Sand type characteristics analysis and mapping in Bengkulu

Fepy Supriani*, Mukhs Islam and Yuzuar Afrizal

Department of Civil Engineering, Faculty of Engineering, University of Bengkulu, Bengkulu, Indonesia

*fepy_ilhan@yahoo.co.id

Abstract. Sand can be classified based on the origin of the quarry, namely sea sand, river sand and mountain sand. Sand provides an important role as filler material in building cementation materials such as in mortar and concrete. The characteristics of the sand determine the strength of the building. Characteristics can be in the form of grain size (gradation), sludge/clay content and specific gravity. This study aims to look at the characteristics of sand from different types of sand while looking at the mapping of sand zones based on SKSNI 03 2834 2000. Sand is taken directly from quarry, in five city districts in Bengkulu Province which consist of sea sand, river sand and mountain sand. Determination of sand gradation is based on SNI 03-1975-1990 sieve analysis test. Examination of sludge/clay content and specific gravity based on SNI 6821-2002 and SNI 03-4804-1998 standards. The conclusion obtained is that sand will have different characteristics based on quarries. 81.25% sea sand tends to have uniform granules, with smooth and very fine characteristics and does not enter any zone. River sand has a good gradation and categorized in zones characteristic of smooth, slightly rough and rough. Mountain sand is categorized as fine sand with good gradation. The sludge content of sand from each type of origin of the sand quarry shows that the river sand with a calm flow has a high level of clay content. Clay content levels that are very high on mountain sand are probably ash that was produced by volcanic activity of the mountain. The specific gravity of each type of sand varies, not depending from the origin of the sand.

1. Introduction

Sand/fine aggregate is an important building material and must be used in every building development process. Sand is an aggregate with granules ranging from 0.0625 to 2mm. Natural and artificial sand is one of the main ingredients in forming concrete and mortar. Mortar cementation material is formed from a mixture of sand and cement plus water, while mortar mixture added with coarse aggregate will form concrete. The importance of sand in building materials affects the strength of the building itself.

Bengkulu City as an earthquake-prone area should pay attention to disaster mitigation for a long term, one of which is building in accordance with earthquake resistant standards. One standard that must be possessed is standard in building materials, workmanship and working methods. High quality building materials are obtained from research so that they are in accordance with existing standards.

Bengkulu Province has a long coastline, and also has mountain ranges. This geographical condition is advantageous because it has abundant resources, especially for building materials. The presence of large to small stones can be used as building materials, although massive exploitation of rocks can damage the environment. Sand is one of the building materials whose availability is abundant. Sand can be categorized based on the origin of the quarry, namely sea sand, river sand and mountain sand. The availability of these three types of sand fulfills the need for sand in the city of Bengkulu.
River sand is sand that comes from excavation or mining in rivers. The steep rivers have a swift water flow, so the deposits of the rock particles will vary considerably at a certain distance, usually content only small amount of fine grains and the rocks are clean enough. On gentle slopes, variations in particle size do not change from one place to another, most of the particles are more rounded and dirtier (http://eprints.ums.ac.id/48276/5/BAB%20I.pdf). River sand is obtained directly from the riverbed, which is generally fine grained and rounded due to friction. Adhesion between granules is somewhat lacking due to the round shape of the granules (http://www.forumbebas.com, February 14, 2011). The sand that is mined from the riverbed has been washed directly and the content of the sludge has decreased a lot, the faster the river flows, the less the sludge contained in the sand. The process of river sand mining is also more difficult because it must be sucked and threatened by flooding. River sand has a clean and smooth type of grain with sizes between 0.06 mm - 2 mm [1].

Sea sand is sand taken from the beach. The grain is smooth and round due to friction. This sand is the worst sand because of its salt content. This salt absorbs water from the air and this causes the sand to always get wet and generate swelling when it become a building [2]. Sea sand is one type of fine aggregate material that is quantitatively available along the coast in coastal areas [3]. In general, sea sand has the characteristics of fine and round granules, which have gradations (variations in grain size) that are uniform and have salt chloride (Cl) and sulfur (SO₄) content [4]. The Public Works Department in its regulation in SK-SNI T-15-1991-03 states that it does not recommend sea sand for concrete mixes unless the usage is already approved by experts [5]. Round and fine grains, and uniform gradations will reduce interlocking mechanism between granules.

