Design of a Portland Cement Plant

H. G. R. Quin

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Quin, H.G.R.
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THE DESIGN OF A PORTLAND CEMENT PLANT.

Utilizing

Blast-Furnace Slag.

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THESIS

Presented to the

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A. M. Raymond

Dean of Eng. Studs.

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The Design of Portland Cement Plant
Using Slag-Limestone Mixture.

The object of this thesis is the design of a plant for the manufacture of Portland cement, which is to have a capacity of 500 barrels per day of 24 hours. The raw materials to be utilized are blast-furnace and other slags produced in iron and steel industries. The plant is to manufacture a true Portland cement using a slag-limestone mixture, where the slag takes the place of the clayey materials usually employed in Portland cement manufacture. Beside the object above stated the author had the end in view of becoming acquainted with the chemical side of the manufacture, as well as the engineering so before entering into a discussion of the plant and machinery, a brief consideration of the former will be made.

Nature of Slag Portland Cement.

This cement is essentially a true Portland and not a real slag cement, the method of manufacture being very little different from that of common Portland cement. This cement has very good qualities and is vastly superior to any slag cement made without calcination. These slag cements which occasion is not to refer to are mixtures of slag, which has been suddenly cooled by quenching in water, and slaked lime. This addition of lime increases the hydraulic properties, which however, are possessed in a large degree by the suddenly cooled slag in itself. In the manufacture of Iron Portland cement as it sometimes called, slag is utilized as the clay ingredient is in the usual clay-limestone mixture.
Nature of Slag which can be Utilized.

All slags cannot be utilized in Portland cement manufacture, and hence a slag brick plant which can use slag of inferior qualities is usually run in conjunction with cement plant so that there will be no financial loss, for furnace men pay no attention to the slag qualities when those of the iron are inconsideration. Slag consists essentially of \( \text{Al}_2\text{O}_3 \) alumina, \((\text{CaO})\) lime, \((\text{SiO}_2)\) silica, small percentages of \((\text{FeO})\) iron oxide, \((\text{MgO})\) magnesium oxide, and sulphur. Slag may therefore be considered a very impure limestone or very calcareous clay from which carbon dioxide has been driven off. The slag to be of any use must be cooled suddenly, which is best done by running it into water, while in a molden condition. The more basic a slag is in its chemical properties, the more valuable it is for cement manufacture. Those especially suited for this purpose should show from 27 to 32 per cent silica, 10 to 22 per cent alumina, 48 to 56 per cent lime, 1 to 2 per cent magnesium and not above 1.25 per cent of sulphur. The following table shows the limits in chemical composition of slag used in a German cement plant.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{SiO}_2)</td>
<td>30-35</td>
</tr>
<tr>
<td>(\text{Al}_2\text{O}_3)</td>
<td>10-14</td>
</tr>
<tr>
<td>(\text{FeO})</td>
<td>.2-.1 2</td>
</tr>
<tr>
<td>(\text{CaO})</td>
<td>46.49</td>
</tr>
<tr>
<td>(\text{MgO})</td>
<td>.5-3.5</td>
</tr>
<tr>
<td>(\text{SO}_3)</td>
<td>.2-.6</td>
</tr>
</tbody>
</table>

Slag has one quality, which beside cheapness, makes it use advantageous and that is the fact that the lime it contains is already decarbonized and hence requires less fuel for
clinkering than a clay-limestone mixture.

**Nature of the Limestone.**

The other raw material used in making slag Portland cement is limestone, which should have the following qualities:

1. Uniformity of composition and structure.
2. Should be fine grained.
3. Low per cent of magnesia so that the per cent of magnesia in cement will not exceed three per cent.
4. The alumina content should not be high enough to disturb proper alumina-silica ratio.
5. Content of Fe₂O₃ must not be too high so as to increase the amount of this substance in the cement beyond 4%.
6. Should be free from concretionary iron sulphide and low in sulphur.

**Method of Making Portland Cement from Slag-limestone Mixtures.**

There are three methods in use for the manufacture of Portland cement from slag-limestone mixtures. These are briefly as follows:

(1) The granulated slag is dried and powdered very finely. Before, the final grinding a calculated amount of limestone which has been dried and crushed similarly to the slag, is added. This mixture is clinkered by running it into rotary kilns, after which process the resulting clinker is ground. Portland cement of high grade is the result.

(2) The granulated slag is dried and mixed with proper amount of limestone, which has been previously dried and powdered.
Slaked limed is added to bring the cement up to correct composition. After fine pulverization in tube mills the mixture is made into a slurry by the addition of 8% of water and is then formed into bricks. The bricks are then built into chamber kilns and burnt. Then the clinker is treated as before.

(3) The slag is granulated by allowing the molten material to run into water and is mixed while still wet with crushed limestone in proper proportions. The mixture is then run through a calciner whose temperature is enough to partly powder the material and to reduce most of the limestone to CaO. The mixture is next clinkerized in rotary kilns.

