
Written for *Mines and Minerals*, by Richard K. Meade, Author of *The Chemical and Physical Examination of Portland Cement*

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(An unrelated article that is included in the images of the above article is entitled, “Intermediate Side track for Tail-Rope Haulage,” written for *Mines and Minerals*, by L. L. Logan, pp. 485.)
PORTLAND CEMENT.

In the English Channel, nine miles off the coast of Cornwall and to the west of Plymouth harbor, there rises from 150 fathoms of water a group of granite rocks. These Kildesstone rocks are covered daily by the tide and until the eruption upon them of the first lighthouse, a wooden affair, in 1606, many ships had been wrecked upon them. This flimsy structure was entirely too frail to stand the fierce onslaughts of wind and wave, and three years after its completion it and its architects were blown into the channel. The next lighthouse, also of wood, had a longer life but was destroyed by fire. When the time came to build a third tower of warning, the necessity of erecting a more enduring structure was understood, and one, John Smeaton, an English engineer, was appointed to set about the difficult task. It is not our purpose to tell of his difficulties and of his achievements, of how he took the trunk of an oak tree for a model and constructed on these rocks one of the most wonderful pieces of engineering of his time, but rather of a discovery which he made in connection with his work.

Lime mortar will not harden out of contact with the air. Lime, Ca(OH)2, forms a hydroxide, Ca(OH)2, in contact with the air. This forms calcium carbonate, CaCO3, by reacting with the carbon dioxide, CO2, in the air, thus hardening the mixture. General Tremaux, who had occasion, in 1822, to demolish one of the bastions of Strasbourg, erected by Vauban in 1696, found that in the interior the mortar after the lapse of 135 years was as hard as before; and as though it was the first day it was laid.

From the nature of the structure designed by Smeaton, which was to stand enormous strains of wave and wind, a good foundation was necessary. Smeaton was called upon to devise a mortar that would harden out of contact with the air. He therefore undertook a series of experiments looking to the discovery of a material which would harden under water. As the result of his researches, he exploded the theory previously held that the hardest and purest limestones made the best lime, and found in its place that the clayey limestones when properly treated produce a lime or cement which would harden out of contact with the air and under water.

In 1837, the date of Smeaton's discovery, to 1824 nothing was added to man's knowledge of cement, but in the latter year, Joseph Aspdin, a bricklayer at Leeds, England, obtained a patent for the manufacture of a cement, which he made from burning an artificial mixture of the scarpings from roads repaired with limestone (consequently powdered lime- stone and clay). This material, he called Portland cement, from the similarity of its appearance, when hardened, to that of the Portland marl from the Portland quarries in England. It must be observed that Smeaton prepared his hydraulic cement from the rock just as it came from the quarry, the name hydraulic coming from its property of hardening under water. He used a limestone stone found in Alberthaw, England, which contained a considerable proportion of clay. Aspdin, on the other hand, made his cement of the mixture of limestone and clay. This diametrically opposed method still holds for Portland cement, and differentiates it from all other hydraulic cements—it must be prepared from an artificial mixture containing the proper elements in the proportions found to give best results in practice. Why the Portland should be superior to the natural or pure rock cements is not hard to understand when one recalls that, given limestone and clay, it will be easy to mix these two in any desired proportion while it would be very difficult to find in nature the two already mixed in just this proportion. The nearest approach to such a natural cement rock is to be found in our own Lehigh Valley, around Allentown, Pa., and in Belgium.

Aspdin immediately began the manufacture of his new Portland cement and other firms, lesser under his patents, began to imitate him. The new cement was used quite soon, and it was used largely in the Thames Tunnel, constructed in 1825, the first use of its kind. It was not until 1832 that the first cement works were established in Germany, near Stettin. Other works followed. These at first used English methods, but as the German chemists studied the problem more closely, they began to originate ways and tricks of their own. They inaugurated a system of testing their cement, a system still in use today, that is the best results as shown by their tests. The outcome of this was soon to displace English by German cement outside of England, and England is only now wakening to the fact that what should be her industry has slipped from her, and English manufacturers are now trying vainly to regain lost export trade.

In America, the first Portland cement works were started at Coplay, Lehigh County, Pa., by the late D. O. Sayler. This plant, now the Coplay Cement Co., is still in operation, and its cement, "Saylor's Brand," ranks with the best cements of the world. Natural rock cement had been made in America Rosendale, Ulster County, N. Y., since 1828, at Louis ville, Ky., since 1829, and at various other points in New York, Kentucky, Ohio, Michigan, and Maryland, and the hydraulic properties of the cements made from the limestones of the Lehigh Valley were known, but Sayler's plant at Coplay was the first to manufacture genuine Portland cement. Other plants to follow the one at Coplay, in America, were the Empire Portland Cement Co., of Senators, N. Y.; the Buckeeye, near Bellefontaine, Ohio, and the Western, at Yankton, S. D.

