If materials other than traditional sand are required in the aggregate for aesthetic or other reasons they will affect the final mortar strength. Separate laboratory testing would be necessary to determine the degree to which they affect the overall performance of the mix.

Historic mortars frequently contain traces of ash, coal and/or charcoal as well as other organic materials such as waterproofing agents and air-entraining proteins. It is possible that these contributed to frost resistance by preventing moisture absorption and hence freezing or by providing porosity allowing sites of stress relief from expansion forces during freezing. These aspects and the mortar requirements to resist frost are discussed further in section 4.5.

The choice of sand and other aggregates for mortar is most important. The aggregate is responsible for the mortar structure, which plays a key role in the development of strength and permeability. Grading curves (Figure 1) show the proportion by mass of the sand retained on standard sieves between 5 mm and 0.075 mm (75 microns) and can be compared with the grading specified for mortar in BS 1200: Type S. The grading curve should show good distribution between the various sizes. Too great a concentration of one or two size(s), although it might conform to the requirements of BS 1200 Type S, will diminish workability, and require the addition of more water to achieve the correct consistency, and can lead to bleeding and staining of the mortar (see section 2.3). A sand with a preponderance of coarse particles will be harsh and difficult to work. European Standard, EN 13139 Aggregates for mortar, gives little helpful guidance when formulating lime mortars.

Examples of well-graded sand and single sized sand are shown in Figure 1. Curves 1a and 1b show the traditional form for comparing gradings with specification ranges. Bar charts 1c and 1d show the distribution between sizes more clearly.

In general the maximum particle size of the sand and aggregate should not exceed one half of the joint width. For applications employing joints of 8 to 12 mm, the maximum size will accord with BS 1200 at 5 mm. In some applications, such as ashlar work with fine joints, it might be necessary to reduce the maximum size to 3 mm, or less, whilst still maintaining good distribution between sizes. Alternatively, where wider joints are used, coarse aggregate of 5 mm and above may be incorporated.

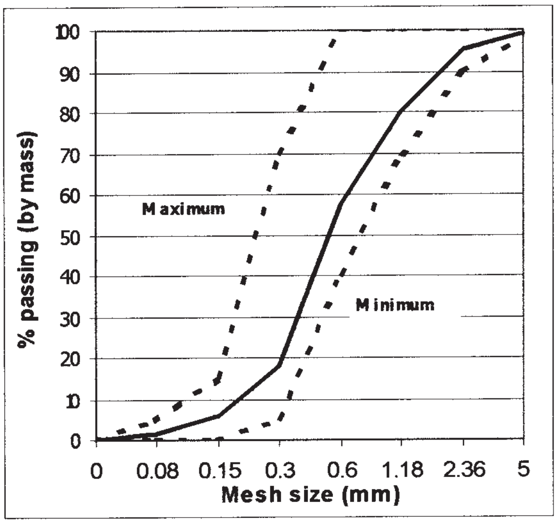

Figure 1a *Example of well-graded sand compared with BS 1200 requirements.*

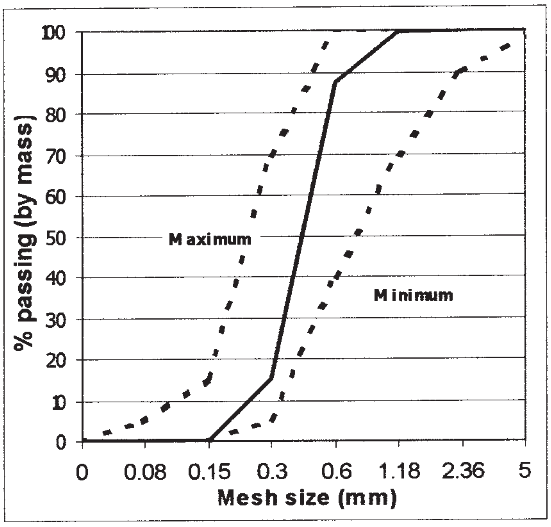

Figure 1b *Example of poorly-graded sand compared with BS 1200 requirements*

The use of coarse aggregate will increase the harshness of the mix so that the amount used should be adjusted to retain workability. Coarse aggregate should be graded and analysed separately using sieves of 6.3 mm, 10 mm and 14 mm as appropriate.

Distribution of sizes in the sand is important in order to achieve close packing in the mortar structure. Even with good distribution there will still be voids between individual particles and these need to be filled with the binder. The space between the sand particles – the

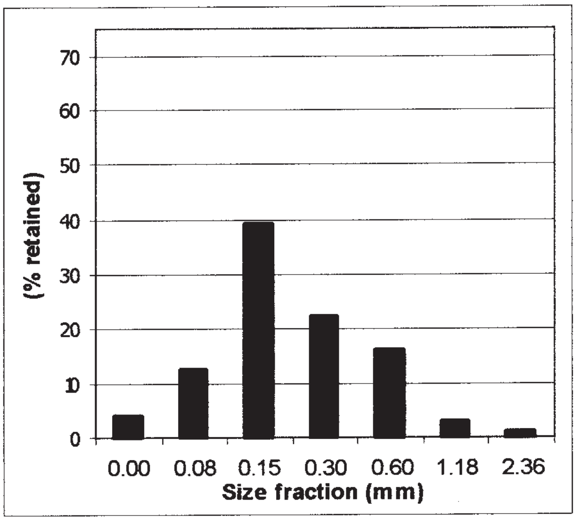

Figure 1c *Example of well-graded sand showing fraction size distribution*

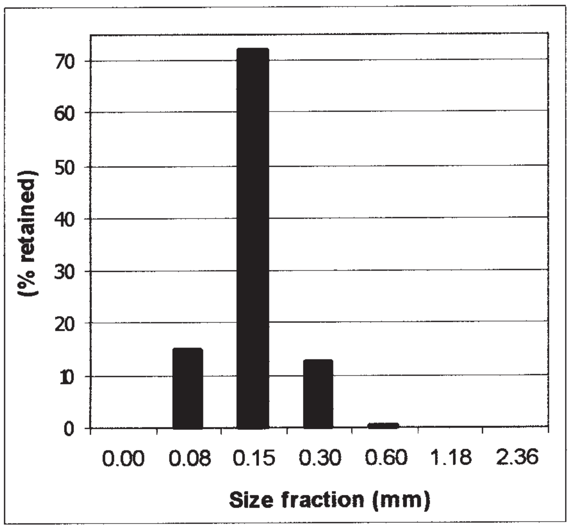

Figure 1d *Example of poorly-graded sand showing fraction size distribution*

voidage – can be measured by checking the quantity of water required to fill the space. The properties of a good mortar must include binder content sufficient to fill this void space. This filling should not be confused with the degree of permeability, which is determined by the characteristic hydration products of the binder.

Whilst the above is 'best practice' it is often more economical to use the material available locally, even though it might require a richer mix, rather than to bring in aggregate from farther afield. This is often the