Paper ID 173

Proper Management of Quarry Dust that is Generated in Crusher Plants as Waste

RMNS Rathnayake# and MB Samarakoon

Department of Civil Engineering, General Sir John Kotelawala Defence University

#nadeesharathnayake95@gmail.com

Abstract: Quarry dust is the by-product produced due to the crushing procedure of stone crushing industry. The unavailability of a proper disposal method to this quarry dust is a huge problem faced by crusher plants. If this quarry dust can be used as a useful product it will be a good solution for this issue. It might be able to use as a substitute material for natural sand in preparation of cement mortar. In this research, a new cement mortar with an adequate quantity of quarry dust as a partial replacement of natural sand was designed. The effect of partial replacement of natural sand with quarry dust on the strength of cement mortar was studied. Here 1:5 cement:mortar mixture with 0.5 water:cement ratio was used as the standard test specimen and another five test specimens were tested by varying the quantity of quarry dust from 15% to 55% out of total sand volume at 10% intervals with varying water:cement ratio from 0.51 to 0.55 at 0.01 intervals with the increment of the quarry dust quantity respectively by keeping cement quantity and temperature constant. The cement mortar exhibits excellent strength with 45% replacement of natural sand with quarry dust with water: cement ratio 0.54.

Keywords: Quarry dust, Cement mortar, Natural sand

Introduction

The stone crushing industry is one of the widely spread industries in Sri Lanka. It produces aggregates with different desired sizes required for various construction activities. It provides many job opportunities for the people and for the people and also it is one of the main industries which has a great contribution to the economy of the country. The stone crushing industry is expected to be growing day by day due to the increase of demand for the aggregates due to the large number of construction activities that are carrying out throughout the country. In Sri Lanka, there can be seen both large and small scale stone crushers.

Quarry dust is the waste material that is generated due to the crushing process in stone crushing plants. It is

abundantly available due to the unavailability of a proper disposal method. It is stored as large stockpiles in crusher plants. Usually in a crusher plant for a day a huge quantity of quarry dust is produced. Therefore it occupies a large land area and this is a huge problem faced by crusher plants due to the limited land area available. If this quarry dust can be used as a useful product, it will be a good solution for this issue.

Today due to the rapid growth in the construction industry, there's a scarcity of construction materials and sand is a good example of it. The usage of quarry dust as an alternative material for natural sand in preparation of cement mortar could solve issues related to the disposal of quarry dust and also it will be a good solution to the scarcity of natural sand. This research was carried out based on this concept and a new cement mortar mixture was designed by using quarry dust as a partial replacement material for natural sand.

A. Research Significance

Introducing a proper waste management system for quarry dust generated in crusher plants is the aim of this study. This is very important for present crusher plants in Sri Lanka. Because the unavailability of a proper disposal method to dispose quarry dust is a huge problem faced by crusher plants. Due to that quarry dust is stored as large stoke piles and it occupies a large land area.

But due to the unavailability of sufficient land area to store quarry dust it is very essential to find out a proper method to dispose of it. If this quarry dust can be used for a useful purpose then it will be a good solution for this issue. This research was carried out based on this concept. Here, a new cement mortar mixture was designed by substituting natural sand with quarry dust. If it can be successfully implemented then it will be a good solution not only for the above issue but also it will be a good precaution to conserve natural resources. The shortage of natural sand is one of the major problems faced by the construction industry. Therefore the usage of quarry dust as a substitute material for natural sand will be a good solution to the scarcity of natural sand. Due to the shortage of natural sand its cost also considerably high and this is hugely affecting the construction activities. But when comparing with natural sand quarry dust is a cheap material. Therefore by using quarry dust, the quantity of natural sand that is required for construction purposes such as in preparation in cement mortar, concrete can be reduced and due to that cost can be reduced to a considerable extent. Due to the huge generation of quarry dust in a crusher plant for a day its availability is also high compared to natural sand and also since it is considered as a waste material, it is easily obtainable and no need to spend money to produce it.

Methodology

Methodology of this research can be divided into 2 phases;

01). Data collection

This was carried out in two steps;

i) Primary data-Questionnaire and Interview
ii) Secondary data-Sieve analysis test and Compressive strength test

02). Design of cement mortar mixture

A new cement mortar mixture with an adequate quantity of quarry dust will be designed using the test results of laboratory tests.

Questionnaire

The questionnaire was distributed among 10 randomly selected crusher plants in Kurunegala district. The questionnaire consisted of 14 questions. The purpose of the questionnaire was to find out the average rock crushing rate of a crusher plant, production rates of different sized aggregates, measures taken to minimize the quarry dust generation, measures taken to prevent the spreading of quarry dust, methods followed by crusher plants to store quarry dust, Current disposal methods followed by crusher plants to dispose quarry dust, issues related to disposal of quarry dust.

