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Creators: Zilch, Nelson W.

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USE OF BLAST FURNACE SLAG

By NELSON W. ZILCH, M.E. 2

In the construction of buildings, highways, and the structures supporting them, the locally available material should be used whenever practicable. No one of the local building materials could be expected to supply the demand imposed by such building programs as have been completed during the past few years and which will doubtless be continued far into the future.

Among the locally available materials for highway, bridge, and building structures in many parts of the United States adjacent to the iron and steel centers is blast furnace slag.

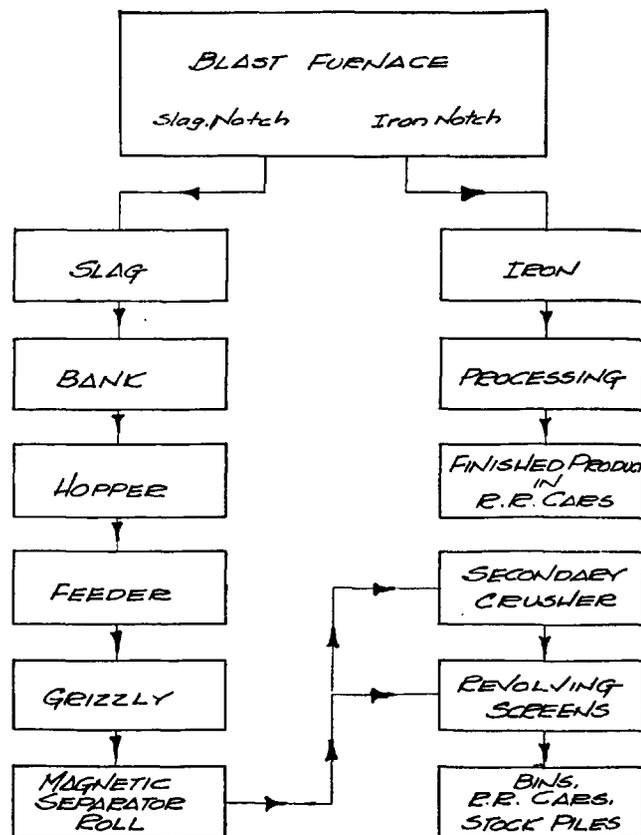
The Germans were the first to develop the principle of the modern blast furnace. Soon after its development it was introduced into England and before long her iron industry "boomed" to such an extent that she became the leading iron producer of the world. This distinction was held by England until 1880, when the United States began to take the lead. This leadership has been retained until the present time.

The possible volume of production of crushed and screened blast furnace slag is in an established ratio to the production of pig iron. Although the individual furnace, or the furnaces of an entire district may vary greatly, it is a safe estimate to anticipate that throughout the industry as a whole, there will be a slag production of 50 per cent of the tonnage represented by the pig iron produced.

There are almost four hundred blast furnaces in the United States, practically all of which are located east of the Mississippi River, and on a general average there are 80 per cent of them in operation.

The commercial use of slag is by no means a present day discovery. Volcanic lava, which is practically identical with slag, was used for various purposes early in the Christian era. During the time of the Roman empire, Pliny and Vitruvius mentioned "pozzuolana" as being used in the place of sand in the construction of many aqueducts and viaducts which have stood for centuries, and parts of which are still standing. They are true examples of the durability of this material. Pozzuolana is of volcanic origin, having been produced by molten lava coming in contact with water during an eruption. Its most important constituents are silica, alumina, iron, and lime. This material is very much like modern granulated blast furnace slag in its appearance and properties. History reveals that in the second century after Christ, a breakwater was constructed at Pozzuola; it consisted of twenty or more arches of brick and stone fitted together with mortar of pozzuolana and lime. Of these arches thirteen are still standing above the water.

The manufacture of slag cement has been tried at a number of places in the United States, but at the present time the author knows of only one such plant in operation. About 1925, the Ford Motor Company, whose manufactured portland cement is widely known, developed a new process of manufacturing a product known as "Ford



Flow Sheet of Process.

Cement." A plant making this cement is now in operation at Buffalo, New York. "Ford Cement" is composed of about 25 per cent slag combined with lime and clay.

There are three distinct methods of disposing of the molten blast furnace slag. The first is to cool it by the use of water. This process is not in very general use in this country today. Water-cooled slag is not unlike popcorn in appearance and color. This slag is crushed to a very fine dust and is used in the manufacture of cement.

The second method of disposal, the air-cooled slag pit, is used only where there is not sufficient space to allow for the common slag dump or bank. The use of this slag is the same as the slag cooled by the other air-cooling method.

The third and last method is the one most generally used in this country. The slag is poured out over a bank, or down an incline in the yard near the furnaces. At first this slag was thought to be a useless or an almost useless by-product, and the banks soon became of alarming size. In many places the slag was dumped into a river or a lake if one was near at hand. Of late, however, this slag has been reclaimed, and after crushing and screening to size, is used as a building aggregate in the mixing of cement and as a ballast on railroads in the place of crushed stone or gravel.

The constant addition of molten material has rendered it nearly impossible for these slag banks

to cool off and the result is that a process of annealing sets in. This slow cooling tends to strengthen and toughen the slag so that it compares favorably with crushed stone for any use that crushed stone may be put to. The resultant material is called annealed slag.

