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# Study on Quality Aggregate Construction Powder

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## Abstract

This research work deals with a view to promote cement replacement materials i-e aggregate construction powder, also known as building powder or construction powder. It has been used as lime substituent in construction work in Myanmar since 1990's. It is mixed with other construction materials such as cement, sand, etc. and used in plastering, tiling, arranging bricks and smoothing the face of the buildings.

This work also deals with some aspects in physical properties of four different aggregate construction powder samples such as Moe Hein, Man Thiri, Shwe Taung and Kyauk Sue. In addition, these four different samples were characterized by using spectroscopic methods such as ED-XRF, AAS, FT-IR and XRD.

In support of the finding by the analytical assays of Moe Hein aggregate construction powder, it indicated the percent composition of the presence of $SiO_2$ 12.13%, $Al_2O_3$ 7.40%, $Fe_2O_3$ 0.94%, CaO 41.00%, MgO 1.50% total sulphur 1.15%, chloride 1.49%, carbonate 43.63% and sulphate 3.44%. The analytical assays of Sin Min cement, Kyant cement, brick powder and pozzolan were also carried out in this research work.

The mixing between various ratios of Moe Hein and Kyant cement as well as Sin Min II cement were done and their mechanical strengths such as setting time, tensile strength and compressive strength of each sample were studied. The quality of mixing ratio 50:50 of Moe Hein and Kyant cement was found to be comparable to the ASTM standard type II Protland cement which is for general use.

*Key Words : Aggregate construction powder, Sin Min cement, Kyant cement, Portland cement, XRD, ASTM standard type.*

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## Introduction

The development of construction materials can be traced to the still standing of ancient colossal buildings, bridges, temples, monuments, statues etc. In those times, the ingredients were usually wetted clay or other admixed clay together with volcanic ash, lime or gypsum. They were normally mixed and they allowed to set in under the weather condition. Only in the early part of the $18^{th}$ century, what is now called cement and Portland cement came to be known. Cement, called hydraulic cement was also made to be used in underwater construction.

One of the building materials, which play the main role in the construction industry is modern cement or modified cement. One type of cement is Portland cement. It is indispensable in sidewalk, highway, bridges, dams, etc. A country's development in a way depends on its cement industry.

Since the 1950s, Myanmar has been producing cement from raw materials but during the all round development of the 1990s; the use of cement have increased manifolds. Today, instead of using the imported cement or high priced produced home cement, resort to using small scale product have become a very common practice. Thus aggregate construction powder such as Moe Hein, Shwe Taung, Man Thiri and Kyauk Sue have been recently used as quality substituent of lime in Myanmar.

Aggregate construction powder is a alternative substitute for lime, because when it is combined with cement, it strengthens the aggregate to harden with age and it is less costly.

This research work explored whether it is feasible to make use of locally available aggregate construction powder by mixing in appropriate amount and then testing the mechanical quality and durability as quality grade cement. The admixtures of the local aggregate construction powder were also mixed with available raw materials like volcanic ash (called pozzolan) as well as dried brick powder.

## Experimental

All the chemicals used in this work were of reagent grade (BDH) and were used as received. Both physical and mechanical properties of samples were measured by methods of testing cement; the standard of the American Society for Testing Materials (ASTM). To find major element concentration, Shimadzu Energy Dispersive X-ray Fluorescence Spectrometer (EDX-700 specifications Ray ny series) was used at Asia Research Center, Yangon. Metal concentration in four aggregate powder samples was analysed by AAS-800 Spectrophotometer. The IR spectra, was obtained by using Fourier Transformation Infra-red Perkin Elmer Spectrum GX (FT-IR) at the Universities Research Center. The mineral compositions of the samples were measured by Multi Flex Rigaku Automated Powder X- ray Diffractometer.

## Results and Discussion

The study of Supplementary Cementitious Material (SCMs) or the blended cement, such as Portland-Pozzolan Cement (PPC), Portland-Fly ash cement (PFC), Portland-Granulated Blast Furnace slag cement (PGBS) or Portland blast furnace cement (PBFC), Portland- condensed silica fume (PCFS) and Portland-rice husk ash (PRHA) have been done in many countries to promote cement replacement activities all over the world (Bogue, 1955).

