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Natural Pozzolan in Mount Popa Area

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Abstract

Mount Popa, in central Myanmar, is a large, steep-sided composite cone that rises a height of 1518 m (4981'). It contains a 1.6-Km-wide, 850-m-deep, horseshoe-shaped caldera that is widely breached to the NW. Kyauktaga-Legyi Agglomerate unit, volcanic ash deposit, covers an area of 20 sq.ml at the north of the breach. Fine-grained pyroclastics of this deposit such as volcanic ash, tuff and scoria are crushed and ground into the finely-divided materials or powder that has been also known as **Natural Pozzolan**. It is an important ingredient in the production of an alternative cementing material to ordinary portland cement (OPC). Although several potential sources of natural pozzolan formed by volcanic origin are identified in Myanmar, Mt. Popa area is more favourable for commercial natural pozzolan production due to lesser erosion and better accessibilities.

Key Words: Mount Popa, composite cone, volcanic ash deposit, natural pozzolan.

Introduction

Location and Size

Popa area it is lies in Kyaukpadaung Township, Myingyan District, Mandalay Division and located about 10 miles NE of Kyaukpadaung where is readily accessible by car throughout the year. This area lies between North latitudes 20° 55′ to 20° 58′ and East longitudes 95° 11′ 6″ to 95° 15′ 20″ of one-inch topographic maps 84-P/1 and P/5. The areal coverage is about 14 square miles. The location of study area is shown in Fig:ure (1).

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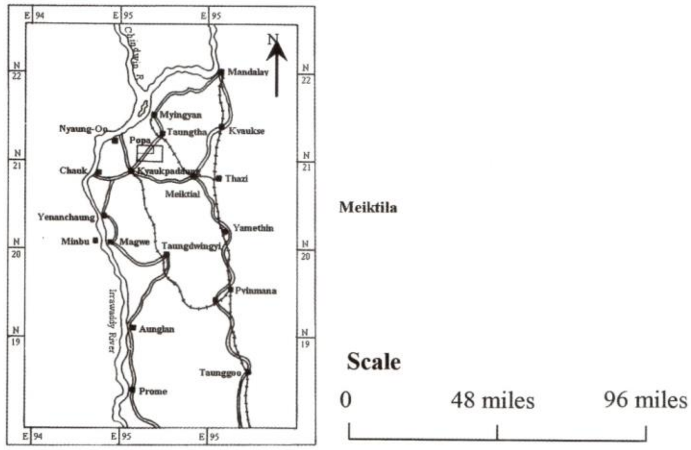

Figure: (1). Location map of the study area

General Geology

Mount Popa, in central Myanmar, is a large, steep-sided composite cone that rises 1150 m above a surrounding lava plateau to a height of 1518 m (4981') (see Fig.2).

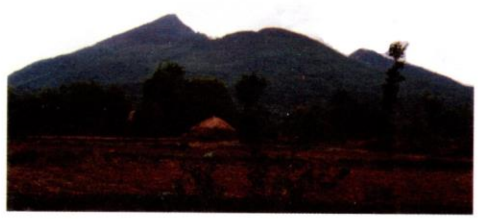

Figure: (2). Photograph showing the appearance of Mt.Popa as a volcanic cone. (Looking from East. Loc: 645445)

The main edifice consists of basaltic and basaltic-andesite lava flows, pyroclastic deposits, and scoriaceous material originated from strombolian eruptions. There are ten flows of lava and pyroclastics in the whole area of Mt.

Popa volcanic terrain (Aung Moe, 1980). In the study area, four types of flow were recognized as followings; (in ascending order in age).

4. KL_A -Kyauktaga-Legyi agglomerate

3. V_5 -Basaltic lava (northwestern flow)

2. V_3 -Black tuff and andesitic lava

1. P_A -Popa plateau andesite

Mount Popa contains a 1.6-km-wide, 850-m-deep. Horseshoe-shaped caldera that is widely breachd to the NW (see Figure.3). The Myanma chronicles of the Konbaung Period describe an eruption in 442 BC (Maung Thein, 1982). Professor H.L.Chhibber of the pre-war University of Yangon estimated that the first outpouring probably took place about 300,000 years ago. However, the geological evidence indicates that the volcanic activity in the Popa area may have begun about two to three million years ago. On the basis of petrological and mineralogical analyses, Stephenson and Marshall (1984) pointed out that the volcanism occurred during Quaternary.

Figure: (3). Satellite Image & Aerial Photo View of Mt.Popa showing horseshoe shaped crater.

Pozzolan

Definition

Pozzolan is a finely divided siliceous or siliceous + aluminous material that chemically reacts with calcium hydroxide and alkalies to form compounds with cementitious properties.