Interview

An interview was conducted with a relevant official in the Provincial Environmental Authority of North Western Province. The purpose of conducting an interview was to find out what are the rules and regulations related to establishment and operation of a crusher plant, clearances that must be obtained by a crusher plant for its establishment, criteria that must be followed by a crusher plant in diposal of the waste that is generated during its operation etc. When considering about the clearances that required to establish a crusher plant, through the interview information such as; the procedure that must be followed to obtain

the relevant license, the procedure of applying for those licenses including the time periods that the applications must be submitted to obtain those licenses, investigations that are carrying out to provide approvals for the establishment of a crusher plant were collected. Also through the interview information like; the regulations and criteria that a crusher plant must follow in waste disposal, the measures that must be taken to prevent the spread of dust with the wind, investigations carried out by relevant officials to investigate whether crusher plants are functioning according to the relevant rules and regulations, were gathered.

Sieve Analysis Test

In the cement mortar mixture which was designed two fine aggregates were used. They were natural sand and quarry dust. Here the type of sand which used was River sand. The Sieve analysis test was carried out for both River sand and quarry dust samples. The specifications that were used to carry out the test were; ASTM C 33-03 : Standard Specification for Concrete Aggregate, ASTM C 136-06 : Standard Test Method for Sieve Analysis of Fine and Coarse Aggregate, ASTM C 117-95 : Standard Test Method for Materials Finer than 75µm(No.200) Sieve in Mineral Aggregate by Washing.

First, the Sieve analysis test was carried out for River sand sample. Here since the sand sample contains particles which pass through 75µm sieve first, the weight of the particles that pass through 75µm sieve was determined according to ASTM C 117-95 specification. First, the sample was oven-dried at a temperature of 110 ± 5°C for 12 hours. Then the mass (W1) of the sample was measured using a balance. After that, the sample was placed on a container and a sufficient amount of water was added to cover the sample. Then the sample was agitated to separate the particles that are finer than 75µm, from the particles coarser than 75µm. After that, the wash water containing the suspended and dissolved solids was poured over the 75µm(No.200) and 1.18mm(No.16) sieves. Here the 1.18mm sieve was placed on the 75µm sieve. Then again water was added to the sand sample and it was washed as before. This procedure was repeated until the wash water became clear. After that sand retained on the nested sieves was returned to the washed sample by flushing.

Then the washed sample was oven-dried at a temperature of 110 ± 5°C for 12 hours. After sand sample got dried mass was measured using the balance (W2) and then the mass of the particles which passed through 75µm sieve was calculated by W1-W2. The total mass of the particles which pass through the 75µm sieve will be calculated by adding this value with the mass of the particles that passed through the 75µm sieve during dry sieving of the sample. Then this oven-dried sample was sieved again using a sieve set it was agitated using mechanical shaker. The sieves were selected according to ASTMC 33-03. The test was carried out according to ASTM C 136-06.

After that, the retained mass on each sieve was measured and using that the mass passing through each sieve was found. Then the passing percentages of each sieve was calculated. Here the total mass of the sample was taken as W1. Finally, the particle size distribution of the sand sample was plotted by graphing the passing percentage of each sieve with the sieve opening size and if this graph lies in between the Upper limit and Lower limit graphs, then

the sample will be adequate to be used in the preparation of cement mortar. These Upper limit and Lower limit are defined in ASTM C 33-03. The same procedure was carried out for quarry dust sample to determine the particle size distribution of the sample.

Compressive Strength Test

For the cement mortar mixture, the Compressive strength test was carried out for both 7 and 28 days. The test was carried out according to ASTM C 109/ C 109M-02 – Standard Test Method for Compressive Strength of Hydraulic Cement Mortar (Using 2-in or [50mm] Cube Specimens). The cement mortar samples were prepared by varying the quantity of quarry dust added and from each cement mortar sample, 3 test cubes were casted for each 7 and 28 days compressive strength tests. Here 1:5 Cement: Sand mortar mixture with 0.5 Water: Cement ratio (Specimen with 0% quarry dust added) was kept as the standard test specimen. Here 1:5 cement: sand ratio and 0.5 water: cement ratio was given in volume-wise. In other five specimens, the quarry dust quantity was varied by 15%, 25%, 35%, 45% and 55% out of total sand volume and water: Cement ratio was varied from 0.51, 0.52, 0.53,0.54 and 0.55 respectively by keeping the cement quantity, and the temperature constant. The quantity of water added was increased with the quantity of quarry dust added. Because when increasing the quarry dust quantity water absorption of quarry dust increases. Therefore, if the water quantity does not increase with the quarry dust quantity added there will be no sufficient amount of water for the hydration process of cement mortar and due to that it may not gain sufficient strength and cracks may occur. The test was carried out under normal room temperature. Here Portland Limestone cement was used and water was obtained from the water supply line. Here the quarry dust sample was obtained from a crusher plant. A sample of which particle size lies in between the upper and lower limits defined in ASTM C 33 – 03 specifications was prepared by sieving. This was done because from crusher plant to crusher plant the quarry dust samples that generating are different and even in the same crusher plant it varies. Therefore as a solution for that quarry dust sample was prepared using the above procedure.

