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Preparation and use of volcanic ash in concrete

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PREPARATION AND USE OF VOLCANIC ASH IN CONCRETE

by

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PREPARATION AND USE OF VOLCANIC ASH IN CONCRETE.

The presentation of the results obtained by using prepared volcanic ash in concrete would not be inclusive unless some information was shown as to the origin of the volcanic ash.

Origin of Volcanic Ash-Explosions in an active volcanic crater force into the air particles of rock fragments. The density of the fragment and the amount of surface which it presents to air currents, account to a great extent for the distance it will be transported away from the crater. The larger and heavier the fragment, in relation to the other fragments thrown out, the shorter distance will it travel suspended in air currents. The sorting action which thus takes place results in the weeding out of the air all particles except the fine dust which is called volcanic ash.

A recent example of the distribution of volcanic ash is found in the records obtained after the explosion of the volcano Katmai in the Alaskan penisula. This volcano erupted in June 1912 and the fall of volcanic ash was fifty inches deep 30 miles from the volcano and six inches deep 160 miles east of the volcano. The amount of dust in the air was so great that total darkness prevailed for sixty hours at a distance 100 miles away.

It has been estimated that the explosion of the island Krakatao in August 1883, threw ash to a height of 17 miles. Actual transportation of volcanic ash during this eruption is recorded in the fact that ships 1,600 miles away were covered with dust three days after the eruption.

In 1783, the ash from a volcano in Iceland drifted 600 miles to Scotland in such quantities as to destroy the crops there that year.

The above brief references are given in order that the existance of deposits of volcanic ash in non-igneous regions may be hooked up with their probable origin.

The accepted explaination of the Kansas deposits of volcanic ash has been that the prevailing westerly winds of Pleistocene times carried the dust, accompanying the volcanic eruptions in the Rock Mountain region, eastward and gradually distributed this dust, or volcanic ash, over the eastern parts of Colorado and New Mexico and the Western parts of Kansas, Nebraska and Oklahoma.

During recent years, Kansas has produced over 90% of the volcanic ash produced in the United States.

Other important areas of volcanic ash are to be found in California, Montana and Idaho. Extensive development of the latter named deposits awaits more advantageous markets than are now present.

Preparation of Volcanic Ash for Market.

Prospecting-The prospecting for deposits of volcanic ash in the Kansas field, has been carried on in a manner different from that used for finding more valuable mineral deposits. As nearly all the deposits now exploited have been known for years, they have been considered of little importance by their owners. The method employed is to have a field man look up the owners of deposits, in any community, and when possible, secure a lease to the tract. While this proceedure is called prospecting, it really belongs under the head of 'procurring deposits'.

A new discovery method has been successfully used by the author. Realizing that the winds have played an important part in keeping the topography of the country in a smooth condition, it seemed apparent that the pure deposits would be found only in pre-volcanic ravines. These ravines might bear no relation to the present topography, and such has been found to be the case. The drill map of a deposit usually discloses an axis which meanders from one edge to the other. Heretofore no extended effort was made to go beyond the pocket in question. But by projecting the axis and putting down a series of test holes on this projected line, extensions of these volcanic ash filled ravines have been found. The blank spaces between the bodies represents a post-deposit ravine which has been refilled with soil. This method is especially adapted to prospecting on comparatively level ground with no surface indications.

When working in a territory in which the present topography has left the volcanic ash on the uplands, two criteria have been found which indicate the proximity of volcanic ash. The most important is the trail of elongated rock fragments. These rocks were formed by the infiltration of calcereous solutions derived from the weathering of overburden. When this overburden is thin, the rock fragments are small but when large stalactite-like rocks are encountered, either the present overburden is thick or the mantle of overburden has been eroded in fairly recent geologic times. An exposed face of volcanic ash weathers rapidly and the residual rocks form the above mentioned trail.

The second indication is a result of the weathering of outcrops which have little or no rock. In this class, the sparce vegetation becomes thinner, and especially during the fall and winter months, causes a semi-bare spot to appear on the hillsides. It is not to be supposed that all the undiscovered bodies of volcanic ash will be found by the application of these principles, but a large addition to the present available tonnage will no doubt be opened up.