Mountain sand is obtained directly from the ground or by digging. The form of mountain sand is usually sharp, angular, porous and free of salt content although it usually has to be cleaned from dirt/soil by washing it first [6].

The characteristics of the three types of sand are visually different; some are smooth, rough and very rough. The characteristics of sand can be seen from the value of grain modulus, sludge content, organic content and specific gravity. Grain modulus is a gradation that shows the fineness of the grains that are tested and left in each sieve set. From the sieve analysis test, the data can be plotted into the sand zone graph as in SNI 03-2834-2000 [7]. This study aims to look at the characteristics of sand from the three types of sand origin namely river, mountain and sea sand, as well as the sand zone that will be used for building materials, hence the results of the study could be used as guidelines of sand usage in connection with its technical properties and requirements so that the overusage of one type of sand could be prevented and the environmental impact due to overexploitation of aforementioned type of sand could be prevented.

2. Literature Review

2.1. Impact of sand exploitation on the environment

Excessive and irresponsible mining / exploitation of sand can accelerate environmental damage in a short time which results in deteriorating environmental quality. Although the former mining area can be used for other economic activities, it will still change the balance of environmental land management and cause disruption of the water system in the area that may be far wider than the mining area itself [8].

The impact of over exploitation of mountain sand is already in effect around Merapi mountain area, in which the permit for sand mining is only for river sand, while in practice, mining activity of mountain sand also happen. One of the observed effects is the lowering of ground water table, from average of 4 m to over 4 m [9].

2.2. Standards for sand as fine aggregates

Pamungkas and Hairunnisa stated that fine aggregates are hard mineral grains whose shape is approximately to round, sharp with the size of the grain mostly between 0.07-5 mm [14].
Requirements to produce good cementitious materials, fine aggregates must meet the following requirements:

1. Fine aggregates must consist of sharp and hard grains and continuous gradations. Grains of fine aggregate must be eternal, meaning they are not broken or destroyed by the effects of weather, such as the sun or rain.
2. The composition of the grain size must have a fineness modulus that ranges from 1.50 to 3.80.
3. The sludge / grain content is smaller than 0.07 mm, the sludge content is a maximum of 5%.
4. Organic content test specimen colour is not darker than the standard color after being given 3% sodium hydroxide solution.
5. Grain hardness, when compared with the hardness of the sand grains originating from Bangka quartz sand, gives a number of fraction number not greater than 2.20.

According to Indonesian National Standards (SKSNI-S-04-1989-F: 28) it is stated the requirements of fine sand or fine aggregate as building materials as follows [13]:

1. Fine aggregates must consist of sharp and hard grains with a hardness index <2.2.
2. Eternal properties when tested with a solution of saturated sulfate salt as follows:
   - If it is using natrium sulfat maximum decayed parts is 12%.
   - If fine parts of magnesium sulfate are used, up to 10%.
   - It should not contain more than 5% mud and if the sand contains more than 5% mud, the sand must be washed.
   - Sand should not contain too much organic ingredients, which must be proven by color experiments from Abrans-Harder with 3% NaOH saturated solution.
   - The large composition of sand grains has a modulus of fineness between 1.5 to 3.8 and consists of various grains.
   - For high durability concrete, the reaction of sand to alkali must be negative.
   - Sea sand should not be used as fine aggregate for all concrete except with instructions from recognized construction material government agencies.
   - Fine aggregate used for plastering and applied species must meet the requirements of the mortar sand

Aggregate gradations are variations in aggregate distribution and size. The tests were carried out using sieve analysis according to BS 812, ASTM C-33, C136, ASHTO T-27 and SKSNI standards. Grain gradation is divided into 3, namely gap gradation, continuous gradation and uniform gradation.

