Quality of rock from Ngrayong Formation as additional material for cement manufacture, Gunem District, Rembang Regency, Central Java

by Tri Winarno

Quality of Rock from Ngrayong Formation as Additional Material for Cement Manufacture, Gunem District, Rembang Regency, Central Java

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Abstract. Due to development of infrastructure in some regions of Indonesia, existing cement producers are expanding their capacity and new investors began to build new factories as well. Portland cement is the most commonly produced cement in Rembang area, mainly using limestone ($CaCO_3$) mixed with additional material clay, shale, sand as source of alumino-silicate. This study aims to evaluate quality of sedimentary rocks from Ngrayong Formation in Gunem District as additional material in cement industry. Detailed field mapping and rock sampling are used to determine lithology types of study area, supported by petrographic analysis. Geochemical XRF analysis aims to determine chemical composition of rock samples as standard parameter for material quality. Lithology of study area is sedimentary rocks composed of layers of quartz sandstone, siltstone, and claystone with slightly to completely weathered. This study uses company chemical standard $SiO_2 > 65\%$, $Al_2O_3 > 16.5\%$, and $SO_3 < 2.5\%$ for rocks. Result of geochemical concluded that quartz sandstone in the western part of study area and claystone meet the aforementioned standard as additional material for cement mixture. Other rocks are unsuitable as they can damage manufacturing equipment as well as compromise the final cement quality.

INTRODUCTION

The ideal raw material for the cement industry is rock which naturally has the right composition to produce cement clinker according to the desired composition. In addition, raw materials must be available in abundance, easy to mine, and have a homogeneous character. The main raw materials for the cement industry are limestone (a source of CaO) and clay (a source of SiO_2, Al_2O_3, and Fe_2O_3). The two raw materials must be mixed with their respective proportions according to the final requirements of the cement chemical composition.

PT Semen Indonesia (Persero) Tbk Rembang has two quarry of cement raw material, they are the limestone quarry and the clay quarry. Limestone is required to meet one of the main components of cement i.e. calcium (CaO), while clay is required to meet the components of alumina (Al_2O_3) and silica (SiO_2). Clay is soil with clay-sized which is plastic and cohesive [1]. SiO_2 is a solid compound with a volume percentage of around 50 to 60% which is used to strengthen the structure of cement [2, 3], while Al_2O_3 is required in order the cement can easily react to water and form cement paste [4, 5].

The study was carried out at the PT Semen Indonesia (Persero) Tbk quarry area in Kajar Village, Gunem District, Rembang Regency, Central Java (Fig. 1)

The purpose of the research is to find out the type of lithology in the study area, to determine the content of Al_2O_3, SiO_2, and SO_3 of the rocks in the study area, to learn the relationship between the types of lithology with the content of Al_2O_3, SiO_2, and SO_3, and to determine the lithology that meet the standards as a cement raw material.

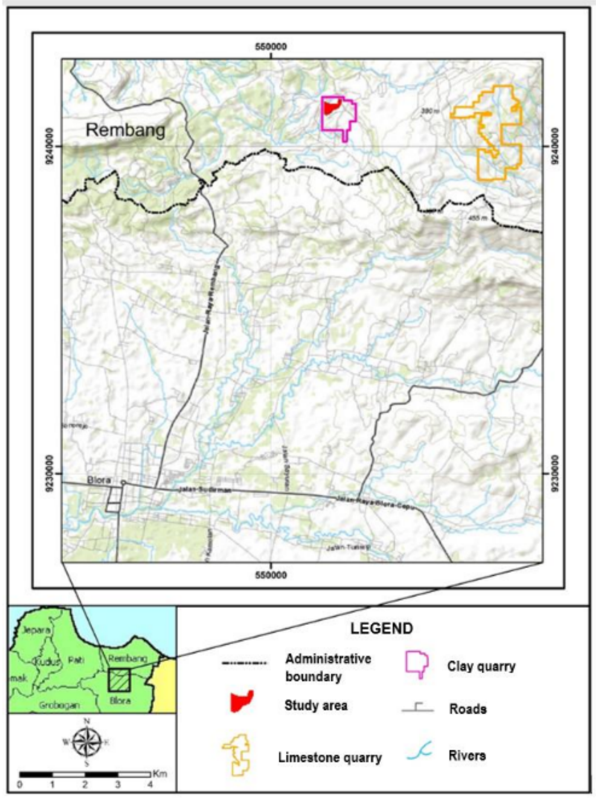

FIGURE 1. Research area location

LITERATURE REVIEW

Regional Geology

The regional geological map of the mining area of PT Semen Indonesia (Persero) Tbk in Rembang Regency can be seen in Fig. 2 [6]. The research area is included in the Ngrayong Formation. The Ngrayong Formation consists of 5 types of lithology, namely sandstone, shale, claystone, siltstone, and coal. The Ngrayong Formation was deposited in the Tertiary Period during the Early Miocene to the Middle Miocene.