Drilling-Drilling is carried on with hand augers equipped for extension rods. The auger is pushed downward with a right hand motion until the bit is full of material. The auger is then drawn from the hole, cleaned of dirt and reinserted for further depth. Holes up to sixty feet in depth have been made by this method.

Prior to the advent of technical direction, any plot of land under examination was laid out in squares and holes drilled at fifty foot intersections. This method resulted in an appreciable amount of wasted effort since a number of holes in the pattern might be barren. The procedure now followed calls for close contact between the drillers and the superintendant in charge so that the direction and outline of the body can be defined and the number of barren holes reduced to a minimum.

The calculation of the tonnage of volcanic ash availabe depends not only upon the depth of volcanic ash shown by the drill hole, but is regulated by the relation existing between the depth of overburden and the volcanic ash beneath. As the thinning along the edges of a deposit is rapid, one should not average the depth of overburden present on the tract, but rather consider the problem from a standpoint of operating economy. This results in leaving out those fringe portions which carry a greater depth of overburden than of volcanic ash.

Stripping-Stripping is the term that has been applied to the process of removing the overburden. Various procedures have been followed depending upon the resources of the operator. Hand shoveling into wheelbarrows still finds its application in cleaning up scattered patches of soil. Teams and scrapers have handled the bulk of the yardage moved in the past. The one-man Fordson trailer scraper has furnished a convenient means of stripping where a portable organization is advisable. The larger deposits are now being uncovered with a power shovel. The material dug by the shovel is discharged into industrial cars. These cars haul the waste to the dump.

Drying- A portion of the volcanic ash, when drying, apparently defies the force of gravity. This feature is due to the lifting power of the expanding steam and entrapped air present as moisture in the raw material. In appearance the surface of the drying mass resembles a multitude of volcanic craters spouting volcanic ash into the air. A complete cycle is present in that some of those particles which rise the highest, cool the most and lose their boyancy. These then fall and entrap more air which is reheated and causes the phenomena to be repeated. A feature of hot volcanic ash is its ability to flow and seek its own surface level. This is analygious to a low viscosity and causes the material to migrate through small openings.

Volcanic ash is taken from the bed and charged into dryers. Several types of dryers have been used. The simplest dryer is a sand dryer as commonly found in railway roundhouses. It is constructed of a central round stove surrounded by a funnel-like trough open at the bottom. The material to be dried is shoveled into the trough and dries quickest next to the stove. This dry material then falls by gravity through the opening provided at the base of the funnel trough.

Rotary driers have been given many trials and are still in use by industries preparing volcanic ash for uses other than that in concrete.

The drier developed for use in preparing volcanic ash for concrete purposes overcomes to a great extent the objections found with the rotary drier. The first of these is the dust menance. The rotary drier cascades the material and thus allows currents of air to become saturated with fine fragments. The second is due to the human element present in that by having the flame in direct contact with the material to be dried, a close scrutiny must be maintained in order that soot does not form and render the product valueless.

This new dryer is termed a "kettle" from the physical resemblance to an ordinary cooking utensil. The flame from the oil burner acts on the bottom and sides of the kettle and these portions, being constructed of iron, transmit to the volcanic ash placed inside. A mechanical agitator drags the bottom and prevents the formation of an insulating layer of hot material.

When raw volcanic ash is heated, or calcined, two components are produced. One is the dry volcanic ash which is called pumicite. The other is a gas composed of expanded air, water vapor and CO_2 gas.

Raw material is fed into the kettle from a hopper at the top of the drying plant and falls through the mass of dry pumicite to the hot zone at the bottom of the kettle. A constant depth of material is maintained by having a discharge opening in the side of the kettle. The pumicite flows out this opening like water while the gases are led through dust collectors.

Screening-After leaving the kettle, the pumicite falls onto a mechanically vibrated screen which removes any sand or small rocks that might be present. The screen is tightly enclosed in order that the dust may be reduced to a minimum.

Sacking-From the screen, the pumicite falls by gravity into a bin. The discharge from this bin feeds a Bates Valve Bag Packing Machine. A noteworthy feature of this packer is its ability to mechanically fill and weigh each sack. The filled sacks of pumicite are then ready for shipment.