Of these three processes, the second is unadapted to American engineering practice, while the third is not used in this country although apparently a good process.

**References on Slag-limestone Mixtures.**

Eckel, E. C., Cements, Limes, and Plasters

P. 411-415

Eckel, E. C. Preparation of slag limestone mixtures

Municipal Engineering

V 25 P. 227-230

Jantzen, Utilization of Blast Furnace Slag.

Journal of the Iron & Steel Institute

#1 P. 634-7, 1903.

Lathbury and Spackman,

Clinton Cement Co. Plant,


The Rotary Kiln P. 82-85
The process for which the plant described in this thesis was designed has been referred to before, and is the first process discussed. The dried granulated slag is ground and is then mixed with a calculated amount of limestone which has been treated similarly. This mixture is a very fine powder and clinker in rotary kilns. The clinker is then pulverized very finely and is Portland cement.

Drying and Crushing Plant.

This consists of two Allis & Chalmers rotary driers and a #5 gates gyratory crusher. The driers are long boiler steel cylinders about 40'x5' free to rotate and driven by gearing. They have a fire-place at one end and a flue at the other. The material to be dried is fed in at the stack end and works its way to the other end where it is discharged into a screw conveyors. The foundations for all these machines are to be built of Portland cement, concrete. They are to be driven by twenty horse power motors. Besides the above equipmment conveyers are to be installed for carrying the raw material from the storage bins, and also conveying and elevating machinery, for transporting the dried materials to the grinding room.
## DRYING PLANT DATA

<table>
<thead>
<tr>
<th>Machinery</th>
<th>Capacity of Single Machine</th>
<th>H. F. required</th>
<th>Cost</th>
<th>(approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Machinery</td>
<td>Foundation and Support</td>
</tr>
<tr>
<td>2 Rotary Dryers</td>
<td>5-10 tons per hr.</td>
<td>20</td>
<td>$3000</td>
<td>$600</td>
</tr>
<tr>
<td>1 Gates Crusher</td>
<td>5</td>
<td>50</td>
<td>$1700</td>
<td>$100</td>
</tr>
<tr>
<td>Totals</td>
<td></td>
<td>70</td>
<td>$4700</td>
<td>$700</td>
</tr>
<tr>
<td>Total cost of drying Plant</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Plant For Grinding Raw Material.

From the drying plant the dried materials are carried separately to bins in the grinding plant where the preliminary grinding is done in ball mills. The ball mill in simplest form consists of a revolving cylinder having die plates arranged around the circumference and the grinding is done by steel balls. The perforated die plates are arranged so as to make a series of steps over which the balls drop when the cylinder is rotated, thus grinding the material. The position of the die plates is such that the over size is automatically returned to the action of the balls. The circumference is enclosed by screens through which the ground material passes to a collecting bin. The following table by Allis Chalmers gives this data concerning this type of ball mill.

<table>
<thead>
<tr>
<th>Size</th>
<th>weight</th>
<th>Capacity</th>
<th>Power required</th>
</tr>
</thead>
<tbody>
<tr>
<td>no.</td>
<td>without charge of balls</td>
<td>on Clinkers 20 Mesh.</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>29500</td>
<td>12-16 Bbbs. per Hr.</td>
<td>30-40 H. P.</td>
</tr>
<tr>
<td>8</td>
<td>41100</td>
<td>18-24 &quot; &quot; &quot;</td>
<td>40-50 H. P.</td>
</tr>
</tbody>
</table>

An improved type of ball mill is in the market known as a Kominuter, for which some advantages over the common type of ball mill are claimed. This machine is constructed so as to carry 50% more balls than the #8 ball mill. It requires about the same horsepower as the ball mill and the following claims are made for it;
52 % more screening surface.
50 % " Balls
65 to 85 more output.

The kominuter appears to possess some advantages over the ball mill and therefore, it was decided to use it in connection with this plant.

The fine grinding is done in tube mills, which are steel cylinders measuring 5 X 22 feet. The machine is supported by hollow trunions through which the material is fed and discharged. The cylinder is partly filled with pebbles which do the grinding when the machine is rotated.

DATA FOR GRINDING PLANT.

<table>
<thead>
<tr>
<th>Machinery</th>
<th>Capacity</th>
<th>H. P.</th>
<th>Cost (Approximate)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Machinery</td>
</tr>
<tr>
<td>2 Smidth Kominuter</td>
<td>24 bbls</td>
<td>90</td>
<td>$8800</td>
</tr>
<tr>
<td>2 (5' x 22') Tube</td>
<td></td>
<td>100</td>
<td>$5600</td>
</tr>
<tr>
<td>mills</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>190</td>
<td>$9200</td>
</tr>
<tr>
<td>Total cost of grinding plant</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The ground and mixed raw material is brought from the grinding plant to bins at the head of the rotary Kilns. The Kilns are fire-brick lined iron tubes, 100 feet in diameter and 100 feet in length. It was decided to use these long Kilns, since the tendency of modern practice is a long that line. Kilns of 150 feet in length are also coming into use and prove to be economical. The Kilns are supported on rollers and power is applied through a system of gearing. Each Kiln is driven by a 20 H.P. motor and has a capacity of 300 barrels per day. Two 80 foot Kilns would probably do the work but it was thought advisable to allow leeway for shut downs for repairs and other causes.