From economic, technological and ecological point of view, cement replacement materials have an undisputed role to play in the future of construction industry. Small amounts of inert fillers have always been acceptable as cement replacements but if the fillers have pozzolanic properties, they impart not only technical advantages to the resulting concrete but also enable larger quantities of cement replacement to be achieved. Many of these mineral admixtures are industrial by-products, and correctly considered as waste so that the resulting benefits in terms of energy savings economy, environmental protection and conservation of resources are substantial.

Therefore the search for alternative binders or cement replacement materials has become a challenge for national development and forward planning. In many developed countries, on the other hand, apart from the need to save energy, there is an urgent requirement to project concrete as a reliable and desirable construction material.

This research work is devoted to cement replacement materials such as aggregate construction powder, pozzolan and brick powder. In this research, emphasis is made on mixing cement with different ratios of selective aggregate construction powder (Moe Hein), pozzolan and brick powder for general use in construction work.

## Physical Properties of Four Different Aggregate Construction Powder Samples

Table 1 showed some physical properties of four different aggregate construction powder samples. From this Table, it can be clearly seen that Moe Hein sample had the specified properties in loss on ignition and specific gravity, moisture content did not vary significantly among the samples.

## Characterization of Aggregate Construction Powder Samples by Spectroscopic Methods

### EDXRF-Measurements

Table 2 showed the relative composition of four different aggregate construction powder samples obtained from EDXRF measurement. These semi-quantitative results indicated the presence of calcium between 17-42 percent, iron between 2-3 percent, chloride between 50-67 percent and phosphorous between 2-4 percent.

### AAS Measurements

More accurate determinations of elements were obtained from atomic absorption spectroscopic measurement. It indicated the presence of calcium, iron, magnesium, manganese and potassium in all four samples and the presence of zinc in only two samples; Moe Hein and Kyauk Sue. These data were reported in Table 3.

### XRD Measurements

According to XRD results, the basic compositions of these four powder samples were calcite, dolomite and quartz. Calcium had the form of oxide, carbonate and hydroxide and silicon of oxide and hydroxide (Table 4).

### FT-IR Measurements

The FTIR assignments of the Moe Hein aggregate construction powder sample were tabulated in Table 5. From the infrared spectra of the four different powder samples, it was found that the FT-IR data of these four different powder samples were more or less the same.

The major prominent peaks in the FT-IR spectra of the samples were related with SiOH carbonate or hydroxide groups. For example, the stretching of OH (SiOH) can be seen between the wave numbers 3400cm$^{-1}$ and 3600cm$^{-1}$.

Similarly C – H stretching, C=O stretching of carbonate compound, Si-O-Si stretching ...etc can be seen between respective wave numbers (Nakamoto, 1986).

**Mechanical Properties of Moe Hein Aggregate Construction Powder Samples and Prepared Samples**

The ASTM standard cement types have specified certain physical requirements (Mechanical Strength) for each type of cement. These properties include (i) fineness (ii) soundness (iii) consistency (iv) setting time (v) compressive strength (vi) loss on ignition and (vii) specific gravity. Each one of these properties has an influence on the performance of the cement in concrete. Based on these properties, the aggregate construction powder was characterized as follows: (ASTM 150-72)

**Fineness**

The finer the cement powder is ground, the greater the surface exposed to water and the faster the set. (Patton, 1976) The minimum cement requirement is met by suitably grading the aggregate particles so that small particles can fill the voids between the larger particles.

The fineness of the aggregate construction powder or the size of the aggregate construction powder was obtained by means of sieve analysis. Figure 4 showed the particle size distribution of Moe Hein aggregate construction powder at 5 minutes and 10 minutes. Both results showed that when the mesh size number is over 200 (< 74 μ m), the weight percent was between 55 and 62. This showed the fineness of the sample.

**Soundness**

Soundness is the ability of hardened cement paste to retain its volume after setting. Le-Chatelier's method indicated the soundness of Moe Hein aggregate construction powder, the mixing of different ratios between Sin Min II cement as well as Kyant cement and the blended cement such as cement + Moe Hein + Pozzolan, cement + Moe Hein + Brick powder, etc.

These data also indicated that the samples had no Le-Chatelier's soundness (mm).