Shipping-Filled sacks are pillow size and shape and lend themselves easily to stacking in box cars. Not all pumicite is sacked as some construction projects are of large enough magnitude to permit the contractor to employ mechanical means of handling bulk cement as well as bulk pumicite. When this unloading feature is available, pumicite is by-passed direct from the bin to paper lined box cars.

Examples of use of pumicite in concrete structures-

Near the begining of the Christian era, the Roman People built the Pantheon in Rome. This temple is still standing today. The enormous dome of this structure, 142 feet 6 inches in span, is cast in concrete made of pumice stone, pozzolana and lime. The pozzolana is a volcanic ash so called because it was found at Pozzuali near Naples.

Thirty-two years ago a power dam was built on the Niobrara River three miles from Vallentine Nebraska. In pouring the concrete in this structure, 50% pumicite was substituted for 50% of the cement. From visual inspection, this dam to-day shows less weathering that found in a great many younger plain cement concrete structures.

The Los Angeles aqueduct is another example where powdered volcanic tuff has been mixed with cement on a 50-50 basis. This mixture was used as cement in constructing a large amount of this 250 mile aqueduct. Conclusions were reached, on this occasion, that greater tensile strength was obtained after ten days, than by using straight cement mixed with the same proportion of sand.

During the past two years pumicite has been widely used in the middle-western States and the list of large structures built with this material includes the new addition to the Southwest Bell Telephone Building, Kansas City, Missouri; Shedd Aquarium, Grant Park Chicago, Illinois; Frisco Viaduct, Memphis, Tenn. and many others.

Effect on Concrete-The first indication one has that pumicite has been mixed in the concrete is the look and feel of richness in the mix coming from the cement mixer. This is due to the fineness of the pumicite. These fine fragments seek out those minute cavities existing between the grains of sand and permit the particles of cement thus replaced to function as a cement instead of as a filler. The fineness acts as a lubricant and this feature cuts down the quantity of water that is needed to make a workable concrete. The lubricating feature is not to be confused in considering the relation between the aggregates. One would suppose that a slippery condition would allow the heavier portions to settle through the mass but such a condition does not exist and is obstructed by