1. Gap gradation, if one or more grain sizes in a set of sieves is not present, then the gradation will show a horizontal line in the graph. The advantages of gap gradations are: 1) on certain water to cement ratio concrete work will be easier if the sand content is less, 2) for high workability concrete tends to experience segregation, 3) slope gradation does not adversely affect the strength of the concrete.
2. Continuous gradation if all aggregate sizes are available and are well distributed. Continuous gradation is often recommended and is often used in concrete mixes. With the availability of all sizes of aggregates there will be good interlocking, where aggregates will fill each other in concrete mixes. Continuous gradation is the best gradation.
3. Uniform gradation are gradations that have the same grain size. Aggregates with uniform gradations are usually used for lightweight concrete which is a type of concrete without sand. Aggregates with uniform gradations can be used to fill aggregates with poorly aggregated intervals to meet standards.

The distribution of sand zones based on the results of sieve analysis will be included in the sand zone on SNI 03-2834-2000 standard [7].
2.3. Fineness Modulus

Fineness modulus is an index used to measure the smoothness or roughness of aggregate grains, the greater the MHB value of an aggregate, the greater the aggregate granular sizes. The smoothness or roughness of an aggregate can affect the workability of the mortar. Fineness grain modulus is defined as the number of percent of aggregate items left above a set of sieves, then the value is divided by one hundred. Sand roughness is grouped into 4 zones (SNI 03-2834-2000) [7], namely:

1. Zone 1: Coarse sand, with value of 2.9 - 3.2.
2. Zone 2: Slightly Coarse sand, with values of 2.6 - 2.9.
3. Zone 3: Slightly Fine sand, with values of 2.2 - 2.6.
4. Zone 4: Fine Sand, with values 1.8 - 2.2.

2.4. Mud Content

Mud is usually mixed in sand. In sufficient quantities it can reduce the strength of concrete, because of its tendency to inhibit the hydration of cement. This mud forms layers that cover the grains of sand, thus preventing the binding of cement. Mud also has properties, which expand in a wet state and shrink at dry time, this property will affect the concrete, namely shrinkage and "creep" in hardened concrete.

The aggregate unit weight is the ratio between the weight of the aggregate and the volume. The unit weight of the aggregate content required in the calculation of the concrete mixture material if the amount of material is measured with a volume size.

3. Research methodology

Research objects are sea sand, river sand and mountain sand from Bengkulu City, Bengkulu Tengah Regency, North Bengkulu Regency, Seluma Regency and Rejang Lebong Regency. After conducting the survey, the type of sand that will be sampled was determined. Sand samples are taken directly

Figure 1. The distribution of sand zones
from the sand quarry. Testing the characteristics of sand is carried out for the gradation of fineness modulus values, mud content and unit weight. Some sand quarry locations are shown in Figure 2

![Sand Quarry Locations](image)

(a) river sand, (b) sea sand, (c) mountain sand

3.1. Sieve Analysis (SNI 03-1968-1990 [14])

3.1.1. Purpose and Objectives. This test is intended to determine the distribution of fine aggregate gradation using filters to be used for concrete mix design. Sieve analysis is a determination of the weight held by each sieve expressed in percent.

3.1.2. Tools and Materials

1. Scales with accuracy of 0.5 grams.
2. A set of sieve No.1 ½, No.¾, No.3 / 8, No.4, No.8, No.10, No.30, No.50, No.100 and PAN
3. Oven with a temperature of 110 ± 5°C
4. Sieve shaker machine
5. Pan
6. Fine aggregate

3.1.3. Work Procedure

1. Aggregates prepared, weighed and are each divided into 2 aggregate samples 3000 grams each specimen
2. The specimen is inserted into the oven for 24 hours at a temperature of 110 ± 5°C.
3. After being ovened for 24 hours, each aggregate sample is weighed with a weight of 1000 grams for fine aggregate.
4. Sieve set is prepared then arranged according to the sieve number, the lowest one is the smallest sieve.
5. The specimen is inserted into the sieve. Experiments on fine aggregates are carried out with a sieve shaking machine for 15 minutes.
6. The aggregates retained in each filter number are weighed with their respective sieve.
7. Observation data is recorded in the observation table.

