Evaluation of Silt Content in Natural Sand Used as Building Materials: A Statistical Analysis Approach

Jauhar Fajrin, Mulyadi, Hariyadi, and Agung Prabowo

Abstract The excessive amount of silt within natural sand may reduce the bonding between sand and other constituent materials when used as building materials. The maximum amount allowed varies from 4 to 10%, and the allowable amount according to the Indonesian Standard (SNI S-04-1998-F) should be less than 5%. This study aims to evaluate the amount of silt in natural sand from several sand quarries in Lombok, Indonesia. The natural sand samples were collected from eight sand quarries in Lombok and the silt content was determined based on weight measurement. The study was designed to assess the silt content of each sand quarry against the SNI and also compared the silt content among the quarries. Two appropriate statistical analysis methods were applied; one-sample t-test and analysis of variance (ANOVA). The main conclusion drawn was that most of the natural sand in Lombok contains high silt content. The one-sample t-test results showed that the P-value of seven out of eight quarries was greater than the significance level (α), except for the sample taken from Sukadana. This value indicates that the silt content pretty close to the maximum value allowed by the SNI, which is already critical to be used as a building material. Meanwhile, the ANOVA result shows that the silt content from all sand quarries does not have a significant difference, which is indicated by the P-value greater than 0.05. Nevertheless, the result of a further analysis using Fisher's test shows that the sand collected from Sukadana quarry has fairly low silt content and differs significantly from the others. It is strongly recommended to give a proper pre-treatment such cleaning process before using sand in this area as a building material.

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1 Introduction

One of the issues related to infrastructure development in Indonesia is the quality of building materials. Although the regulations in the form of standards have been issued, the implementation has not been well managed. Based on field observations, a lot of building materials especially those originating from nature or traditionally handmade, are directly delivered to users without sufficient quality checking process. As a result, many infrastructures built up using those materials were damaged earlier than their intended service life. Silt content is one of the important parameters to define the quality of sand. The maximum amount allowed varies between 4 and 10%, with the Indonesian Standard (SNI S-04-1998-F) stating that the maximum amount authorized should be less than 5%. Meanwhile, the maximum amount allowed by the British Standard (BS) is 4%, but the American Standard for Testing and Materials (ASTM) allows up to 10% [1].

Research related to the assessment of sand quality has not been widely reported, especially in Indonesia. Among a few reported studies, Qomaruddin et al. [2] who conducted a comparative study of river sand characteristics in Jepara reported that the silt content ranges from 10.55 to 14.37%, which means 2–3 times exceeds the maximum standard required by SNI. In addition to silt content, the study also evaluated several other parameters such as fine aggregate gradation, organic material content, density, and specific gravity. Endroyo [3] reported that the quality of sand depends on the time and the location of the sand quarry. Further, Koraila and Joshi [4] reported the results of their research on sand quality and its management in Nepal, which indicated that the quality of sand is also greatly influenced by how it is being managed. It was also observed in the study reported in Ref. [4] that the awareness of using sand that meets the technical requirements is very low among local contractors. Likewise, the attention of the local government to ensure the use of appropriate sand is also very low.

Some previous research reports the contribution of sand when it has been used as a certain building material, for example after being used as a mortar or concrete. Triadi et al. [5] conducted a compressive strength analysis of concrete made of fine aggregate from Rokan river sand, which showed that the compressive strength of concrete produced ranged from 12 to 14 MPa. Meanwhile, Ginting [6] conducted a comparative study of the utilization of Ciliwung, Cisadane, and Cikeruh river sand as normal fine concrete aggregates. The results reported in reference [6] show that concrete made with Cikeruh river sand has the highest compressive strength, which is 18.74 MPa. Furthermore, Ngugi et al. [7] reported that the high content of silt and organic material within sand reduces the bonding strength between concrete and reinforcement. It was also found that 86.2% of the observed sand samples in the study reported in Ref. [7] did not meet the requirements stated in the BS 882 standard. Gashahun [8] studied the impact of sand quality on concrete strength and found that using sand with silt levels over the permitted limit affected concrete strength significantly. In addition, Obafaye et al. [9] stated that the percentage of silt content that is unfit for engineering usage, notably concrete, is around 7%. Meanwhile, Kirthika et al. [10] proposed a fine aggregate content of less than 5% for alternative fine aggregates to make concrete with satisfactory performance.