For the casting of Cement mortar test cubes 50mm x 50mm x 50mm cube moulds were used. A thin coating of a releasing agent was applied on the interior faces of the cube mould and then it was placed on the base plate. After that, a watertight sealant was applied at the outside contact lines between the mould and base plate. Then the first layer of cement mortar sample was placed about 25mm of the mould depth and it was tamped using a tamping rod by giving 32 strokes within 10s in about 4 rounds. Then the second layer was placed and it was tamped in the same way. Next, the top surface of the cement mortar cube specimen was placed and it was level by using the flat side of a trowel. Here the test cubes for both 7 days and 28 days tests were casted together. After casting, the test specimens were kept for setting for 24 hours. After 24 hours the cube moulds were removed and the test cubes were cured by soaking inside a water container (7 and 28 days). The temperature of the water was maintained at 23 ± 2°C. After curing, all the specimens were wiped well. Then the specimens were kept on the Compressive strength test machine. Then the load was applied at a rate of 900 to 1800 N/S. The load was applied on the test cubes until it starts cracking and at the cracking point load was recorded. Then the compressive strength of each specimen was calculated and using that the average value of the compressive strength of each 3 test specimens of each cement mortar mixture was calculated for both 7 and 28 days.

Results and Discussion

Through the questionnaire it was found that out of 10 crusher plants 60% are Cone crushers, 20% are Jaw crushers and another 20% have both Cone and Jaw crushers. When considering the quarry dust generation, the dust generation rate of a cone crusher is higher than a jaw crusher. When considering

the monthly boulders crushing rates of crusher plants 80% of crusher plants have a crushing rate of 5000-15,000m^3/month. 30% of crusher plants generate 20%-30% of quarry dust out of the total crushing rate of boulders per month. When considering the current disposal methods followed by crusher plants to dispose quarry dust 40% of crusher plants do not have any issue with the disposal of quarry dust. These crusher plants dispose quarry dust by selling it to manufacture concrete fence posts, concrete blocks and in preparation of concrete etc. But 60% of crusher plants do not have any proper method to dispose quarry dust. Therefore these crusher plants have to stockpile quarry dust for about one month or more. Since there is no enough space to stockpile this quarry dust there is a huge necessity of finding a proper disposal method of quarry dust for these crusher plants. When it comes to the measures taken to minimize the spreading of quarry dust with the wind in most of the crusher plants they have used methods such as; covering of crushing units with dust barriers, covering of crusher plant boundary using rubble walls, Properly covering the stockpiles of aggregates etc. When considering the measures taken to minimize the generation of quarry dust in most of the crusher plants they have used methods such as; usage of water sprinklers at the crushing units, water spraying at quarry and feeding units, adjusting crushing units to minimize dust generation and wet crushing process. In some of the crusher plants, it was observed that they haven't taken any measures to minimize dust generation. Then the issues related to the stockpiling of quarry dust are; the spread of dust with wind and lack of enough space to stock quarry dust.

Then through the interview the information such as; clearances that required for the establishment of crusher plant, rules and regulations related to the sound and dust emission of a crusher plant. There are 3 clearances that required for a crusher plant for its establishment. They are; Environmental clearance which is issued by Central Environmental Authority or Provincial Environmental Authority and it must be obtained before installing the crusher plant, Environmental Protection License(EPL) which is issued by Central Environmental Authority or Provincial Environmental Authority and it must be obtained within one month of its installment and it is valid for 6 months or 1 year, Trade License which is issued by Pradeshiya Sabha and it is valid for 1 year. When considering the rules and regulations related to the sound emission; the permissible sound limit at site boundary is 55dß, soundproofing of generators using canopies or placing inside a fully covered room which is constructed with a 9-inch hollow brick wall, proper Maintainance of all other noise-generating machinery and equipment to minimize noise generation, carrying out of all high noise generating operations inside closed chambers. The rules and regulations related to dust emission are; must spray water into the feeding and crushing units using water sprinklers, must locate stockpiles of aggregates behind wind barriers, must keep the stones on the stockpiles sufficiently wet by water spraying, must spray water on to the ground using water sprinklers and bowsers etc.