There are 4 lithological units in the Ngrayong Formation that are found in the Tempuran Blora area. The lithological units are siltstone interbedded with sandstone which deposited in the delta plain facies, sandstones interbedded with siltstone (with carbon material interbedded) deposited in the facies of the distributary mouth bar, sandstones deposited in the backshore facies, and clastic limestones deposited in shallow marine [7].

Chemical Composition of Portland Cement

Oxides interact with each other and form more complex compounds. Portland cement is composed of four basic chemical compounds, they are belite, alite, aluminate, and ferrite [8]. Belite or dicalcium silicate (C_2S), composed about 15-30% of ordinary portland cement clinker. This compound is hydrated and hardens slowly. It has a very important role to strengthen the cement after one week.

Alite or tricalcium silicate (C_3S), is the most important component, composed about 50-70% of ordinary portland cement clinker. This compound is hydrated and hardens very quickly. It has a very important role in the initial set and initial strengthening of the cement.

Aluminate or tricalcium aluminate (C_3A), composed about 5-10% of ordinary portland cement clinker. This compound releases a lot of heat during the initial stages of hydration, but has little contribution in cement strengthening. Gypsum slows down the hydration of this compound. Cement with low C_3A is resistant to sulfate.

Ferrite or tetracalcium aluminoferritic (C_4AF), composed about 5-15% of ordinary portland cement clinker. This compound is a fluxing agent that reduces the temperature of raw materials in kilns from 3000° F to 2600° F. It is hydrated quickly, but does not contribute much to the strength of the cement.

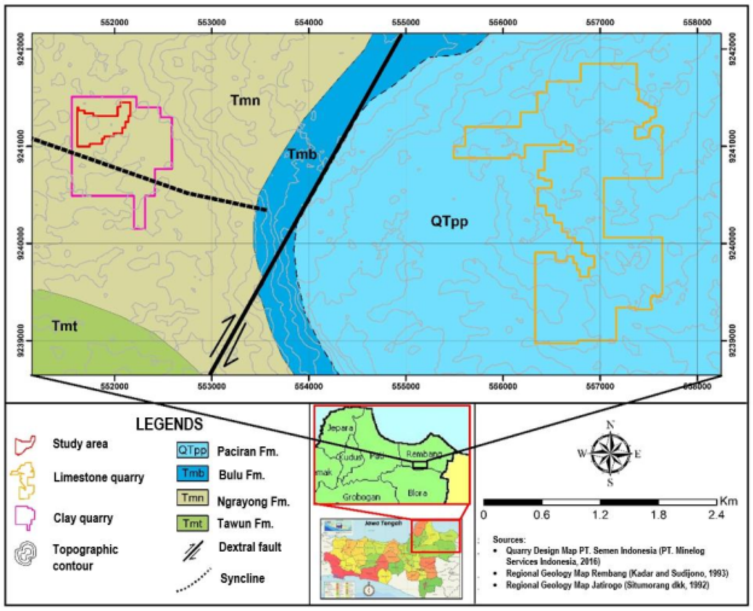

FIGURE 2. Regional geology map

Quality Standards for Cement Raw Materials

Producing cement requires a mixture of raw materials, which have chemical composition in line with certain limits [9]. Sustainable production of high quality cement is only possible if the mixture of raw materials has an optimal composition. The limit of raw material composition values can be seen in Table 1 which is commonly used by cement factories.

TABLE 1. Oxide composition limits

Oxides	Wt %
CaO	60-67
SiO_2	18-24
Al_2O_3	4-8
Fe_2O_3	1-8
MgO	<5
Alkali (K_2O, Na_2O)	<2
SO_3	<3

The oxide classification used by the laboratory of PT Semen Gresik Rembang for materials obtained from clay mining can be seen in Table 2 [10].