(CSH paste = Calcium Silicate Hydrate)

The pozzolanic reaction can be simply stated as:

$$Ca(OH)_2 + SiO_2 + H_2O \longrightarrow CaO.SiO_2.H_2O$$

Amorphous! Cementitious C-S-H Phase

(The particles must be fine generally 45 μm in maximum size).

Pozzolan has little or no binding property but, when mixed with lime in the presence of water, will set and harden like a cement. They are an important ingredient in the production of an alternative cementing material to ordinary portland cement (OPC).

The pozzolanic reactivity of a given material is determined by the amount of amorphous constituents (e.g, volcanic glass from explosive volcanic activity, sedimentary opaline silica, fly ash).

(extracted from *Technical Note on Pozzolan*: PECC 1-Son La HPP, Vob, Hanoi, 2004).

Background History

There are 1282 volcanos in the world considered to have been active in the past ten thousand years. Only 3 volcanoes deposited high quality natural pozzolan.

The first one is Santorini Volcano, Greece, which erupted during 1600 BC ~ 1500 BC. Mt.Vesuvius, Italy, is the second volcano which erupted in AD 79. Pozzolan was named after the town of Pozzoli where it was deposited. The third, Mt. Pagan, is the only one which has erupted in modern times.

Scientists have proven that the ancient Greeks began to use natural pozzolan-lime mixtures to build water-storage tanks, sometime between 700 BC and 600 BC. This technique was then passed to the Romans about 150 BC.

Many great ancient structures, such as the Colosseum, the Pantheon, the Bath of Caracalla, as well as other structures that are still standing in Italy, Greece, France, Spain and the islands in the Mediterranean Sea, were built with natural pozzolan-lime mixtures. Many of them have lasted two thousand years.

After the invention of Portland cement, natural pozzolan was used concrete strengthening additive to improve characteristics, such as durability, compressive strength, chemical resistance, hydration heat, permeability etc.,.

In Europe and the USA, there have been numerous high rise buildings, highways, dams, bridges, harbors, canals, aqueducts and sewer systems built with natural pozzolan-cement mixtures.

Due to the limited supply of high quality natural pozzolan, in the last 30 years, the USA and European countries were compelled to lower their quality criteria so that waste materials such fly ash could be used as substitute for natural pozzolan.

Classification

The term "Pozzolan" includes both technical and natural pozzolanic material:

(A) Natural Pozzolans (Class N)

- Classic/ historical pozzolans = pyroclastic materials consisting of volcanic glass, all of explosive volcanic origin.
- Diatomite earth and opaline shales: biogene and sedimentary shales respectively, both consisting of opaline silica frameworks, both require calcination (at 900°C or higher) to become reactive.
- Metakaolin: formed by heating natural kaoline clays. Activity depends on the kaolin content of the clay. Requires T to 900°C.
- Rice Husk Ash: Little known, large potential. Requires controlled incineration to produce residual ash containing over 90% of amorphous silica, highly pozzolanic activity.

(B) Technical Pozzolan (waste products from industry):

- Fly ash Class F (low-calcium): obtained from burning anthracite or bituminous coal.
- Fly ash Class C (high-calcium): obtained from burning lignite coal.
- Condensed Silica Fume (CSD): By- product of manufacturing silicon or silicon alloys.

Origin of Natural Pozzolan

Natural Pozzolan is formed when silica rich magma meets with a large quantity of under ground water in the volcano conduit. Under high pressure and high temperature, water in steam form dissolves into the magma mixing with the dissolved carbon dioxide and sulfur gases. When this magma reaches the earth's surface, it blows off the top of the volcano cone. Because the pressure is suddently reduced, all the gases inside the magma are released and the magma, blown up like pop-corns, falls to ground then cools into small porous rocks.

Pozzolans are present on earth's surface such as diatomaceous earth, volcanic ash, opaline shale, pumicite and tuff.

Result and Discussion

Natural Pozzolan Exploration in Mount Popa Area

Potential Mining Sites

The study area, Mt. Popa area, is a potential source of natural pozzolan formed by volcanic eruption. Geologically, a suitable pyroclastic deposit could be noted in the Kyauktaga-Legyi Agglomerate unit in the present area. It could be easier to porduce volcanic ashes or natural pozzolan because of thin overburden and less compact of volcanic ashes.

Kyauktaga-Legyi Agglomerate

Distribution - This rock unit is highly distributed between Kyauktaga and Legyi villages. Mt.Popa originally would have a circular crater but the whole of northern side was blown away, probably by the final paroxysmal outbrust. The outbrust reached as far north as the Legyi village which marks the northern limit of the agglomerate. This agglomerate unit extensively distributed in the vicinity of Ngayangon village in the north and Taung baw village. This unit covers about 6.5miles from crater to Legyi village.