It is interesting to note that the section within a radius of 15 miles of Coplay, the first home of the cement industry in America, now produces over 72 per cent. of the total American output. From this section, in the busy months of the year, over 1,000,000 barrels of cement are shipped on an average. Recently, in one day, November 1, 1901, 21,000 barrels were shipped from the Central mill of the Atlantic Portland Cement Co., of Northampton, Pa. It required over a mile and a half of cars to move this quantity. The manufacture of Portland cement has become in the last ten years a recognized established American industry. Its growth in that time has been marvelous. Exactly how rapid the table given below will show.

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**FIG. 1. GRAPHIC TABLE REPORT, N. J. STATE GEOLOGY.**

This table also shows us the increasing demand for Portland cement, and the falling off of imports. The domestic production now seems to have caught up with the consumption, as there is a falling off in the imports for the nine months ending September 1, 1901, of 65 per cent. over that of a corresponding period in 1900. Indeed, it is feared that home production will be in excess of the demand when the works now in construction or proposed are in operation. It is hoped, however, that new uses for cement and the establishment of an export trade will relieve this tendency to overstock the market. There is already a picking up in this latter field, and the exports of the last nine months were four times as great as during a corresponding period of 1900. Belgium, Pa., and in Belgium.

For a long time the German cements were considered the best. This was due in part to their marked superiority over many of the English brands, but principally to the rigid testing to which the German manufacturer subjected his product and the guarantees based upon this, which he gave. German cement was also tested by German methods will give apparently higher results than American cements tested by American methods, but, tested by the same method, the American cements will give fully as good results. Indeed, in a report to the Mayor of Philadelphia, Mr. Richard H. Humphrey states that the American cements are superior to the German ones. Other engineers also make the statement that many American cements are as carefully made, show as good tests, and prove as satisfactory in practice as the best German cements.
The first Portland cement made by Aspden, while a great improvement over the natural rock cement of Smeaton, was still a very crude building material in comparison with any of the well-known brands of today. At first the kiln used for burning the cement was the ordinary dome-shaped lime kiln of that time, modified by the addition of a descending part for cooling. Rules of experience were discovered for making the mixture of clay and limestone, or else trial tests in small kilns; and the grinding machinery was of the crudest description. However, when burned night and day until stopped for repairs, they had disposed of three lime kilns. All plants of any pretentions employ a chemist, who daily analyzes the raw materials and proportionates them so as to get the best results, while modern grinding machines pulverize the cement clinker so fine that over 90 percent of the ground product will pass through a sieve with 100 meshes to the linear inch.

Portland cement must not be confounded with natural, Roman, or Rosendale cement. Portland cement is made by heating at incipient fusion an artificial mixture of limestone and clay or other materials rich in alumina, silica, and lime. Natural cement, on the other hand, is made by heating natural clayey limestones until part of the carbon dioxide is driven off. These limestones are found in various parts of the United States, notably, Rosendale, N. Y., Louisville, Ky., Cumberland and Roundroy, Md., Utica, Ill., and Balcony Falls, Va. In the case of either Portland or natural cement the resulting burned mass or clinker, as it is called, is finally ground.

When this powder is mixed with water to a stiff paste and allowed to stand for a sufficient time, the paste undergoes chemical change and a solid mass results. This "setting," as it is called, usually requires but a few hours at most. After setting, a slower chemical reaction goes on, and the mass gradually gains strength. Usually this gain of strength or hardening extends over a period of from six months to a year—sometimes even beyond this period. Quite a number of chemists have examined into the chemical composition of cement and the changes which it undergoes when set. Their results and conclusions are not very concordant, and there is still much room here for investigation.

Le Chatelier's ideas are probably nearest the truth. He undertook a very complete series of experiments, in which he not only examined hardened cement and cement clinker, but also cemented pure lime, silica, and alumina in varying proportions.

As the result of his work he concluded that Portland cement was a mixture of tricalcium silicate, $3CaO\cdotSiO_2$, and tricalcium aluminate, $3CaO\cdotAl_2O_3$. When mixed with water the following reaction or change takes place:

$$2(3CaO\cdotSiO_2)+9H_2O=5Ca(OH)_2\cdotSiO_2+4Ca(OH)_2$$

The calcium hydroxide formed then unites with the calcium aluminate and the water, giving hydrated basic silicate and hydrated basic aluminate.