3.2. Mud Content Test (SNI 03 – 4141 – 1996 [13])
3.2.1. Purpose and Objective. This test is intended to determine the aggregate mud content which can interfere with cement paste bonding on aggregate which of course can affect the quality of concrete or cementitious material.

3.2.2. Tools and Materials
1. Oven with temperature of 110oC
2. Pan
3. Scales with accuracy of 0.5gr
4. Aggregate samples

3.2.3. Work Procedure
1. Aggregates are taken from the sampling site
2. The weight of the pan is weighed (W1)
3. Aggregate and pan weighed using scales after oven drying for ± 24 hours (W2)
4. Aggregate net weight is calculated using formula W3 = W2 - W1
5. Specimens then washed thoroughly.
6. Specimens that have been washed are then dried using oven at 110o C for 24 hours.
7. After being oven dried for 24 hours the specimen was weighed (W4).
8. Calculate the weight of dry specimens using a formula W5 = W4 - W1

3.3. Unit Weight Test (SNI 03-4804-1998 [14])
3.3.1. Purpose and Objective. This test is intended to determine the unit weight of the aggregate. The unit weight is the ratio of weight and volume of the aggregate.

3.3.2. Tools & Materials
1. Scales
2. Compacting rod 15 mm in diameter, 60 cm long with rounded edges should be made of steel.
3. 3. 4. A steel container that is quite rigid in the form of a cylinder with holder.

3.3.3. Work Procedure
1. Mold is weighed and then record the weight (W1).
2. Aggregate is inserted into the mold carefully hence not to cause grain separation, from a maximum height of 5 cm above the container. Fill it up to the full
3. Flatten the top of a mountainous surface by using a leveling bar.
4. The aggregate and the mold then weighed and recorded (W2).
5. Aggregate weight is calculated using the formula (W3 = W2 - W1).

4. Results and Discussion
4.1. Sieve analysis
Sea sand which is the object of research is sea sand obtained from along the coast of Bengkulu City, Bengkulu Tengah Regency (Benteng) and North Bengkulu. After sieve analysis, the results are as shown in Table 1.
Table 1 shows that only 3 types of sea sand (18.75%) entered the zone and had various grains (good gradation). While 13 types of sea sand (81.25%) tend to have uniform and very fine grains. Uniform granules are less preferable because they do not interlock and reduce density if used for building materials.
Table 1. Results of Fineness Modulus testing and zone of Sea Sand

| #  | Type of Sand          | Location     | FM  | Zone                          | Characteristics | Ordinat         |
|----|----------------------|--------------|-----|------------------------------|-----------------|-----------------|
| 1  | Pasir Laut Pondok Kelapa | Benteng   | 0.8 | not conform to zone IV      | Fine            | 3°41' 748"S    |
| 2  | Pasir Laut Air Padang (Kasar) | Bengkulu Utara | 1.103 | not conform to zone IV    | Fine            | 102° 14' 677"E |
| 3  | Pasir Laut Air Padang (Halus) | Benteng Utara | 1.101 | not conform to zone IV    | Fine            | 102° 00' 06,6"E |
| 4  | Pasir Laut Air Lakok | Benteng Utara | 2.55 | not conform to zone IV     | Fine            | 3° 28' 41,2"S  |
| 5  | Pasir Laut Serangai | Bengkulu Utara | 1.31 | not conform to zone IV    | Fine            | 101° 55' 07,1"E |
| 6  | Pasir Laut Selolong | Bengkulu Utara | 0.99 | not conform to zone IV    | Fine            | 101° 52' 53,6"E |
| 7  | Pasir Laut Selubuk (Kasar) | Bengkulu Utara | 1.13 | not conform to zone IV    | Fine            | 101° 52' 53,6"E |
| 8  | Pasir Laut Selubuk (sedang) | Bengkulu Utara | 2.22 | Zone III                   | Slightly fine   | 3° 40' 33,7"S  |
| 9  | Pasir Laut Selubuk (halus) | Bengkulu Utara | 0.94 | not conform to zone IV    | Fine            | 102° 09' 11,5"E |
| 10 | Pasir Laut Air Sabu | Bengkulu Utara | 0.87 | Zone III                   | Fine            | 3° 28' 41,2"S  |
| 11 | Pasir Laut Air Uray | Bengkulu Utara | 1.17 | not conform to zone IV    | Fine            | 101° 52' 53,6"E |
| 12 | Pasir Laut Ketahun | Bengkulu Utara | 1.33 | not conform to zone IV    | Fine            | 102° 18' 50,5"E |
| 13 | Pasir Laut Kota Agung Lais | Bengkulu Utara | 0.87 | not conform to zone IV    | Fine            | 102° 05' 44,1"E |
| 14 | Pasir Laut Teluk Sepang | Benteng | 0.87 | not conform to zone IV    | Fine            | 103° 54' 04,9"E |
| 15 | Pasir Laut Pantai Panjang | Bengkulu | 2.097 | Zone III                  | Slightly fine   | 102° 17' 06,5"E |
| 16 | Pasir Laut Pantai Zakat | Bengkulu | 0.85 | not conform to zone IV    | Fine            | 3° 49' 889"S   |