**Normal Consistency**

Quality control testing and research on cement properties are usually done on cement paste or cement mortars made with standard sand. The properties of hardened cement paste, mortar and concrete are similar functions of the water- cement ratio.

In this research work, the Myanmar ISO standard sand (BSEN, 196-1; 1995) (ISO 679; 1989) produced by Ministry of Industry (I) Myanmar Ceramic Industries was used to determine the normal consistency of Moe Hein aggregate construction powder. Vicat needle was used to determine the amount of mixing water to make cement paste of a given consistency. The resulting data and reported data were shown in Table 6.

**Setting Time**

The setting time depends on the composition of cement, temperature and quantity of water used in gauging. For ordinary cement, the initial setting time should not be less than 45 minutes and the final setting time not less than 10 hours. Tables 7 showed the setting time of the samples. It was found that the experiment done for this research work was within the limits of the standard setting time.

**Compressive Strength**

The American Standard of Testing Material (ASTM) prescribes that the compressive strength of the general use of Type II cement should not be less than 1000 psi (6.8965 MPa) after three days and not less than 1800 psi (12.4137 MPa) after seven days. The compressive strength results obtained were based on ISO Molding Methods for mortar, $H_2O$: Cement: Sand = 1:2:6 = 225 g: 450 g: 1350 g.

When measuring the compressive strength of the various ratios of Sin Min II cement and Moe Hein aggregate construction powder, it was found that the compressive strength of these mixtures conformed to the standard value in 3 days, 7 days and 28 days. These data were shown in Tables 8 On the other hand the compressive strength of various ratios of Kyant cement and Moe Hein mixtures exceeded the standard value in 3 days, 7 days and 28 days.

Tables 8 showed the compressive strength of the various ratios of the other admixtures and Moe Hein aggregate construction powder mortars in 3 days, 7 days and 28 days. These strengths had also acceptable standard limits but it was observed that the compressive strengths of this blended cement depended on the amount of cement replacement. When the replacement of cement increased, the compressive strength of cement decreased in 3 days, 7 days and 28 days respectively.

In this research, more work had been carried out to understand the nature of sand used in the cement mortar. Three types of sand, China imported sand, Myanmar standard sand for cement mortar and sand for general purposes in construction work were mixed with different ratios of Moe Hein-Sin Min II mortar. It was found that the mechanical strengths among these three types of sand were different from each other.

The development of tensile strength of this blended cement was similar to that of compressive strength.

## Loss on Ignition

This is essentially a measure of the unburnt carbon present in samples, and is considered (i) to affect the colour of the sample and (ii) to adversely affect quality by increasing the water requirements (because of the high porosity of the carbon particles) and reducing fineness and pozzolanic activity.

The Indian Standard Institution (ISI) prescribes specification for loss on ignition to be not more than 4 percent. In this research, it was observed that the loss on ignition value of four different aggregate construction powder samples was more than the ISI specification. It was due to the decomposition of calcium carbonate, magnesium carbonate, dehydration of surface water and binding water.

In support of Thermal analysis data for Moe Hein aggregate construction powder, it was found that at the initial stage of 100° C to 140°C, the dehydration of surface water and binding water were observed and the decomposition of calcium carbonate and magnesium carbonate were revealed between 480°C and 600°C.

## Typical Major Oxides of The Samples

Chemical analysis data of Moe Hein aggregate construction powder were shown in Table 9 and also compared with the chemical analysis data of Portland cement in USA. (Keyser, 1986). According to these analyses, it was found that Moe Hein aggregate construction powder has the least content of CaO and $SiO_2$, compared to the different types of Portland cement in USA. It was also found that the percent content of $Al_2O_3$ was higher in Moe Hein aggregate construction powder.

Similarly, the percent content of CaO and $SiO_2$ in Moe Hein aggregate construction powder was less than Myanmar cement such as Sin Min II and Kyant cement so that the influence of the low value of CaO reduced the tensile and compressive strength of Moe Hein aggregate construction powder (Table 10).

Because of the lower value of $SiO_2$ and higher content of $Al_2O_3$ in Moe Hein aggregate construction powder; compared to Myanmar cement, Moe Hein aggregate construction powder had shorter initial and final setting time. The results presented in the Table 10 served to illustrate another point regarding that $Fe_2O_3$ did not appear to play a direct part in the reactivity of Moe Hein aggregate construction powder. Too much MgO in cement might lead to the crystallization of periclase, an expansion reaction leading to its volume instability and eventual deterioration.