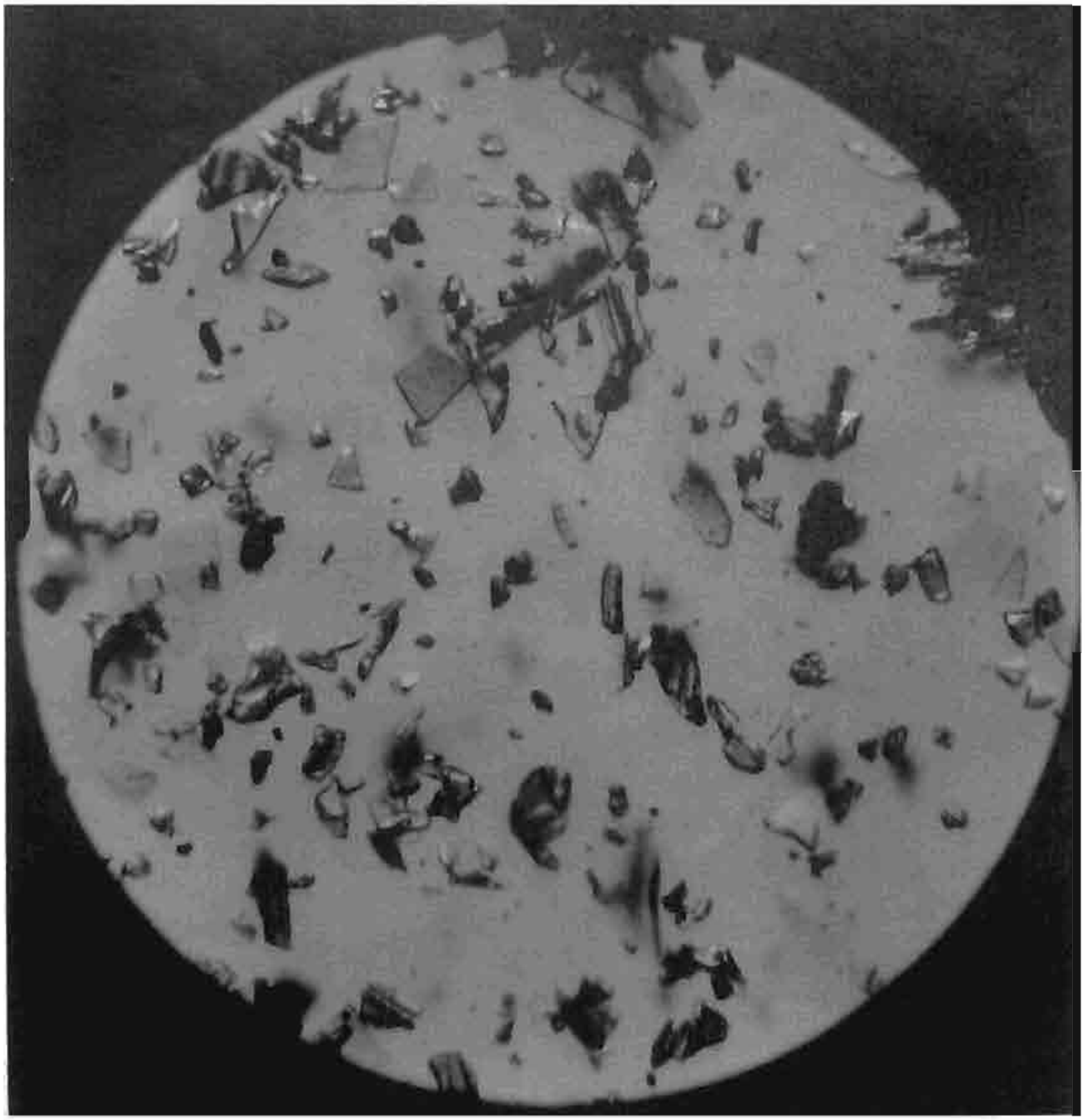

PHOTO MICROGRAPH OF <u>PUMICITE</u>
(Enlarged about 180 diameters)

the physical shape of the pumicite. The photo micrograph shows the irregularities present in every particle.

The strength of concrete having pumicite as one of its constituents is greater than the strength of concrete made with straight cement.

A series of tests to determine the effect of pumicite mixture on the tensile strength of Portland cement have been made. For this purpose the Portland cement used conformed with the standard specifications as reported by the American Society for Testing Materials.

Tensile Strength (Pounds per square inch)

Neat Portland Cement

	6Hours	9Hours	12Hours	18Hours	24Hours	36Hours	48Hours
Av.	48	103	148	263	313	345	413

Neat Portland Cement (10% Pumicite Admixture)

	6Hours	9Hours	12Hours	18Hours	24Hours	36Hours	48Hours
Av.	61	117	255	307	358	393	460

1/3 Portland Cement, Standard Ottawa Sand

	6Hours	9Hours	12Hours	18Hours	24Hours	36Hours	48Hours
Av.	63	97	123	160	198	263	310

1/3 Portland Cement, Standard Ottawa Sand
(10%, by weight, of cement replaced with Pumicite)

	6Hours	9Hours	12Hours	18Hours	24Hours	36Hours	48Hours
Av.	73	107	145	183	227	300	343

Lehigh Cement, Montgomery Sand and Birmingham Slag were basic ingrediants of standard 6" x 12" cylinders used for making tests with regards the relation in tensile strength between cement and pumicite in concrete.

Straight Cement

		Pounds per square inch obtained in		
		7 Days	28 Days	60 Days
Mixture 1-2-4	Av.	1157	1894	2061

Water Ratio 7½ gallons

45.0# cement, 100.8# sand, 153.6# slag, 30.3# water.

10% pumicite addition to cement by volume

		Pounds per square inch obtained in		
		7 Days	28 Days	60 Days
Mixture 1-2-4	Av.	1198	1935	2183

Water Ratio 7½ gallons

45.0# cement, 100.8# sand, 153.6# slag, 30.3# water.

10% pumicite substituted for 10% cement by volume

		Pounds per square inch obtained in		
		7 Days	28 Days	60 Days
Mixture 1-2-4	Av.	1435	2001	2339

Water Ratio 7½ gallons

40.5# cement, 100.8# sand, 153.6# slag, 27.3# water.