The results of sieve analysis for river sand as shown in Table 2 shows that river sand has a good gradation. Out of 7 types of river sand samples 86% entered into zone I, II and III and categorized as slightly fine, coarse and slightly coarse.

Table 2. Results of Fineness Modulus testing and zone of River Sand

| #  | Type of Sand          | Location     | FM  | Zone      | Characteristics | Ordinat         |
|----|----------------------|--------------|-----|-----------|-----------------|-----------------|
| 1  | Pasir Rawa Indah Seluma | Seluma | 1.96 | Almost conform to zone III | Fine           | 4° 14' 56,7"S  |
| 2  | Pasir Sungai Talang Rasau | Benteng | 2.2  | Zone III  | Slightly Fine   | 3° 30' 19,6"S  |
| 3  | Pasir Sungai Limau  | Benteng | 2.119 | Zone III  | Slightly Fine   | 3° 40' 33,7"S  |
| 4  | Pasir Sungai Penanding | Benteng | 2.097 | Zone III  | Slightly fine   | 3° 76' 484"S   |
| 5  | Pasir Sungai Kembang Sri | Benteng | 2.94  | zone II   | Slightly coarse | 4° 12' 75,3"S  |
| 6  | Pasir Sungai Lubuk Kebur | Seluma | 3.47  | zone I    | Coarse          | 4°4,5' 03"S    |
Mountain sand is sourced from the City of Curup, Rejang Lebong Regency, which is a mountainous area. The adjacent location produces almost the same characteristics. Rough and fine APJ mountain sand is based on the location of the sand depth. The top of the excavation layers tends to be coarser compared to the bottom layers. The mountain sand of Lubuk Penyamun is also in the same location, the color of which is different based on the depth of the excavation. The top layer tends to be yellowish and the lower layers of the grayish black as shown in figure 3.

Table 3. Results of Fineness Modulus testing and zone of Mountain Sand

| #  | Type of Sand                | Location       | FM     | Zone  | Characteristics    | Ordinat                          |
|----|-----------------------------|----------------|--------|-------|--------------------|----------------------------------|
| 1  | Pasir Gunung APJ kasar      | Curup          | 1.998  | Zone III | Slightly fine     | -3° 29' 54,7"S 102° 30' 19,0"E |
| 2  | Pasir Gunung APJ Halus      | Curup          | 1.976  | Zone III | Slightly fine     | -3° 29' 54,7"S 102° 30' 19,0"E |
| 3  | Pasir Gunung lubuk Penyamun kuning | Curup    | 1.523  | almost conform to zone IV | Fine | -3° 49' 80,4"S 102° 50' 18,81"E |
| 4  | Pasir Gunung lubuk Penyamun hitam | Curup    | 1.783  | almost conform to zone III | Fine | -3° 49' 80,4"S 102° 50' 18,81"E |