Table 1. Physical Properties of four different aggregate powder samples

| Name of sample / Physical Properties | Shwe Taung | Kyauk Sue | Man Thiri | Moe Hein |
|---|---|---|---|---|
| Fineness (%) | 27.6 | 26.24 | 28.2 | 26.2 |
| Moisture (%) | 0.23 | 0.21 | 0.20 | 0.23 |
| Specific Gravity (g/cc) | 2.5643 | 2.5277 | 2.6580 | 2.7480 |
| Loss on Ignition (%) | 34.35 | 28.59 | 29.13 | 29.39 |
| Soundness (mm) | nil | nil | nil | nil |

Table 2. Quantitative results of four different aggregate construction powder samples by ED-XRF

| Sample / Element | Concentration (%) | | | |
|---|---|---|---|---|
| | **Moe Hein** | **Man Thiri** | **Shwe Taung** | **Kyauk Sue** |
| Ca | 39.60 | 32.93 | 42.03 | 17.51 |
| Fe | 3.04 | 3.28 | 3.60 | 2.97 |
| Pb | - | 0.24 | 0.491 | 0.31 |
| Zn | 0.44 | - | - | 0.146 |
| Mn | 1.40 | - | - | - |
| $Cl^{-}$ | 50.60 | 58.423 | - | 67.57 |
| P | 3.275 | 2.725 | 4.39 | - |

Table 3. Metal concentration in four different aggregate construction powder samples

| Sample / Element | Concentration (ppm) | | | |
|---|---|---|---|---|
| | **Moe Hein** | **Man Thiri** | **Shwe Taung** | **Kyauk Sue** |
| Mn | 6.990 ± 0.336 | 1.603 ± 0.196 | 1.739 ± 0.162 | 2.834 ± 0.494 |
| Zn | 1.961 ± 0.008 | ND* ± 0.001 | ND* ± 0.003 | 0.520 ± 0.518 |
| Fe | 23.78 ± 0.333 | 20.45 ± 0.133 | 15.13 ± 0.121 | 26.75 ± 0.139 |
| K | 0.669 ± 0.059 | 0,440 ± 0.003 | 0.167 ± 0.002 | 0.496 ± 0.032 |
| Mg | 11.21 ± 0.008 | 9.94 ± 0.015 | 11.79 ± 0.018 | 11.54 ± 0.013 |
| Ca | 196.1 ± 4.448 | 191.7 ± 4.710 | 172.3 ± 11.99 | 178.2 ± 10.36 |

ND* – Non-Detectable in ppm range

Table 4. Mineral compositions of four different aggregate construction powder samples, pozzolan and brick powder

| Sample | Mineral Composition |
|---|---|
| Moe Hein | Calcite, $CaCO_3$/Dolomite, Ca Mg $(CO_3)_2$/Quartz, $SiO_2$/ Magnesite, $MgCO_3$/ Gismodine, $CaAl_2Si_2O_8$ $4H_2O$. |
| Man Thiri | Calcite, $CaCO_3$/ Quartz, $SiO_2$/ Muscovite, $KAl_2$ $(Si_3Al)O_{10}$ $(OH, F)_2$ |
| Shwe Taung | Calcite, $CaCO_3$/ Dolomite, Ca Mg $(CO_3)_2$/ Calcium Oxide, CaO/Gypsum, $CaSO_4$ $2H_2O$ |
| Kyauk Sue | Calcite, $CaCO_3$/Dolomite, Ca Mg $(CO_3)_2$/ Quartz, $SiO_2$/ Gismondine, $CaAl_2Si_2O_8$ $4H_2O$/Portalandite, Ca $(OH)_2$. |
| Pozzolan | Anorthite sodium Ca 66Na 34 Al.66 $SiO_2$ 34 $O_8$<br>Cordierite Mg $2Al_4$ $Si_5$ $O_{18}$<br>Augite aluminium Ca(Mg.Fe, Al) (Si, Al) $2O_6$ |
| Brick Powder | Albide NaAl $Si_3$ $O_8$ Quartz $SiO_2$<br>Scorzalite (Fe, Mg) $Al_2(PO_4)_2$ $(OH)_2$<br>Sidorenkite Na 3Mn $(PO_4)$ $(CO_3)$ |

