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PORTLAND CEMENT, AND ITS MANUFACTURE FROM LOCAL MATERIALS.

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EXCELLENT building stone, sand, brick, and pottery clays occur in inexhaustible quantities in the neighbourhood of Sydney, but there is a singular absence of deposits of limestone, or of similar formation from which lime for building purposes may be obtained.

In the early days of the city shell lime was largely used for building purposes, but the local deposits of shells have long since been exhausted. Stone lime at one time was brought in large quantities by sea from the Manning River, distant about one hundred and fifty miles north from Sydney, but after the extension of the trunk railways extensive limestone beds at Piper's Flat, near Wallerawang, on the Mudgee branch of the Western Main Line, and at Marulan, on the Southern Line, distant respectively one hundred and twelve and one hundred and fourteen miles from Sydney, were opened up, and have supplied immense quantities of building lime to the metropolis. The lime obtained by calcination of these limestones is nearly pure, or is what is usually called fat lime. This is about the worst condition in which a lime for building operations can be used. Fat limes only harden when they become dry, or, by the union of carbonic acid, to form a carbonate of lime; this latter action requiring centuries to accomplish, hence mortars made from them are weak.

The best lime for building purposes is an hydraulic lime. There are few deposits of the limestone which yields hydraulic lime known to exist in this country, and none within a reasonable distance from the city.

Hydraulic limes are such as develop a slaking action on the addition of water, and contain sufficient of such foreign constituents as combine chemically with lime and water to confer an appreciable power of setting and hardening, without drying or access of air, in water or out of water. The advantages attending the use of mortars made from such limes are obvious. This deficiency in one of the necessary building materials is more than compensated for by the abundance and excellence of the others; and Sydney is so favourably situated as a trade centre that supplies of hydraulic lime or cement may be obtained from outside sources at a fairly reasonable rate. Very little hydraulic lime, until quite a recent date, has been imported, Portland cement being used whenever a mortar stronger than a fat lime mortar is required.

The following table of the imports of Portland cement for the decade ending December, 1889, will show to what extent supplies have been drawn from abroad—chiefly from Europe. During that period no cement, so far as the writer is aware, was made in the colony and used locally.

IMPORTS AND EXPORTS OF CEMENT—1880-1889.

Year.	IMPORTS.		EXPORTS.	
	Quantity.	Value.	Quantity.	Value.
	Barrels.	£	Barrels.	£
1880	49,196	41,855	2,795	2,517
1881	142,874	118,083	2,025	1,497
1882	156,144	124,389	5,254	4,443
1883	136,896	115,258	3,772	3,201
1884	267,352	216,353	5,817	4,866
1885	275,654	213,118	5,535	4,362
1886	352,282	229,566	28,010	17,975
1887	147,313	87,058	24,589	15,237
1888	168,486	99,531	9,701	7,130
1889	176,516	118,712	12,639	10,292

The dependence upon outside sources for a supply of building cement has led many to consider the possibility of manufacturing it from materials obtainable within the colony. A brief description of the composition of hydraulic limes and cements, and the process of manufacture, will enable the subsequent remarks with regard to the suitability of local materials to be better understood.

Hydraulic Lime.

As before stated, the colony is deficient in accessible deposits of limestone from which natural hydraulic limes may be obtained. Good hydraulic lime may be made artificially from fat limes, but as the cost would be considerable, and a comparatively small additional expense would enable a cement of very much greater strength and value to be made from the same materials, it is not likely that its manufacture will ever be undertaken, except in special cases inland, where the cost of erecting expensive machinery for making cement would not be justified. A method of making artificial hydraulic lime will be described presently.

Hydraulic limestones are impure; the impurity usually consists of clay, and the proportion in which its presence is of practical value, varies from 8 to 27 per cent.; with the smaller percentage the limestone, on being burnt and wetted, slakes with considerable energy, but not equal to that of fat lime. When the larger proportion of clay is present the least slaking energy is exhibited, and it is, in fact, hardly discernible unless the lime be ground. Hence, all hydraulic limes should be thoroughly ground to ensure their being used with safety. If the foreign matter in the limestone consists of sand, hydraulic properties would not be produced. If the proportion of sand exceed a certain limit the lime is difficult to slake, and under any circumstances the result is about equivalent to a mixture made up with fat lime and sand.

Clay is a silicate of alumina, and its physical condition is such, that on the application of sufficient heat to drive off the carbonic acid in the limestone in which it is present, followed by the addition of water to the resultant lime, the silica alumina, lime, and part of the water enter into chemical combination, producing the phenomenon of setting. The proportions of silica and alumina in hydraulic limestones vary greatly, and it is not often that the most beneficial amount is found prevailing unvaried throughout a large body of stone.