TABLE 2. Classification limit levels of clay compounds

Oxides	Percentage (%)
Al_2O_3	*low* < 16.5 < *high*
SiO_2	*low* < 65-70 < *high*
SO_3	*low* < 1-2.5 < *high*

METHODOLOGY

The methods used in this study are field observations, X-Ray Fluorescence (XRF) analysis, and petrographic analysis.

a. Field observations were carried out to determine the geological conditions of the study area, such as the type of lithology and geological cross section and to collect the rock samples to be analyzed in the laboratory.
b. The geochemical analysis is carried out by using XRF analysis. XRF analysis is carried out to analyze the main elements and trace elements along with their concentrations in the rocks deposits using spectrometric methods. Currently, XRF is the most common method of analysis used in the determination of major elements and traces elements on rock samples. Compared to other geochemical analysis methods, the XRF analysis has the ability to detect the lowest elements more sensitive but cannot detect elements lighter than Na which have an atomic number of 11.
c. Petrographic analysis was carried out to determine the rock description optically. Thin section samples were prepared to identify mineralogical and petrographical characteristics under polarizing microscope. The rock samples from the research area were polished to make the thin sections. The thin sections were analyzed using polarization microscope. This analysis aims to determine the character of the rock and the microscopic composition of the rock composition of each sample.

RESULTS AND DISCUSSION

Geological Conditions

The research area is clay quarry owned by PT Semen Indonesia (Persero) Tbk in Kajar Village, Gunem District, Rembang Regency. There are four different types of lithology units found in the research area, they are yellow sandstone, siltstone, claystone, and brown sandstone. The distribution of the four lithology units can be seen in Fig. 3.

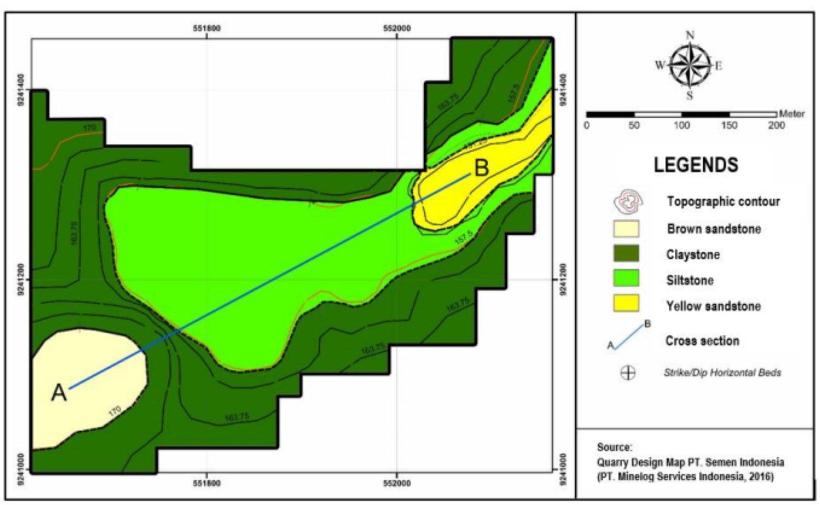

FIGURE 3. Geological map of research area

The yellow sandstone unit consists of sandstone with medium weathered degree. This lithology has a massive structure, whitish yellow colour, grain size 1/16 - 1/2 mm (very fine sand - medium sand), closed package, and well-sorted (Fig. 4). From petrographic observation, the compositions of the sandstone are quartz (45%), clay minerals (50%) and opaque mineral (5%). Based on the compositions, the rock is Quartz Wacke [11].

The siltstone unit consists of three lithologies; they are siltstone, lignite, and sandstone with slightly weathered degree (Fig. 5). Siltstone has a black colour, grain size 1/256 - 1/16 mm (silt). The structure is partially massive, in several places are found lamination structure, and ichnofossil (burrowing). Lignite is found with a thickness of approximately 5 mm, black, has a very light density and brittle. Sandstones found with a thickness of approximately 5-10 mm, grey, with grain size 1/16 - 1/4 mm (very fine sand - fine sand). From the petrographic observation, the mineral compositions of siltstone are quartz (20%), clay mineral (75%) and opaque mineral (5%). Based on the compositions, the rock is Mudrock [11].