The strength of the cement is due to the tricalcium silicate, the rapidity with which it sets to the tricalcium aluminate. Cement made from lime and silica only, takes a long time to set and slowly hardens to a very rough, hard mass. Cement made from lime and alumina, however, shortens the time required for setting. Cements which set moderately slow are likely to give best results, as in the end they will produce the harder mass. In submarine work, quick setting cements are used for obvious reasons.

It is possible from these two formulas $3CaO\cdotSiO_2$ and $3CaO\cdotAl_2O_3$ to calculate the correct proportion of lime which should be present for various quantities of silica and alumina. In the first formula, for every molecule of silica there are three molecules of lime, and since the molecular weight of silica is 60.04 and of lime 16.93, for every 60.04 molecules of silica present in the compound, there should be 168.93 pounds of lime, or 2.78 of lime for 1 of silica.

Similarly, for every molecule of alumina there should be 3 of lime, or for 102.2 pounds of alumina 168.93 of lime, or 1.68 of lime for 1 of alumina.

The importance of correctly proportioned cement will be well understood when it is known that when lime, that is an excess of lime over that chemically combined with the silica and alumina, causes cement to distort and crack after setting. Beside the silica, lime, and alumina, essential to hydraulic cement, iron, magnesium, and sulphur are always present. Iron oxide forms hydrous compounds with lime and counts as alumina. The color of the iron, the amount of other accompanying cement slow setting properties, and should be present in less than 2 percent of sulphur trioxide in which form it usually exists and should not be present in larger proportion than 2 percent. A larger amount than this causes the cement in time to expand and crack. Below are the analyses of some well-known cements:

<table>
<thead>
<tr>
<th>Silica</th>
<th>Alpha</th>
<th>Slayders</th>
<th>Empire</th>
<th>Sandusky</th>
<th>Dyckerhoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.83</td>
<td>22.58</td>
<td>22.04</td>
<td>25.08</td>
<td>26.64</td>
<td></td>
</tr>
<tr>
<td>8.71</td>
<td>15.59</td>
<td>21.65</td>
<td>6.15</td>
<td>7.15</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>3.40</td>
<td>5.40</td>
</tr>
<tr>
<td>lime</td>
<td>61.45</td>
<td>62.58</td>
<td>62.05</td>
<td>62.36</td>
<td>63.66</td>
</tr>
<tr>
<td>Magnesia</td>
<td>2.02</td>
<td>3.14</td>
<td>3.52</td>
<td>1.21</td>
<td>2.33</td>
</tr>
<tr>
<td>Sulphur trioxide</td>
<td>1.53</td>
<td>1.98</td>
<td>2.75</td>
<td>1.60</td>
<td>1.30</td>
</tr>
</tbody>
</table>

The composition of some of these materials is shown below:

<table>
<thead>
<tr>
<th>Silica</th>
<th>Alpha</th>
<th>Slayders</th>
<th>Empire</th>
<th>Sandusky</th>
<th>Yankton, S. D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>22.84</td>
<td>22.58</td>
<td>22.04</td>
<td>25.08</td>
<td>26.64</td>
<td></td>
</tr>
<tr>
<td>8.71</td>
<td>15.59</td>
<td>21.65</td>
<td>6.15</td>
<td>7.15</td>
<td></td>
</tr>
<tr>
<td>lime</td>
<td>61.45</td>
<td>62.58</td>
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<td>63.66</td>
</tr>
<tr>
<td>Magnesia</td>
<td>2.02</td>
<td>3.14</td>
<td>3.52</td>
<td>1.21</td>
<td>2.33</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>34.49</td>
<td>40.63</td>
<td>35.01</td>
<td>35.40</td>
<td>4.05</td>
</tr>
</tbody>
</table>

The "cement rock" of the Lehigh Valley possesses many advantages over other forms of raw material. In it, as will be seen by the above analysis, the silica and alumina are mixed with alumina in such amounts that the required amount of lime. Since the mixture has been done by nature it is very intimate and thorough, and the union of the silica and alumina with the lime in burning is assured. Most of this rock is used in lime, and the amount of pure limestone is necessary to bring the mixture to the correct composition. These materials, however, are rather hard, but since the rocks are of a very porous nature, fine grinding is unnecessary. The composition of marl is very similar to that of lime, and this material is extensively used in the central States. It is soft and unconsolidated, and can be easily and cheaply reduced to the required degree of fineness. Chalk is extensively used in England, Germany, and France for Portland cement making. It lies between marl and limestone in point of hardness, and is similar to these substances in composition. In Michigan, alkali waste, a form of calcium carbonate precipitated in the manufacture of caustic soda, has been used mixed with clay for cement making.