Table 5 Infrared spectra of selective aggregate construction powder (Moe Hein)

| **Peak** | **Wave number ($cm^{-1}$)** | **Remark** |
|---|---|---|
| A | 3614<br>3422 | $\nu_{O-H}$ of SiOH |
| B | 2982<br>2924<br>2874 | $\nu_{C-H}$ |
| C | 1798 | $\nu_{C-0}$ |
| D | 1424 | $\delta_{OH}$ (in plain) of SiOH and POH |

| | | |
|---|---|---|
| E | 1079<br>1026 | $\nu_{Si-O-Si}$ (asymmetric) |
| F | 911<br>875 | $\nu_{Si-O}$ (symmetric) |
| G | 799<br>728<br>712 | $\nu_{P-O}$ |
| H | 530<br>473<br>410 | $\nu_{metal-carbon}$ |

Table 6. Comparison of mechanical strength of Moe Hein aggregate construction powder and Sin Min II cement

| No. | Mechanical strength | Result | | |
|---|---|---|---|---|
| | | Reported Data* | Present work | Sin Min II |
| 1 | Specific gravity | 3.036 | 2.748 | 3.120 |
| 2 | Fineness | 37 % | 26.20 % | 9.3 % |
| 3 | Normal consistency | 17.94 % | 23 % | 21 % |
| 4 | Soundness | Nil | Nil | Nil |
| 5 | Setting Time<br>(a) initial setting<br>(b) final setting | <br>52 min<br>600 min | <br>60 min<br>580 min | <br>190 min<br>225 min |

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Table 7. Mechanical strength of the mixture of cement ( Kyant) and Moe Hein aggregate construction powder in various ratios

| No. | Mechanical strength | Moe Hein : Kyant | | | ASTM : C 150-72 (Type II, General use) |
|---|---|---|---|---|---|
| | | 1 : 1 | 1 : 3 | 1 : 4 | |
| 1. | Setting time | | | | |
| | - Initial setting time | 65 min | 77 min | 110 min | Not less than 45 min |
| | - Final setting time | 405 min | 407 min | 415 min | Not less than 480 min |
| 2. | Tensile strength (MPa) | | | | |
| | - 3 days | 1.1931 | 1.6413 | 2.8137 | 0.8620 |
| | - 7 days | 1.4620 | 2.3586 | 3.0896 | 1.7241 |
| 3 | Compressive strength (MPa) | | | | |
| | - 3 days | 10.0413 | 13.6827 | 18.2413 | 6.8965 |
| | - 7 days | 10.4965 | 20.0068 | 22.4344 | 12.4137 |
| | - 28 days | 15.4205 | 28.0827 | 37.3931 | |

Table 8. Mechanical strength of the mixture of cement ( Sin Min II) and Moe Hein aggregate construction powder in various ratios

| No. | Mechanical strength | Moe Hein : Sin Min II | | | ASTM : C 150-72 (Type II, General use) |
|---|---|---|---|---|---|
| | | 1 : 1 | 1: 3 | 1 : 4 | |
| 1. | Setting time | | | | |
| | - Initial setting time | 175 min | 135 min | 125 min | Not less than 45 min |
| | - Final setting time | 215 min | 175min | 185 min | Not less than 480 min |
| 2. | Tensile strength (MPa) | | | | |
| | - 3 days | 1.37 | 2.07 | 2.21 | 0.8620 |
| | - 7 days | 1.52 | 2.38 | 2.53 | 1.7241 |

| **No.** | **Mechanical strength** | **Moe Hein : Sin Min II** | | | **ASTM : C 150-72** |
|---|---|---|---|---|---|
| | | **1 : 1** | **1: 3** | **1 : 4** | **(Type II, General use)** |
| | - 28 days | 3.53 | 4.33 | 6.05 | - |
| 3 | Compressive strength (MPa) | | | | |
| | - 3 days | 7.29 | 10.88 | 12.50 | 6.8965 |
| | - 7 days | 9.01 | 14.06 | 16.25 | 12.4137 |
| | - 28 days | 18.75 | 24.90 | 35.68 | - |