This annealed blast furnace slag is removed from the bank by steam shovels, loaded upon standard railroad hopper cars, and taken to the crusher where it is dumped into hoppers from which it is fed to the crusher through a mechanical feeder. This feeder, when viewed from the top, resembles a group of parallel notched bars, spaced at approximately four-inch intervals, with every second bar moving back and forth in the plane of the bars. However, if viewed from the side, the moving bars are seen to travel as around an ellipse, that is, in a somewhat flattened circle. This action moves the material along toward the grizzly crusher at a constant speed, and allows any pieces under four inches in diameter to pass down through the bars and into a pit under the crusher. The operator watches the slag that passes over the feeder and picks out all pieces of iron that may come to his attention. Any iron present is in thin flat layers; it is never in thicker chunks as is the slag.

The grizzly is a primary crusher which is supplied by the mechanical feeder. In this machine, the reduction of the material is effected by forcing a jaw, hinged at one end, against another jaw fixed to the frame of the machine, the necessary force being furnished through toggle plates placed almost horizontally in order to take the great pressure required to effect the crushing. The slag, being crushed, descends as the swinging jaw recedes, so that the crushing action takes place on one-half the stroke of the machine. A flywheel of extremely heavy design is provided to equalize the load during the crushing. The shape of this type of crusher enables a larger piece of material to be received between the jaw faces than in any other type of equal weight. The size of the product, in this case four inches, is regulated by adjusting the lower end of the swing jaw, and its capacity by the discharge opening and speed of the machine. The simplicity of construction of the machine enables the wearing parts to be quickly changed; in this machine the jaws are reversible, a feature resulting in a longer life than would ordinarily be expected in a machine of this type.

The crushed slag discharged from this machine falls into a pit with the material that passed through the feeder. An endless bucket elevator then carries this crushed slag to the secondary crusher floor level where it is deposited on a short endless belt that conveys it to the secondary crusher. This belt passes over a highly magnetized roller that removes all particles of iron from the material. This metal would severely damage the roller crushers if it were allowed to pass into them. The slag passing this magnetic roller is of all sizes from dust up to four inches.

The path of the product from this point can be altered at will to satisfy the demand. A divider in the outlet of the magnetic separator can be adjusted to pass the slag through both of the secondary crushers, or it can be by-passed around them if the larger sizes of slag are needed. This divider is so arranged that all or a part of the

product can be passed through either crusher. The adjustment of this divider usually is decided by the quantities of the different grades needed for filling the day's orders.

The secondary crushers are both of the double roller type, consisting of two corrugated faced rollers running at different speeds. The ratio of reduction in these rollers is variable and is adjusted to suit the size demand. As a safety factor, to relieve any emergency stress due to foreign matter such as tramp iron or wood accidentally mixing with the slag, a series of compression springs give a deflection beyond that required by the normal working load of the rollers.

The materials, after passing through the secondary crushers, unite and are lifted by endless bucket elevators to the top floor level where they again pass over a divider that distributes the mass between two revolving screen graders. The material is graded here in sizes from dust up to three inches. Bins directly under the screens receive the graded product.

Railroad cars are run directly under the bins to be loaded. The loading chutes are so arranged that almost any combination of grades can be run together and be well mixed while loading into the cars. Chutes at the sides of the bins are arranged for loading trucks directly from the main storage hoppers.

A plant of this type is capable of producing about 200 tons of crushed and screened slag every hour, day and night. These crusher buildings are of all-steel construction, and have every safety feature possible.

Commercial air-cooled slag, when it reaches the market, is gray in color. The individual particles are roughly cubical in shape with no elongated or thin pieces present. It has more bonding surface per unit volume than any other commercial building aggregate. This is due to the countless number of bubbles that were trapped in the molten material when it solidified. In the process of crushing the larger fragments of slag, it has cross-sectioned these bubbles so that commercial slag is pitted on all of its faces. However, do not think that this finished product resembles a sponge in that it will absorb water and saturate the material. As indicated above, each pit is individually developed and is not connected with its neighbor. An inspection of the product will make this statement quite apparent, and numerous recorded laboratory absorption tests verify the fact. Exceptionally light pieces of slag selected on account of their porousness, have floated in laboratory tanks for periods up to nine years, apparently indicating no absorption whatever.

The continuous commercial use of slag concrete dates back to the early nineties. One of the earliest reinforced slag concrete buildings was erected in Philadelphia in 1897. When this building was razed in 1913, both the concrete and steel reinforcement were in excellent condition. This same condition was found to exist when the Ulmer and Higgins buildings were torn down in Cleveland, Ohio, after standing 16 and 17 years respectively. The steel reinforcement in both cases was in as good a condition as the day the concrete was poured.

Mr. John S. Brodie, Civil Engineer, Street Department of Liverpool, England, states: "Blast

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furnace slag has served England for the past twenty years as the mineral aggregate of a bituminous preparation known as Tarmac. Slag, due to its pitted surface, bonds with the bitumen better than do any other mineral aggregates. Hundreds of thousands of square yards of this material have been laid in England, much to the alarm and dissatisfaction of the crushed stone producers. It gives unparalleled service as a pavement under heavy traffic."

Records available in nine states show that slag has been used in the construction of hundreds of buildings, such as banks, office buildings, stores and offices, department stores, city halls, fire stations, court houses, factories, warehouses, theaters, schools, colleges, churches, hotels, hospitals, apartments, and farm buildings.

The foregoing facts clearly indicate that slag concrete has been successfully used in reinforced concrete construction and has served admirably in all types of highway construction.

The American Institute of Mining and Metallurgy held their last meeting on Wednesday, January 21, 1931. At this meeting two interesting talks were given by L. J. Rautio and Earl Kirk. Rautio's subject was "Transportation of Oil on the Great Lakes." Kirk spoke on "Shop Writing."