The cost of one Kiln outfit including Kiln, raw material bin, coal bin and conveyer, will be about $6500.

**Kiln Outfit.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Kiln (etc)</td>
<td>$13000</td>
</tr>
<tr>
<td>3 Coal pulverizers (cyclone)</td>
<td>$3000</td>
</tr>
<tr>
<td>Briaks for lining and setting Kilns</td>
<td>$1200</td>
</tr>
<tr>
<td></td>
<td>$17800</td>
</tr>
</tbody>
</table>

The cooling of the clinker is to be done by piling in heaps in a yard, so no special machinery will be required to accomplish that end.

The clinker grinding plant is in all respects similar to that for grinding the raw material, consisting of two Smith Duminater and two #16 tube mills (5' x 22').
Conveying and Elevating Machinery.

For handling crushed limestone:

1 Bucket elevator 36' long.
   (suited for vertical position)

For handling granulated slag:

1 Bucket elevator 31' long.
   Inclined 60 degrees.
   Approximate cost--------$150

For handling dried raw material:

1 Pan conveyor-----34' long
1 bucket elevator--36 feet long
1 screw conveyor---31 feet long
1 "       " ---16 feet 
   cost of above machinery------$250

For handling ground raw materials:

1 Screw conveyor-----22 feet long
1 Elevator (bucket)--37 "       "
1 Screw conveyor-----18 "       "
1 Elevator (bucket)--36 "       "
   (75C inclination)
1 Screw conveyor-----50 "       "
   Cost------------------------$500

For handling hot clinker:

1 Pan conveyor-----35 feet long
1 Elevator(60 degrees) 20 feet long
1 Screw conveyor-----30 "       "
   Cost------------------------$250
Cold Clinker handling Machinery.

1 Elevator---------30 feet long
(inclination 60 degrees.)
1 Screw conveyor----40 feet long
Cost-----------------§200

Cement handling machinery.

1 Elevator (bucket)---------36 feet long
(inclination 75 degrees)-----
1 Screw conveyor-------------21 " "
1 " " ------------------23 " "
1 Elevator------------------26 " "
(inclined 60 degrees)
1 Screw conveyor-------------40 " "
1 " " ------------------85 " "
Approximate cost-----------------§1000

Cost of Buildings.-------------------

As a plant of this kind is to be permanent in character, being located near the blast furnaces and not depending on a natural occurring source of supply; the buildings are to be constructed of brick and steel. The cost of each building will approximate §10000.

Power.

Power is to be supplied to the machinery by induction motors, since they are best suited to the dusty atmosphere of a cement plant. Power will be required as follows;

Drying and crushing Plant-70 H. P.
Grinding " -190 H. P.
Kiln House Plant--------80 H. P.

Clinker Grinding Plant-------------------180 H. P.

Total------------------------530 H. P.

These figures represent the output of the motors.

Cost 600 H. P. Motors\(\text{\&}\)transformers--------\$18000

Cost Data:

- Drying plant------------------------\$5600
- Grinding "------------------------9700
- Kiln House------------------------17800
- Cement grinding------------------------9700
- Shafting belts and pulleys and setting up------------------------5000
- Conveyors------------------------2350
- Buildings and mins------------------------30000
- Freight------------------------10000
- Plans and specifications and superintendence------------------------3000
- Office and laboratory------------------------1500
- Motors------------------------18000

Total cost of Plant \$130650

References:

Those already given,

Geological Survey of Ohio,

Manufacture of Hydraulic Cements

(Fourth Series, Bulletin No. 3.)
The pulverizers would be placed 10 feet nearer the kiln than above shown were it not for the belt air being there. It can be driven from the opposite side if desired.

By drawing the belt down to the requirements of the kiln (say 300 ft per hour) a small furnace of boiler is thrown in with the advantages that combustion is improved. There is a saving in coal.

Each pulverizer required 13 actual bhp. It should be given 18 1/2 for this. It should be bought in 200 hp. each.

The EXTRA pulverizer on a stand and on a truck (wooden) behind the coal pulverizers. It handles any one machine for a few hundred tons of ore in the case of accidents or in case of breakage of machine or the old-fashioned manner, shown here for use.

This idea is for a small the one you saw in Shanklin. Both are to efficiencies above.

This idea was drawn by Portland cement Works for own use.

Copy of our catalogue on lead cement Institute.
LOCATION

or

BUILDINGS

Rail Road. R.O.W.

Grinding of Raw Material

Clinker Grading

Kiln House

Packing Room

Coal Storage Reservoir

Compliments of

Portland Cement Plant

May 1916