*