The application of statistical methods in research in the field of civil engineering materials is still limited to descriptive statistics where the data are presented in such a way that they are easily read and understood by readers. The use of statistical methods for decision-making or inference is still limited. Fajrin et al. [11] reported the results of their research related to the development of composite materials by applying inferential statistical methods, namely the t-test method. The application of other inferential statistical tools, which is the F-test method, in the development of civil engineering materials was comprehensively reported in Refs. [12–14]. Moreover, the analysis of variance method was also applied by Fajrin et al. [15] to study the physical and mechanical properties of mortars with silica fume as additional material. Furthermore, Parmar et al. [16] applied the independent sample t-test method in their study of ready mix materials in the Gujarat region, India.

To further ensure the quality of the sand used as building material currently in Lombok, it is important to conduct a comprehensive investigation and laboratory testing. This article reports the results of an investigation into the silt content within the sand used as a building material in Lombok as a place for case studies. Furthermore, the results of laboratory tests in this study were statistically analyzed using Minitab software.

2 Materials and Method

The initial stage of this research is determining the sampling locations that represent the area in Lombok. Lombok is divided into 5 regencies/cities. Based on the mapping results it was decided that the sampling locations were in 4 districts namely: Gebong and Keling (West Lombok), Srojan and Pondok Omak (Central Lombok), Lenek Daya and Ijo Balit (East Lombok), and Luk and Sukadana (North Lombok). This study was conducted in the form of field surveys and laboratory testing which were further analyzed using inferential statistical methods. There are two research questions in this study that also become the focus of research. First, how much is the silt content at each sand quarry location, and how significant is the difference with the maximum content required by SNI. Second, how significant the difference of silt content among sand quarry locations. The measurement of silt content within the sand can be done in two ways, which are based on volume or weight. In this study, the second method was chosen which is based on weight measurement.

The suitable statistical method to elaborate the first research question is the one-sample t-test method. This method is commonly used to compare the average of a single variable or a set of data with a certain value [17]. In the case of this study, the average silt content at each sand quarry location was compared to the maximum value specified in SNI S-04-1998-F, which is 5%. There are two prerequisites for applying this statistical test method [17]; the data should be quantitative and satisfied a normal distribution assumption. The decision to accept or reject the null hypothesis (H_0) is based on the following rules; (1) The null hypothesis (H_0) is accepted if the P-value is greater than the confidence level (α). If the value is smaller, then the alternative hypothesis (H1) should be accepted. (2) The null hypothesis (H_0) is accepted if the calculated t value (t_{score}) is smaller than the t value obtained from the table of t distribution (t_{table}).

The second research question is related to several (more than two) sets or groups of data, so the appropriate statistical method used is the analysis of variance (Anova). This method is commonly used to test mean differences in more than two groups. According to Reference [17], three important assumptions must be satisfied to apply this method; (1) The groups must be independent, (2) There has an equal variance among the groups (homogeneous data), and (3) Data are normally distributed. The null hypothesis (H_0) in Anova states that there is no difference between the means of the n groups. In contrast, the alternative hypothesis (H_1) states that there is a difference between the means of the n groups. ANOVA results are expressed in the form of F values, which are further called the F-test or F-score. An inference or decision is drawing by comparing the F-score to the F value obtained from the F distribution table (F_{table}). The conditions are; if the F-score is greater than F-table, then H_0 is rejected, and as a consequence, the alternative hypothesis (H_1) is accepted. Another way to draw inference is to observe the P-value; if the value is less than the confidence level (α), then H_0 is accepted.

3 Results and Discussion

The average percentage of silt content for each sand quarry location is shown in Fig. 1. It is clearly shown that the percentage of silt content lies at around 5%, which is the maximum limit allowed according to SNI S-04-1998-F. There are four sand quarry locations with the percentage of the silt content exceeds this limit, while the other three are pretty close to this number. There has only a single location that has a fairly low level of silt content, which is safe to be used as a building material.

Overall, the average silt content from the eight sample locations in Lombok is 4.8%. The silt content at 4 locations has exceeded the maximum limit, with an average percentage of 5.58%. The other 3 locations are pretty close to the maximum limit determined by SNI, with an average value of 4.56%. Although the silt content at 3 sand quarry locations is currently still below 5%, the average value is very close to the limit and if the samples are checked one by one, there are samples whose values have exceeded 5%. To further confirm the results of the analysis, it is also necessary to do a more in-depth analysis using inferential statistics. As stated in the research methods section, the statistical method that can be used to assess whether the average silt content at a sand quarry location is the same or not with the maximum limit allowed in the SNI is the one-sample t-test method.