Table 9. Comparison on chemical compositions of some typical cements* and Moe Hein aggregate construction powder

| **Composition** / **Sample** | **$SiO_2$ (%)** | **$Al_2O_3$ (%)** | **$Fe_2O_3$ (%)** | **CaO (%)** | **MgO (%)** | **$SO_3$ (%)** | **Loss** | **Insoluble residue** |
|---|---|---|---|---|---|---|---|---|
| TYPE I* | 20.9 | 5.2 | 2.3 | 64.0 | 2.8 | 2.9 | 1.0 | 0.2 |
| TYPE II* | 21.7 | 4.7 | 3.6 | 63.6 | 2.9 | 2.4 | 0.8 | 0.4 |
| TYPE III* | 21.3 | 5.1 | 2.3 | 64.9 | 3.0 | 3.1 | 0.8 | 0.2 |
| TYPE IV* | 24.3 | 4.3 | 4.1 | 62.3 | 1.8 | 1.9 | 0.9 | 0.2 |
| TYPE V* | 25.0 | 3.4 | 2.8 | 64.4 | 1.9 | 1.6 | 0.9 | 0.2 |
| MOE HEIN | 12.13 | 7.4 | 0.94 | 41.0 | 1.5 | 2.8 | 1.2 | 0.6 |

* Portland Cement in USA, designed by American Society for Testing and Materials (ASTM)

Type I* The special properties are not required
Type II* General use
Type III* High early strength
Type IV* Low heat hydration
Type V* High sulphate resistance

Table 10 Comparison on the average compositions of different oxides in Portland cement, Sin Min (II) cement, Kyant cement and Moe Hein aggregate construction powder

| Composition / Sample | $SiO_2$ (%) | $Al_2O_3$ (%) | $Fe_2O_3$ (%) | CaO (%) | MgO (%) | $SO_3$ (%) |
|---|---|---|---|---|---|---|
| Average composition in cement | 20-25 | 5-10 | 1-2 | 50-60 | 2-3 | 1-2 |
| Moe Hein | 12.13 | 7.4 | 0.94 | 41.0 | 1.5 | 2.8 |
| Sin Min (II) cement | 23.70 | 3.46 | 4.53 | 65.32 | 1.32 | - |
| Kyant cement | 24.72 | 3.20 | 2.86 | 60.69 | 1.32 | - |

## Conclusion

The results of the research work have shown that among the four types of the locally available aggregate construction powders (Moe Hein, Man Thiri, Shwe Taung and Kyauk Sue), the Moe Hein representative sample was found to possess a quality corresponding to a specified construction powder in terms of the physico-chemical and mechanical properties.

The nature, texture and other physico-chemical properties of the aggregate construction powder were characterized by modern techniques, such as EDXRF, XRD, AAS, and FT-IR analyses. The AAS measurement quantitatively showed the presence of Ca, Fe, Mg, Mn and K in all samples and the presence of Zn in only two samples, Moe Hein and Kyauk Sue.

These techniques revealed the main elemental composition of the samples, the texture and crystalline form as well as the presence of the major ingredients. Other ingredients, which were added, to act as fillers or binders such as pozzolan and brick powder were found to be strengthening the durability of the powder, when it set in after the wetting or sprinkling process. Moe Hein aggregate powder proved to be possessed with higher specific cementing quality than others.

The analytical assays of the Moe Hein aggregate powder sample revealed that calcium oxide 41.00 percent, silicon dioxide 12.13 percent, aluminium oxide 7.40 percent, chloride 1.49 percent, magnesium oxide 1.50 percent, total sulphur 1.15 percent, carbonate 43.63 percent, sulphate 3.44 percent and iron 0.98 percent. The durability, mechanical strength, texture and hardening quality of Moe Hein were assessed by the properties such as, fineness, normal consistency, setting time, soundness, tensile strength and compressive strength.

It was found that 1:1 ratio (wt/wt) of Moe Hein with Sin Min II or Kyant cement, produced high-grade cement powder, compared to all other types of admixtures.

This study had revealed that it is feasible to prepare cost effective and productive cement with cementitious materials such as the aggregate construction powder comprising a locally produced powder Moe Hein together with available pozzolan and brick powder to be used in the construction industry of Myanmar.

The aim is to produce cost effective construction powder ready to be used which is comparable to more expensive commercial cement powder.

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