Hydraulic mortars may be made by mixing certain descriptions of volcanic ash, ground to a powder, with slaked lime. Suitable volcanic ash is found in New Zealand; excellent natural hydraulic limestones are also found there. Hydraulic mortars from the above sources are often weak and of variable and uncertain quality, though greatly, as a rule, superior to mortars made with ordinary lime. An artificial hydraulic lime may be made by adding suitable clay to fresh lime in the proportion of from fifteen to twenty parts of clay to fifty-nine to sixty-three parts of quick lime, wetting, grinding, and thoroughly amalgamating the mixture, forming it into bricks or lumps, which are then to be dried and moderately calcined. The lumps are afterwards slaked or ground to a powder, which is then fit for use, in the same way as natural hydraulic lime. This process does not require very expensive machinery, a good mortar-mill being sufficient to do all the necessary grinding operations. The advantages attending the use of hydraulic limes are so great that before works, which include the construction of a large amount of masonry or concrete, are undertaken inland, where Portland cement is very costly, the possibility of making a hydraulic lime from local materials should be thoroughly investigated. Engineers, architects and builders have grown so accustomed to the use of Portland cement that it is unlikely that at present many will care about the extra trouble necessitated in the production of a substitute. When, however, the long-looked for Local Government Bill becomes law it will cause much needed de-centralization and the local authorities of a district will no doubt endeavour to turn their local resources to the best account.

CEMENT.

Sometimes hydraulic limestones contain suitable clay in such a proportion and physical condition as to produce, on careful calcination, a lime of superior setting and hardening properties. These limes, whether ground, or unground do not slake on the addition of water, and are called natural cements. It can readily be understood that hydraulic limestones and natural cement stones are found of varying qualities, and pass from one class into the other by almost imperceptible gradations.

PORTLAND CEMENT.

This well known building material is an artificial cement made from lime, silica and alumina. The discovery of the mode of preparing it was made in England about sixty years ago, being the outcome of researches of several investigators into the composition of the natural hydraulic limes and cements. When the function of the silica and alumina in producing hydraulicity in the natural hydraulic limes was recognized, attempts were made to produce like results by calcining mixtures of carbonate of lime and clay. At first the results were not very encouraging, but the investigators were on the right track, and eventually a cement was produced which equalled any known natural cement. Improvements continued to take place, and now, by the application of chemical science and improved processes, an article is produced which probably exhibits the best possible results attainable with the materials used. Portland cement is now one of the most useful and valuable building materials that is at the command of engineers and architects, and has become so indispensable for constructive purposes that it is a staple article of manufacture or trade in almost all countries. The consumption of this material in a country affords a good indication of that country's progress.

The first works for the manufacture of Portland cement on a large scale were located near London, where chalk and suitable clay abound, and the cheapness and suitability of these materials, combined with cheap fuel and facilities for trade, ensured the permanent establishment of the industry.

For very many years Portland cement was wholly made from soft materials, and the opinion appeared to be universal that it was impossible to produce a marketable cement from anything else but chalk and clay. When, however, the chemistry of the process became better known, it was clearly seen that other forms of carbonate of lime and silicate of alumina if subjected to suitable treatment could be manufactured into a good cement. However, chalk and clay, the materials first used, being naturally soft, and, consequently, easily reduced and amalgamated, present such economic advantages that they are invariably used whenever easily accessible in preference to harder materials. Limestones and marble are a valuable source from which to obtain the lime element for a cement when chalk is not obtainable; and there are many forms of silicate of alumina, such as slate and clay shales which are efficient substitutes for river or plastic clay. Carbonate of lime, in one or another of its various forms, and clay, are so profusely distributed over the surface of the earth that there are few centres of population which do not possess, within a reasonable distance, deposits suitable for cement making. When the materials are not pure, and are of variable composition, they require careful treatment and the exercise of every precaution in the blending to produce a mixture in which the elements shall be always properly proportioned. The absence of accessible chalk deposits in this country has led many persons to believe that Portland cement cannot be manufactured here. This disability happily does not exist.

The following analysis of good Portland cement shows the proportions in which the chief ingredients, marked, * are necessary, and must be adhered to within very narrow limits. The first two are taken from Mr. H. Reid's work on concrete; the third is the average of several analyses of good cements;

the fourth is from a report by the Government Analyst (W. M. Hamlet). The percentage of silica in this is higher than usual.

	1	2	3	4
Lime *	60·40	62·81	60·82	60·00
Magnesia	1·17	1·14	1·04	
Alumina *	9·14	5·27	9·10	10·00
Silica *	21·84	24·63	22·48	25·00
Iron Oxides... ...	3·21	2·00	2·88	
Sand	0·36	2·54	0·82	
Potash	0·59	1·27	0·64	
Soda	0·53		0·42	
Carbonic Acid ...	1·40		0·37	
Sulphate of Lime ..		1·30	0·87	
Sulphuric Acid ...	1·43		0·37	

In the manufacture of a cement the raw materials must be carefully scrutinized, and the proportions of the three elements carefully and constantly checked, so as to maintain them at the requisite standard. Limestones are frequently of very uniform composition, so also are clay shales, and in this respect are favourable to the maintenance of regularity in the mixture. Clay, whether plastic or firm, is a compound of silica and alumina with water, chemically known as hydrated silicate of alumina. The silica and alumina, either alone or in combination, are practically infusible. The presence of iron, potash, or soda will cause fusion to take place. Lime alone is infusible. When mixed with silicate of alumina, fusion will take place at a temperature depending upon the proportion the alumina bears to the silica, and these combined to the lime. The presence of iron or alkalies in the mixture facilitates fusion, and there is a danger of slag or glass being produced in the kiln. This, if it should form, is almost a worthless product, as, in any case, the powder produced from it is almost inert. The temperature should only be pushed sufficiently far to cause incipient vitrification of the lime and silicate. The union of