CHAPTER V

PROPERTIES AFFECT PORTLAND CEMENT

5.1 Soundness

It is highly important that a cement, after gauging with water and setting in place, shall not undergo any appreciable change of volume. It is evident that all set cements undergo some shrinkage when allowed to dry out, and some expansion when continuously stored under water. These movements are quite small, and of a much lower order of magnitude than those with which we are concerned in considering the soundness of cements. Certain defective cements have been found to undergo a large expansion after setting, leading to the disruption of the hardened mass. This is a very serious defect in a cement, it does the risk of destruction of any structure in which it is used. The testing of the soundness of cements has always therefore been considered of prime importance.

Actually three errors in composition, which may give rise to unsoundness, are known

1. An excess of lime above that which can become combined with the acidic oxides of the cement mix under the condition of manufacture.

2. An excessive proportion of magnesia.

3. An excessive proportion of sulphates.

The expansion of defective cement is due to the slow hydration of certain of its constituents. Cements prepared from mixes of too high lime content, or of correct lime contents but insufficiently well burnt,

contain free calcium oxide in an unreactive, dead-burnt condition, when free calcium oxide exceeds certain limits, the cement shows unsoundness.

It was for long accepted that contents of magnesia up to 5 percent could be safely carried. Some MgO is taken up in solid solution in the other clinker compounds. It is only that has crystallised as periclase (MgO) which may cause unsoundness. The degree of unsoundness depends also on the crystal size. The quicker the clinker is cooled the smaller will be the periclase crystals formed. Hence clinkers which rapidly cooled can carry more magnesia safely than slowly cooled clinkers.

The third compound liable to cause expansion is Calcium sulphate. The increase of volume or expansion is not due in this case to the hydration of the sulphate but to the formation of calcium sulphoaluminate. The maximum amount of gypsum which form calcium sulphoaluminate, is allowed in the specifications of most countries vary from 2.5% SO_3 for cements of low C_3A content to as high as 4% for cements of high C_3A content.

Since unsoundness in cements often does not exhibit itself until after a considerable period of time, accelerated tests are required to detect it. Le Chatelier soundness tests when the free lime content is relatively high. Since the autoclave test detects expansion arising both from free CaO and MgO it has entirely replaced the other forms of soundness test in the ASTM specification. Unsoundness due to an excessive gypsum content is not detected with any certainty in the usual soundness tests.

The finer raw mix decreases free lime content because it enhances

the surface area to be sintered during the clinker formation.

5.2 Strength

The value of cement when employed as a structural material depends primarily on its mechanical strength in the set and hardened condition. A strength is due to the cohesion of the particles of the cement and to their adhesion to the grains of sand or other aggregate with which they are mixed. When used as a mortar, the adhesion of the material to the surface of brick or stone is also of prime importance. Mechanical tests therefore play a most important part in determining the quality of cement and every specification requires a certain mininum strength that must be attained under given conditions. The strength is in a high degree dependent on the conditions of mixing, preparing of the specimens, and testing, and it is necessary to prescribe the exact manner of testing in order to obtain comparable results.

Strength tests take three different forms, the specimen being subjected to tension, compression or bending. The last, commonly known as a transverse test, is not much used in cement testing. The strength developed by a cement is dependent on many factors, such as the grading of the sand or aggregate, the proportion of water used, the degree of mixing, and the temperature and humidity of the atmosphere.

5.3 Fineness

The surface area (fineness) is of more importance with regard to the quality of the cement. The more finely ground a cement, the greater the surface exposed in proportion to its mass, the more rapid rate of

hydration and the more finely a cement is ground, the greater is the strength, and particularly the early strength, it yields. An increased in fineness also affects other properties of a cement or concrete. It tends to raise the amount of gypsum required to control setting or to give optimum strength. It may slightly increase the amount of water required to give a neat cement paste of standard consistence but, in contrast, reduce slightly the amount needed to obtain a given workability in a concrete mix. This latter effect does not extend indefinitely as fineness is increased.

A given specific surface in a cement could be produced with a variety of particle-size distributions, but no final answer can be given to the question whether there is some optimum grading. Basically, strength and other properties of cements are functions of the amount hydrated and initially this will be related to the specific surface rather than to particle grading. As hydration proceeds, however, the finest particles become completely hydrated and the surface area of the remaining anhydrous material will become progressively less related to the original value, and more dependent on the original particle-size distribution. Thus, there is evidence that at one day strength is related more or less linearly to the specific surface, but that at longer ages it is influenced also by the kind of particle-size distribution.

5.4 Setting time

Setting implies loss of plasticity or workability. Setting time classified cement and is the necessary property because cement pastes must be finished from working and decorating before the cement pastes set.

So, the setting time gives the range of working time with that cement. The setting time is a somewhat arbitrary magnitude, being the time which elapses after mixing the cement with the water before the paste will resist a certain arbitrary fixed pressure. In general, the greater proportion of alumina and ferric oxide in a cement, the more rapid is the initial set. The coarsely ground and contained appreciable amounts of free lime tended to retard the set. Clinker from rotary kilns was better burnt and contained less sulphate, with improvements in grinding methods, it was also progressively more finely ground. The use of some agent to control the setting of cements then became necessary and the addition of gypsum during grinding of the clinker became general. The setting time of present-day Portland cements is controlled by the regulated addition of gypsum to the cement clinker as it is fed to the grinding mill. The amount added corresponds to about 1-3% SO_3 and is limited by specification requirements, which in all countries permit only of the presence of a certain proportion in the finished cement. It effects on strength and the presence of large quantities leads to slow expansion in the set cement, this is the reason for its stringent limitation. The infuence of gypsum on the setting of cement is not proportional to the amount added and its effect may appear quite abruptly, a small increase beyond a certain amount producing large changes in the setting time. The addition of lime, or its presence in the free condition in the clinker, assists in the retardation of set produced by the gypsum.