The results of other tests using crushed limestone universal cement and Mississippi river sand follow the same trend as those enumerated above. All cylinders were 6" x 12" and the average tensile strength follows.

Straight cement

	Pounds per square inch obtained in		
Mixture 1-2-3½	3 Days	7 Days	28 Days
Water ratio 7 gallons	1024	1312	2160
87.44# cement	60 Days	6 Months	
199.20# sand	2049	2059	
285.52# crushed limestone.			
54.0# water			

10% pumicite addition to cement

	Pounds per square inch obtained in		
Mixture 1-2-3½	3 Days	7 Days	28 Days
Water ratio 7 gallons	1330	1569	2200
87.44# cement	60 Days	6 Months	
8.744# pumicite	2409	2177	
199.20# sand			
285.52# crushed limestone			
54.0# water			

10% pumicite substituted for 10% cement

	Pounds per square inch obtained in		
Mixture 1-2-3½	3 Days	7 Days	28 Days
Water ratio 7 gallons	1354	2023	2730
78.7# cement	60 Days	6 Months	
8.744# pumicite	3265	4742	
199.20# sand			
285.52# crushed limestone			
48.6# water			

Actual determination of just what minerals or compounds are formed when cement sets has been difficult to determine as the analysis of cements from different plants vary.

The average analysis of portland cement is as follows:

Calcium Oxide	62.92	percent
Silica	21.92	"
Aluminum Oxide	5.91	"
Iron Oxide	2.91	"
Magnesium Oxide	2.54	"
Sulphuric Anhydride	1.72	"
Insoluable Residue	.60	"

Fineness, passing 200 mesh-84.6 percent.

As ordinarily found, portland cement is a mixture of calcium silicates and calcium aluminates. When water is added, the constituents of the mixture undergo hydrolysis with the probable formation of calcium hydroxide together with calcium hydro-silicates and calcium hydro-aluminates. The gradual hardening process is due to crystallization of the calcium compounds from a colloidal state.

When mixed in concrete, the cement forms the binder which holds the aggregates together. The binder then has the burden of the load to carry and one looks for the weakest part of the binder to fail first. From our previous experience with lime mortar, we have found that hydrated lime will weather out of the mortar through its change to two other compounds. First, it changes to calcium carbonate, absorbing the necessary carbon dioxide from the air, and second, this calcium carbonate is soluble in atmospheric moisture which has absorbed a slight amount of CO_2 from the air. The solution of calcium carbonate washes out of the concrete and leaves a binder weakened by its absence.

The chemical theory for the increased strength imparted to concrete by pumicite is based on its chemical composition as shown by the following average analysis.

Silica	71.92	percent
Iron as (Fe_2O_3)	2.08	"
Aluminum Oxide	12.74	"
Calcium Oxide	.82	"
Magnesium Oxide	.21	"
Alkalies as(Na_2O)	7.22	"
Sulphur	none	
Loss on ignition	4.95	"

Fineness-passing 200 mesh-79.3 percent

Fineness-passing 300 mesh-63.2 percent.

Two thousand years ago the Romans mixed volcanic ash and lime and made the concrete of which the ancient buildings, still standing in Rome, were constructed. The similarity of the strength imparted by the addition of pumicite to cement as compared to the lasting hardness of the ancient mortars of volcanic ash and lime, brings one to the conclusion that it is the ordinarily detrimental excess of calcium hydroxide formed when cement hydrates that acts with the abundant silica present in pumicite to form calcium silicates. The calcium hydroxide may be the catalytic agent which accelerates the solution of pumicite in the gelatinous mass of cement binder. The fine division of the pumicite presents a large surface area and facilitates solution.

Pumicite also contains nearly twice the percentage of alumina as is ordinarily present in cement. This alumina probably assists in the spreading of the gelatinous binder. The calcium silicates and aluminates formed are insoluble in atmospheric moisture and the whole body of hydrates form a more resistant binder than is the case when cement is used alone.

The physical theory takes into account the angular and pointed nature of the individual particles. The pointed ends overlay between and around the concrete aggregates and these offer additional resistance to shear stresses than would ordinarily be found.

The greater tensile strength imparted to concrete by the addition of pumicite is probably due to its action both chemically and physically.

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