Nature of exposure – The ejected blocks occurred along the Kyaukpadaung-Myingyan car road, especially, between the Kyauktaga and Legyi village Fig: (4). In the east of Gyaingywa, bombs and blocks are noted in the stream section in which they occurred as ash layers Fig: (5). The ash layers are also observed in the plantation area of Ngayangon and Taungbaw villages.

Lithology - *Pyroclastic Rocks Unit*

This rock unit is generally grey and light grey in color which consists of bomb, block, lapalli and ash. These blocks are the fragments of basalts and andesites. This rock type is agglomerate which consists of consolidated ash, various size of basalt and andesite fragments. Aggregation of lamprobolites, pumices, and scorias are also observed in this unit.

Figure:(4).Photograph showing unsorted volcanic agglomerate. Eastern side of Kyaukpadaung-Myingan car road, 5.5 km due N of Mt.Popa volcano.

Figure: (5).Photograph showing the massive, unsorted ash-flow tuff, exposed along the stream section, just west of Taungbaw village. (Exposure is about 15 m high)

Thickness of unit - This unit is about 15 m in thickness in the stream sections Figure: (6).

high)

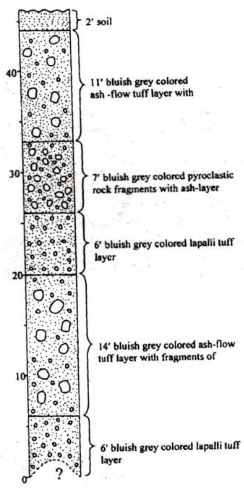

Fig: (6). Columnar section column of pyroclastic layers in KL_A Unit. (along stream section: Loc: 586439)

Estimating Reserves

Random samples were collected throughout the volcanic ash deposit with an area of 20 square miles. Numerous test reports have confirmed that the natural pozzolan can be produced. Estimation of probable tonnage values are shown below in table (1).

Table (1). Estimation of propable tonnage values

Test pit No.	Locality	Tonnage
$P_1 - 9$	985458	3.5 million tons
$P_1 - 13$	985439	32.0 million tons

In 2005, Natural Pozzolan production has been started by the influence of Department of Hydroelectronic Power Figure: (7 and 8).

Figure: (7). Open-pit mining site (No. P_1-13) in Kyauktaga-Legyi Agglomerate unit, for the production of natural pozzolan.

Figure: (8). Open-pit mining site (No. P_1-9) in Kyauktaga-Legyi Agglomerate unit, for the production of natural pozzolan.

Chemical and Physical Requirements

The grade of ash deposits can be determined as its chemical assay results by using ASTM C-618 Specification. The table below shows the chemical and physical requirements listed in the ASTM C-618 Specification.

Table (2). The Chemical and Physical requirements listed in the ASTM C-618 specification.

ASTM Specification C618 - 92a	Class N (Natural Pozzolan)
$SiO_2 + Al_2O_3 + Fe_2O_3$ minimum %	70
SO_3, maximum %	4.0
Moisture content, maximum %	3.0
Loss on ignition, maximum %	10.0
Available alkalies as Na_2O, maximum %	1.5
Finess, maximum % retained on 325-mesh sieve	34

Source : Annual Book of ASTM standard, vol.04.02

Natural pozzolans from Popa sites have been tested and the results are presented in table (3).

Table (3) Test Results of Myanmar Natural Pozzolan

Area and Spl No / Chemical analysis	I Mt.Popa Region			II Popa-Gyaing-ywa	II Twin-daung/ Wunbo	II Twin Taung	ASTM C618 Specification	Comparisom	
	P_1-4	P_1-9	P_1-13	PN-1	TDWB-1	TT-i		Algeria	Bolivia
SiO_2%	76.78	52.84	51.39	46.30	51.52	64.84		42.50	0.00
Al_2O_3%	10.63	15.71	16.80	15.30	14.80	6.68		14.60	.28
Fe_2O_3%	2.99	8.02	8.13	9.83	8.65	9.69		8.50	.18
SiO_2 + Al_2O_3 + Fe_2O_3	90.40	76.57	76.32	71.43	74.97	81.21	≥ 70%	65.60	0.46
SiO_3	0.07	<0.07	0.19	0.91	0.47	0.48	≤ 4%	0.30	.11
Loss On Ignition (LOI)%	3.66	2.79	2.65	2.00	5.67	2.65	≤ 10%		
MgO%				6.13	4.25	5.50	≤ 5%		
Available alkalies Na_2O_3%	1.97	1.51	3.04	3.52	1.93	1.61	≤ 1.5%	4.20	.42
CaO%	0.91	9.27	9.69	12.08	7.00	6.65		24.00	.30
Specific Gravity	2.64	2.96	2.66	2.73	2.53	2.61			
Moisture Content Wt%							≤ 3.0%		
Remarks								Best	orst

Source : I – Data from Department of Hydroelectronic Power.