Clay is used extensively as the basis of the silica and alumina in cement mixture. It should be as free as possible from quartz sand, or free silica, as it requires very fine pulverizing of these quartz particles to get them to combine with the lime. If sand is present the amount should be determined, and not calculated as silica in making up the cement mixture, the resulting cement will probably be over-limed, that is, contain free lime, due to the fact that the sand has not combined with its proportion of lime, and both substances of lime are not satisfactorily for use with clay, as it is very hard and must be ground very fine to mix properly with the clay. Clay requires several times its own weight of limestone to make a correct cement mixture, and the cost of grinding such large amounts of hard stone is considerable. For the same reason slate and shale, which are solidified clay, are not suitable for cement making. Most of the rocks used for preparing natural cements are unsuitable for the preparation of Portland cement by admixture of limestone, marl, etc., as they contain a high percentage of magnesia. If these are burned at the high temperature over
Intermediate Side Track for Tail-Rope Haulage.

By L. L. Logan.

The accompanying figure shows a plan and elevation of an intermediate side track for a tail-rope haulage in operations at the Slope Mine at Robinsondale, Pa. There are three tracks at this point, the main one in the middle, the loaded one to the left going out, and the empty one to the right. The main track is always kept clear of standing cars. As shown in the figure, it has a grade of about 5 per cent. in favor of the loads, starting from a point near the outside end of the bridge and on this pitch until it is about 6 or 8 inches lower than the loaded and empty tracks on each side, when the grade for the remainder of the side track becomes about level or slightly in favor of the load.

The reason for having the main road lower than the side roads of the side track is to insure the tail-rope to take the rollers when loads are hauled off the side track, and to leave rollers properly when empty cars are placed on the side track. The loaded track has about 1 per cent. grade in favor of loads, and the empty side track is about level.

It will be noticed that the tracks are so arranged that the loads coming from right or left butt heading can be hauled onto the loaded track to the left and the empty which are placed by the rope to the left coming in can be taken to right or left butt heading. In the first case, the loads are hauled under the bridge; in the second, the empties. The tail-rope passes through a box under the switch for the empty track, thence between this track and the main track. The haulage or main rope keeps the center of the main track throughout. The large sheave wheel is placed at the far end of the inside end of side track. But two pair of latches (those marked throw-latches) need attention. The men catch the loads and pass between these and the rib until they come to the outside end of the side track, where they cross the roads and ropes and continue between the empty trip and the other rib until they come to the head end of this trip. They are then hitched to the cars and proceed to make another trip to butt headings.

The engineer always stops when a trip of cars is near this sidetrack unless he is bid to pass without stopping, which is generally done. As the party who signals the engineer stands where the main car cross the tracks, there can be no danger to the mules even though they are unattended. The sidetrack has been in use for over one year, and no accident of any kind has occurred. Empty trips pass in and loaded ones out, while drivers place cars on the loaded track and take empties away. The cars and mules never interfere with the wires, which continue to end side track without deflection.

Before this intermediate side track was put in by the writer, a local hoist was used to haul loads from end side track to rope, as the grade was too great for mule haulage. The grade was also such that the empties would not take the rope in with them. This necessitated a mule and driver to place the empties on inside turnout. The hoist, engineer, driver, and mule are now not needed; the outside haulage engine does all the work.

Although conditions were especially favorable for this style of side track there is no doubt but that it could be used to advantage elsewhere where considerable coal must be put on the rope at intermediate points. In grading next the bridge, care must be taken that the grade is kept under the maximum on the haul. As will be seen by referring to figure, the empty and the loaded track are cut down in solid rock near crossing, while the main track is raised. In this way sufficient height is gained for the mules and cars to pass under the bridge. Large iron rails are used on the bridge, and 4-inch oak plank laid alongside of them. Two 2-inch cross-planks are bolted to the 4-inch plank, and center posts placed under them as shown. Regular tents of square timber are at the ends of the bridge.

This side track is quite as simple in operation as the ordinary end tail-rope side track—in fact, more so, as the ropes do not interfere with the mules. The side track holds one trip, or 16 to 24 cars, depending on the number ready. The output of the mine is 600 to 800 tons a day. The grade next the bridge should be somewhat less than the maximum grade on the haul, so as not to increase the stress in the tail-rope by putting in the bridge, either by pulling in empties or holding back loads. This haulage road is 4,500 feet long.

The figure shows the grades of tracks and measurements. The arrows indicate the direction the cars run on the several tracks, except in cases showing direction of pitch, where the amount is stated.

Correction.

In the April issue an error was made in the list of successful candidates at the mine foremen’s examination in the Eleventh Bituminous District. First-grade mine foremen’s certificates were granted to A. N. Price of Pleasants; Archibald Swain of Tarr; Andrew Laiing, Summit Mine; Albin S. Snyder, Summit Mine. It was erroneously stated that the above received certificates of the second grade.