The methods of determining the setting time are distinguished in two periods, the "initial set" or interval between the gauging and partial loss of plasticity and the "final set" or time required for the

gauged cement to acquire sufficient firmness to resist a certain definite pressure. The vicat needle in its original form or in one of its modifications, is now used almost universally. For normal cements the initial setting time shall not less than 45 minutes, nor the final more than 10 hours.

The following factors affect the setting time.:

Setting time is reduced by:	Setting time is increased by:
under-burning of clinker	hard-burning of clinker
higher-alumina content	higher-silica content
alkalies	Sodium chloride
Soda	barium chloride
very fine grinding	magnesium chloride
	coarse grinding
	sulphates, e.g., gypsum
	iron sulphate
	hard water

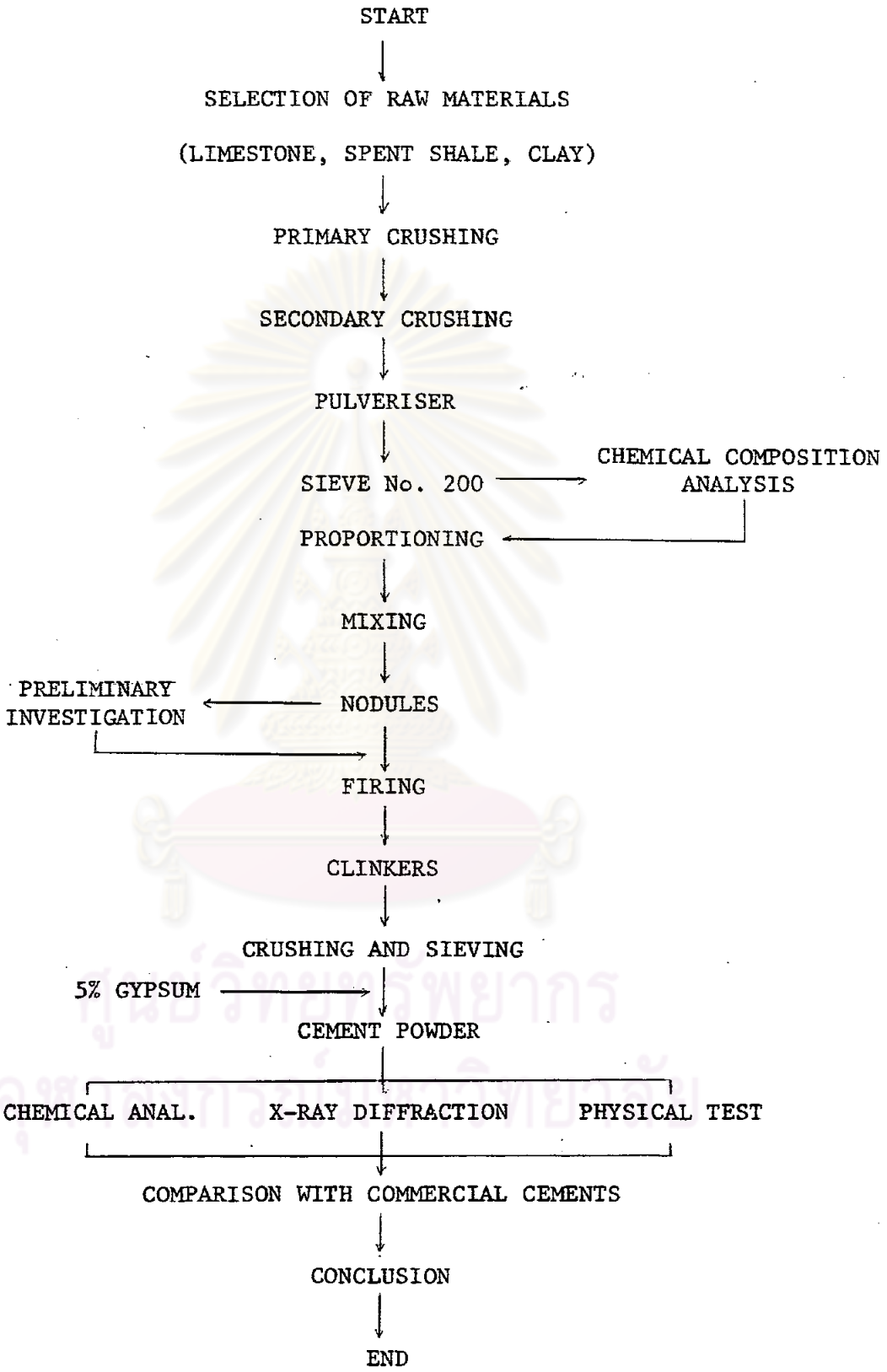

FIGURE 6.1 EXPERIMENTAL PROCEDURE CHART