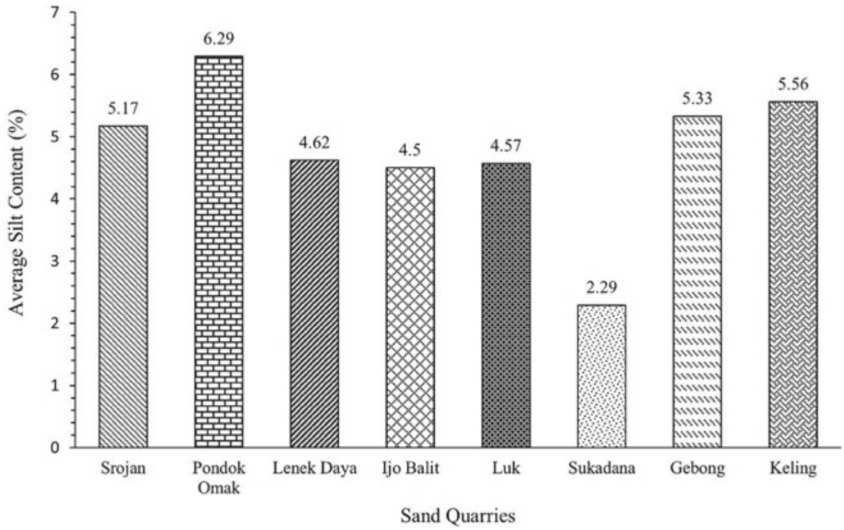

Fig. 1 The average percentage of silt content at each sand quarry location

Like many other statistical analysis methods, the first thing that needs to be done as a condition for applying the one-sample t-test method is that the data must be normally distributed. For this reason, a normality test had been performed using Minitab software based on three models; namely Anderson–Darling (AD), Ryan-Joiner (RJ), and Kolmogorov–Smirnov (KS). The results are presented in Table 1, which clearly shows that the data are normally distributed that indicated by higher P-values over the significance level (α).

Having been convinced that the data were normally distributed, a one-sample t-test was performed for all sample locations and the summary of results is shown in Table 2. The results of the one-sample t-test show that almost all locations have

Table 1 The summary of normality test results

Sample location	Anderson–Darling		Ryan-Joiner		Kolmogorov–Smirnov	
	AD	P-value	RJ	P-value	KS	P-value
Srojan	0.341	0.321	0.954	>0.1	0.239	>0.150
Pondok Omak	0.256	0.539	0.968	>0.1	0.218	>0.150
Lenek Daya	0.432	0.170	0.931	>0.1	0.255	>0.150
Ijo Balit	0.600	0.053	0.892	0.075	0.349	0.046
Luk	0.365	0.272	0.936	>0.1	0.286	>0.150
Sukadana	0.316	0.378	0.957	>0.1	0.227	>0.150
Gebong	0.275	0.497	0.968	>0.1	0.212	>0.150
Keling	0.227	0.640	0.974	>0.1	0.186	>0.150

Table 2 The summary of one sample t-test results

Sample location	Significance (α) 5%		Significance (α) 1%	
	t-score	P-value	t-score	P-value
Srojan	0.24	0.824	0.24	0.824
Pondok Omak	1.27	0.275	1.27	0.275
Lenek Daya	−0.39	0.715	−0.76	0.488
Ijo Balit	−0.39	0.716	−0.39	0.716
Luk	−0.67	0.538	−0.67	0.538
Sukadana	−4.59	0.010	−4.59	0.010
Gebong	0.27	0.800	0.27	0.800
Keling	0.47	0.662	0.47	0.662

a P-value greater than the significance level (α), except the sand quarry location in Sukadana, North Lombok. It has a meaning that the H_0 hypothesis which states that the silt content is equal to 5% must be accepted or the alternative hypothesis H_1 is rejected. Another way to conclude is by looking at the value of the t-score with the t-table. Based on the t distribution table, the value of the t-table is 2.31 and 3.75 for the value of 5 and 1%, respectively. It can be seen clearly in Table 2 that, except for the Sukadana location, the t-score value for all other locations is smaller than the value of the t-table, so that the H_0 is accepted. As the hypothesis null (H_0) is accepted, this means that the level of silt within the sand in Lombok is mostly pretty close to the maximum value tolerated by SNI, hence the sand must be cleaned up before be further used as a building material. The results of the homogeneity test which is based on two models; Bonett's test and Levene's test, are displayed in Table 3.