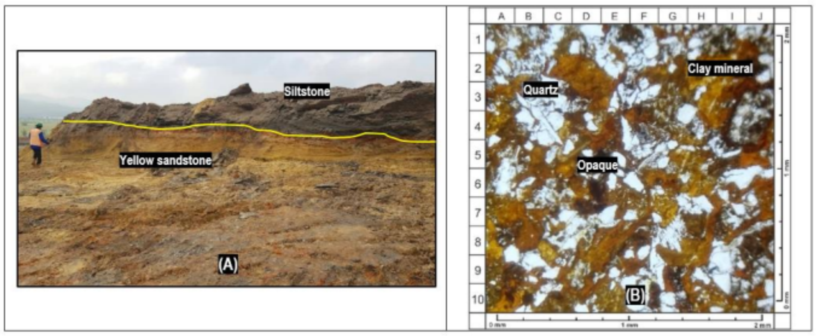

FIGURE 4. Outcrop of yellow sandstone (A) and its petrographic thin section (B)

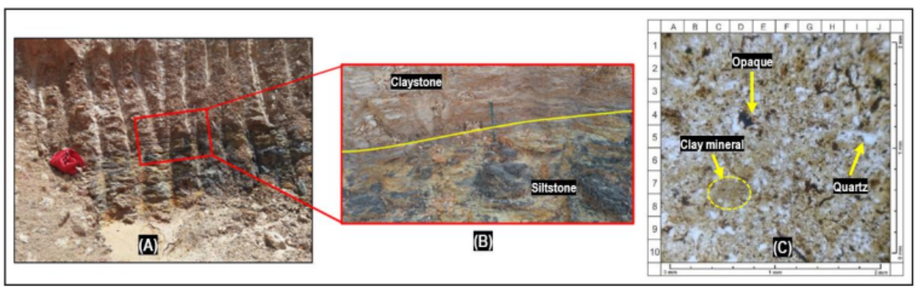

FIGURE 5. Outcrop of siltstone with lamination structure (A, B) and its petrographic thin section (C)

The claystone unit consists of two lithologies, they are claystone and sandstone, with medium weathered degree (Fig. 6). Claystone has a reddish grey colour, grain size <1/256 mm (clay). The structure is massive and in some places are found lamination structure. Sandstone has a brownish yellow colour, found with a thickness of ± 1-5 mm with lamination structure. From the petrographic observation, the mineral compostions are quartz (3%), clay mineral (82%) and opaque mineral (15%). Based on thecompositions, the rock is Mudrock [11].

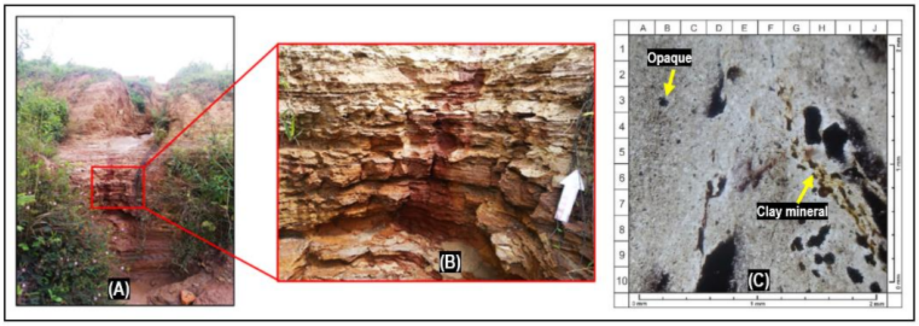

FiGURE 6. Outcrop of claystone (A, B) and its petrographic thin section (C)

The brown sandstone unit consists of sandstone, with slightly weathered degree (Fig. 7). This lithology has a massive structure with a greyish brown colour, grain size 1/4 - 1/2 mm (medium sand), closed package and well-sorted. In this lithology, coal fragments found with diameter ± 1 cm. From the petrographic observation, the mineral composistions are quartz (30%), clay mineral (69%) and opaque mineral (1%).Based on the compositions, the rock is Quartz Wacke [11].

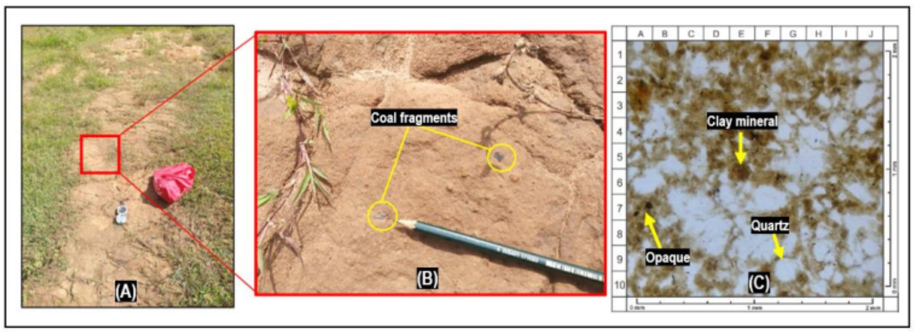

FIGURE 7. Outcrop of brown sandtone with coal fragments (A, B) and its petrographic thin section (C)

The Relationship Between Rock Types and Chemical Content

The range of chemical content for each lithology from the XRF analysis results can be seen in the Table 3.