II – Data from Twinza Oil Ltd. & Bildan Group Inc.

In accordance with the test results Myanmar natural pozzolans meet the above requirement. Myanmar natural pozzolans are glassy (i.e. amorp-hous) material and specific surface (Blaine) for RCC trial mixes are more than 4,000 cm^2/g. Comparison of chemical compositions of Myanmar natural pozzolan with world's known natural pozzolan is shown in Figure: (9).

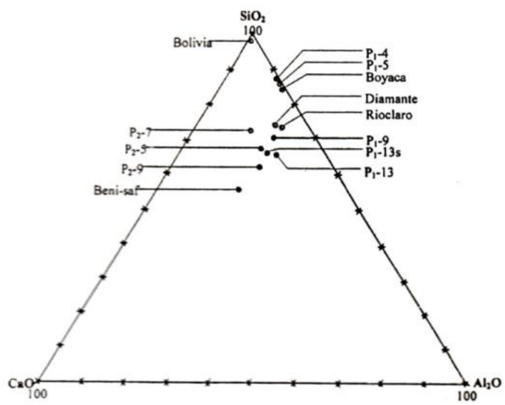

Figure: (9) Comparison of chemical compositions of Myanmar natural pozzolan with known natural pozzolan.

NB: P_1-4, P_1-5, P_1-9, P_1-13s, P_1-13 = Popa area

P_2-5, P_2-7, P_2-9 = Monywa (Chindwin) area

Beni-saf = pozzolanic material from Algeria (best quality).
Source: Data from Department of Hydroelectronic Power

Discussion

Uses of Natural Pozzolan

Natural pozzolans mixed with lime were used in concrete construction long before the invention of portland cement because of their contribution to the strength of concrete. The Greek discovered pozzolan-lime mixtures sometimes between 700-600 BC. Today, natural pozzolans are used with Portland cement not only for strength but also for controlling heat of hydration and alkali-silica reaction of concrete in RCC dams.

The natural pozzolan may be used as partial replacements for Portland cement or in addition to Portland cement. Many natural pozzolans were usable in raw state. If moist, they usually required drying and grinding before use. The various cementitious material (cement + mineral admixture) have been used in RCC dams to date.

Mineral admixtures are used to serve one or more of the following purposes

- as a technical purpose to minimize the Alkali-Aggregate Reaction;
- as a proportion of the cementitious content to reduce heat generation and cost;
- as an additive to provide supplemental fines for mixer workability, and impermeability.

Benefits of Natural Pozzolan

Substituting the Portland cement with high quality natural pozzolan will accomplish the followings:

1. Reduces permeability and voids,
2. Reduces expansion and heat of hydration,
3. Reduces micro-cracking,
4. Increase compressive strength,
5. Reduces freeze-thaw damage,
6. Protects steel reinforcement from corrosion,
7. Lowers water requirement with high fluidity, Self-levelling and compression,
8. Reduces cost of construction and production, and
9. Improves durability.

Conclusion

- Through some volcanic ash deposits could be found in the other parts of Myanmar particularly in the northern Myanmar, the volcanic ash deposits of Lower Chindwin and Mount Popa Regions are more favourable for commercial natural pozzolan production because of lesser erosion and better accessibilities.
- Natural Pozzolan was used concrete strengthening additive to improve characteristics such as durability, compressive strength, chemical resistance, hydration heat permeability etc.
- Pozzolans of natural or technical origin have been used in ancient mortar structures, and modern mass concrete constructions in many parts of the world. The use of pozzolan in concrete is a vary attractive partial replacement or additive to portland cement, which is rather expensive to manufacture due to high temperatures required.

- Significant cost saving has been achieved because domestic pozzolanic material from Mount Popa volcanic area can be used instead of imported fly ash.
- The technical benefits of pozzolan for large mass concrete structures such as dams are well known, and a lot of research and studies has been done in this field by many countries.
- At the end of 2003, there were 251 completed RCC dams (>15 m in height) and a further 37 were under construction. Yeywa dam is the first RCC dam in Myanmar and the third largest one in RCC volume among the world RRC dams.
- The majority of RCCs contain mineral admixtures, as an active constituent of the concrete and one of the major advances in concrete technology brought about by the development of the RCC dam has been the greater understanding of the performance of the mineral admixtures in concrete.

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