Ideally, a building material should have the same quality although it is provided or obtained in different ways. Hence, it is necessary to further analyze the consistency of the silt content observed at all sand quarries. A quick look at the data presented in Fig. 1 indicates that the silt content differs from each other. But how significant the differences have to be further analyzed using the appropriate method. The most relevant statistical method to apply for this case is the analysis of variance method. One of the prerequisites for data to be analyzed by the Anova method is that variants between groups must be homogeneous. To find out whether the data meets these requirements, it is necessary to do a data homogeneity test.

The homogeneity test result demonstrates that the variations (variances) of the silt content data are equal which is indicated by a P-value greater than the significance level ($\alpha = 0.05$) for all locations. Another requirement for applying the ANOVA method is that the sample must be independent of each other. This requirement has been satisfied because the samples were obtained from different locations. The third requirement is the data have a normal distribution and this has been confirmed as shown in Table 1. The results of statistical analysis using Minitab software are presented in Table 4.

Table 3 The summary of homogeneity test results

Sample location	Homogeneity test	
	P-value Bonett	P-value Levene
Srojan - P Omak	0.412	0.531
Srojan – L Daya	0.380	0.586
Srojan – I Balit	0.154	0.532
Srojan – Luk	0.795	0.636
Srojan – Sukadana	0.580	0.733
Srojan – Gebong	0.182	0.260
Srojan - Keling	0.307	0.447
P Omak - L Daya	0.898	0.980
P Omak – I Balit	0.550	0.786
P Omak - Luk	0.335	0.306
P Omak - Sukadana	0.246	0.318
P Omak - Gebong	0.645	0.607
P Omak - Keling	0,730	0.827
L Daya – I Balit	0.442	0.780
L Daya – Luk	0.300	0.362
L Daya – Sukadana	0.182	0.391
L Daya – Gebong	0.525	0.617
L Daya – Keling	0.636	0.820
I Balit - Luk	0.116	0.395
I Balit - Sukadana	0.077	0.429
I Balit - Gebong	0.876	0.967
I Balit - Keling	0.854	0.906
Luk – Sukadana	0.859	0.812
Luk – Gebong	0.139	0.141
Luk – Keling	0.250	0.273
Sukadana - Gebong	0.091	0.131
Sukadana - Keling	0.194	0.288
Gebong - Keling	0.962	0.809

Table 4 The summary of statistical analysis using Minitab software

One-Way ANOVA	Tukey Test	Fisher LSD Test
F-Value: 1.42 P-Value: 0.23	All sand quarries labeled as a single letter A	4 quarries labeled as A 3 quarries labeled as AB 1 quarry labeled as B

The most important information from the data shown in Table 4 is the P-value and the F-score, which are 0.23 and 1.42, respectively. As the P-value is greater than the significance level of 0.05, then the hypothesis H_0 is accepted. The conclusion to accept the null hypothesis is also confirmed by the value of the F_{score} (1.42), which is smaller than the value of the F_{table} (2.26). This indicates that the average sand content at all sand quarry locations is just basically the same. However, there is a little doubt about the Anova results because they equate the highest average of mud content at the Pondok Omak (6.29) with the lowest one (2.29) at Sukadana. For this reason, it is essential to carry out further tests (simultaneous tests) which usually employing Tukey, Fisher, and Dunnet tests. The simultaneous tests provide two information in the form of numbers and grouping information. The result of means grouping based on the Tukey and Fisher test is also shown in Table 4. The result of Tukey's test laid all the sand quarries within only one group labeled with the A letter, which means that there has no distinct difference in the silt content for all sample locations. The LSD Fisher test showed a more comprehensive result where the sand quarries were categorized into 3 levels that were labeled with a different letter. Meanwhile, the result of another simultaneous test using Dunnet's test provides a similar result with the Tukey test. It seems that the Fisher LSD method provides more accurate results.

4 Conclusions

The main conclusion drawn from this study is that most of the sand in Lombok has a silt content of approximately 5%, which is a maximum limit allowed by the National Indonesian Standard (SNI) S-04-1998-F. More specific findings are as follows:

(1) Most of the sand in Lombok has a fairly high silt content with an overall average of 4.8%. The result of inferential statistical analysis using the one-sample t-test method proves that the silt content in 7 out of 8 sand quarry samples already within the maximum limit allowed by SNI S-04-1998-F.

(2) The result of ANOVA shows that the silt content in the sand collected from 8 sand quarry location do not have any significant difference. However, the results of the simultaneous or pairwise test using the LSD Fisher method show that the sand sample taken from the Sukadana region in North Lombok has a fairly low silt content and differs significantly from the rest sand quarry locations.

(3) As the sand in Lombok contains fairly high silt, in which some of which have exceeded the maximum limit allowed by SNI, the sand must be cleaned up before being used as a building material.

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