TABLE 3. The range of chemical content for each lithology in research area

Lithology	Al_2O_3 (%)	SiO_2 (%)	SO_3 (%)
Yellow sandstone	12 - 16	62 – 82	0.5 - 1.5
Siltstone	18 - 22	50 – 60	1 - 3.25
Claystone	18 - 26	50 – 68	0 - 1.5
Brown sandstone	15 - 21	60 – 80	0 - 0.5

The rocks which have high Al_2O_3 content are claystone. followed by siltstone. brown sandstone. and yellow sandstone. From the texture of the rocks. it can be concluded that the finer the grain size. the greater the Al_2O_3 content. The composition of Al_2O_3 in siliciclastic sedimentary rocks comes from weathering. erosion. and transportation of feldspatic source rock. As a result of this process. the minerals that composed the feldspatic rock which have the composition of Al_2O_3 become very fine. therefore the composition of Al_2O_3 commonly found in claystone which have very fine grain size.

The rocks which have high SiO_2 content are yellow sandstones. followed by brown sandstones. siltstone and claystone. The composition of SiO_2 in siliciclastic rocks comes from weathering. erosion. and transportation of quartz minerals which are formed from magma which is rich in silica. Quartz minerals are minerals that have the most stable properties. and mostly form sand grains.

The rocks which have high SO_3 content are siltstone. followed by yellow sandstone. claystone. and brown sandstone. The SO_3 composition in siliciclastic rocks comes from pyrite minerals which are formed due to chemical processes in the depositional environment. The siltstone unit contains pyrite mineral. either disseminated or concentrated around the iron oxide nodules. Pyrite mineral can be formed due to sulfate compounds that are abundant in seawater reacting with iron ions carried by river water with the help of bacterial activity.

Quality of Rock as a Cement Mixture

The chemical composition of the yellow sandstone consists of Al_2O_3 (12% - 16%). SiO_2 (62% - 82%). and SO_3 (0.5% - 1.5%). Based on the chemical content standard set by the laboratory of PT Semen Gresik Rembang this sandstone cannot be used as a cement material mixture. If this sandstone is still used as a cement material mixture at an early stage. it will require more corrective material. thus increasing production costs.

The chemical composition of siltstone consists Al_2O_3 (18% - 22%). SiO_2 (50% - 60%). and SO_3 (1% - 3.25%). Based on the chemical content standard set by the laboratory of PT Semen Gresik Rembang. this siltstone cannot be used as a cement material mixture because it has a dominant sulfur content that exceeds the specified limit. If this siltstone is still used as a cement material mixture. It will reduce the performance of production equipment, especially kilns. because it will accelerate the formation of coatings on all sides.

The chemical composition of claystone consists of Al_2O_3 (18% - 26%). SiO_2 (50% - 68%). and SO_3 (0% - 1.5%). Based on the chemical content standard set by the laboratory of PT Semen Gresik Rembang. this claystone can be used as a cement material mixture by regarding the SiO_2 content. If the SiO_2 content of the claystone is less than 65% it can be added with quartz sandtone at the mixing stage at the raw mill.

The chemical composition of brown sandstones consists of Al_2O_3 (15% - 21%). SiO_2 (60% - 80%). and SO_3 (0% - 0.5%). Based on the chemical content standard set by the laboratory of PT Semen Gresik Rembang. this brown sandstone can be used as a cement material mixture.

From the explanation of the chemical quality of each rock. it can be concluded that yellow sandstones cannot be used as a cement material mixture because only meet the requirement of SiO_2 content. but can be used as a corrective agent for cement. Siltstone cannot be used as a cement material mixture because the SO_3 content exceeds the maximum limit. Claystone can be used as a cement material mixture by regarding the SiO_2 content. Brown sandstone can be used as a cement material mixture.

CONCLUSION

1) There are four types of lithology units in the study area. they are yellow sandstone unit. siltstone unit. claystone unit. and brown sandstone unit.
2) The highest content of Al_2O_3 level is found in claystone. the highest content of SiO_2 are found in yellow sandstones. and the highest content of SO_3 are found in siltstone.
3) Yellow sandstone cannot be used as a cement material mixture because the Al_2O_3 content does not meet the requirements. siltstone cannot be used as a cement material mixture because the SO_3 content exceeds the maximum limit. brown sandstone and claystone can be used as a cement material mixture.

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