4.2. Examination of mud content and unit weight

Examination of mud content and unit weight were carried out for 12 sand samples, each representing 4 types of sand origin (Table 4). Maximum mud content according to the standard is below 5%. The mud content obtained from the test results as shown in Table 4 shows that sea sand, except air lakok sand, has a mud content level below 5% (comply to standards). Consequently, the materials do not need to be washed, while Sea sand obtained from Air Lakok has a high mud content level of 9.33%. Kembang Seri river sand has a high level of mud content since it comes from a relatively calm river, hence the sand and mud settle together. The quarry method of Penanding river sand used pumps that directly wash the mined sand so as to reduce the mud content.

Mountain sand has a very high level of mud content, hence in its usage it is recommended to wash it first. However, from some observations for the mountain sand, the mud content contains volcanic ash from the activity of the mountain itself so that it contains beneficial silica as cementation building material mixture.
Table 4. Results of Testing of Mud Content and Sand Unit Weight

| #  | Sand Type          | Unit Weight (kg/m³) | Mud Content (%) | FM      | Zone        |
|----|--------------------|---------------------|-----------------|---------|-------------|
| 1  | PL. Air Lakok      | 1880                | 9.33            | 2.55    | Zone II     |
| 2  | PL. Selubuk Kasar  | 1400                | 0.32            | 2.22    | Zone III    |
| 3  | PL. Serangai       | 1380                | 0.48            | 1.31    | not conform to zone IV |
| 4  | PL. Selubuk Halus  | 1420                | 0.89            | 0.94    | not conform to zone IV |
| 5  | PS. Penading       | 1452                | 2.464           | 2.097   | Zone III    |
| 6  | PS. Kembang Seri   | 1184                | 19.84           | 2.94    | zone II     |
| 7  | PS. Talang Rasau   | 1510                | 1.41            | 2.2     | Zone III    |
| 8  | PS. Lubuk Kebur    | 1531                | 3.176           | 3.47    | Zone I      |
| 9  | PG. APJ Kasar      | 1420                | 21.28           | 1.998   | Zone III    |
| 10 | PG. APJ Halus      | 1350                | 21.83           | 1.976   | Zone III    |
| 11 | PG. Lubuk Penyamun Kuning | 1441 | 20.69 | 1.523 | almost conform to zone IV |
| 12 | PG. Lubuk Penyamun Hitam | 1329 | 29.12 | 1.783 | almost conform to zone III |

The unit weight of the sand as shown in Table 4 shows the diversity of values. Unit weight is the ratio between the weights of sand to its volume. Sand that has a large unit weight indicates a relatively high density. Solid masses can give strength to sand. Air Lakok sea sand has the highest unit weight, while the mountain sand from Lubuk Penyamun having the lowest unit weight.

For building materials in addition to gradation, mud content and unit weight, several other characteristics also affect the strength of sand such as strength, wear and durability of the sand material itself. Very fine sand and does not enter the zone is usually only used for filling materials / non cementitious materials and filling material between paving blocks. While sand which entering the zone can be used for mortar and concrete building materials.

5. Conclusion
a. Sand based on the quarry location will provide different characteristics.
   b. 81.25% sea sand tends to have uniform grain, with fine and very fine characteristics and does not enter any zone. 18.75% sea sand has a good gradation
   c. River sand has a good gradation and enters the predefined zone with fine, slightly coarse and coarse characteristics.
   d. Mountain sand is categorized as fine sand with good gradation.
   e. The mud content level possessed by each type of sand origin shows that river sand with a calm flow has a high level of mud content. Mud content levels that are very high on mountain sand are probably ash that is produced by volcanic activity of the mountain.
   f. The unit weight of each type of sand varies, can not be determined from the quarry location nor origin of the sand.
   g. All source of sand could be used as construction as long as the said sand characteristics meet technical requirements among others gradation and mud content. However, the long-term effect of each different sand source should be carefully studied in future researchs.

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