The test results of Sieve analysis tests are as follows;

River sand sample

Sieve analysis test was carried out for a River sand sample with dry weight 695.2g. The grading curve of the river sand sample is given below, which was plotted by using the test results of the Sieve analysis test.

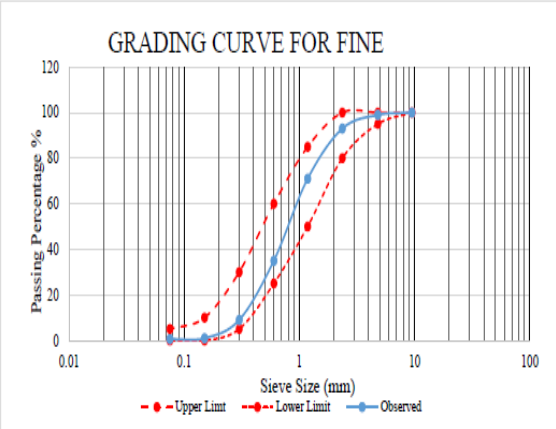

Figure 1. Particle size distribution curve of the River sand sample

The two red-coloured curves depict the upper and lower limits that have defined in ASTM C 33-03. The particle size gradation curve must lie in between these specific limits. The blue-coloured curve depicts the particle size distribution curve of the River sand sample and since it lies in between these two curves it is adequate to be used in the preparation of cement mortar.

Quarry dust sample

Sieve analysis test was carried out for a Quarry dust sample with weight 678.52g. The grading curve of the quarry dust sample is given below, which was plotted by using the test results of the Sieve analysis test.

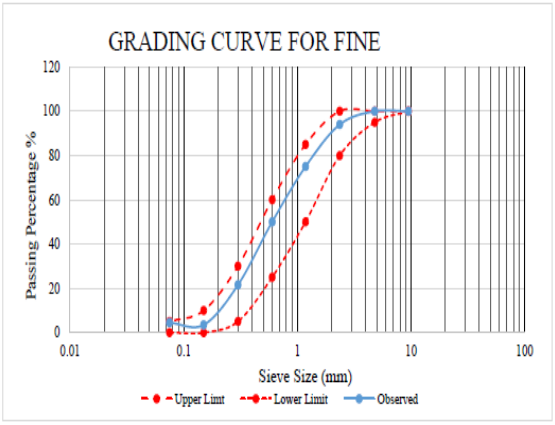

Figure 2. Particle size distribution curve of the Quarry dust sample

Since the particle size distribution curve lies in between two specific limits curves it is adequate to be used in the preparation of cement mortar.

The test results of 7 and 28 days Compressive strength tests are as follows;

7 days Compressive strength test

The test results of 7 days compressive strength test is illustrated in the graph given below.

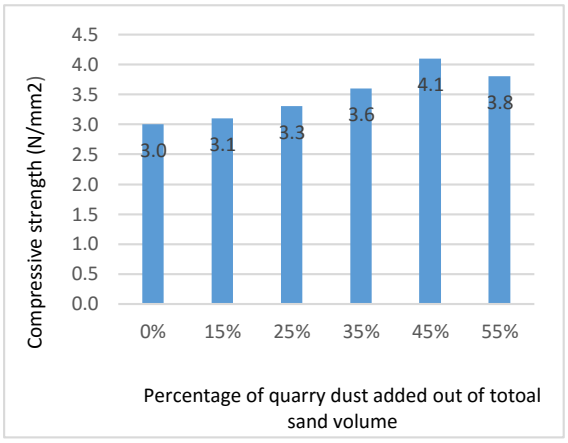

Figure 3. Compressive strength test (7 days)

Here the compressive strength of each cement mortar mixture was calculated by taking the average value of its 3 samples. The cement mortar mixture with 45% quarry dust and 0.54 Water: Cement ratio has the highest compressive strength and it is 36.67% greater than the compressive strength of standard cement mortar mixture.

The compressive strength of cement mortar samples increases with the quantity of quarry dust and it has increased up to 45% but after that, it has started to reduce. This may be due to the fact that 45% replacement of natural sand by quarry dust may show the optimum reaction with optimum filler capacity.

28 days Compressive strength test

The test results of 28 days compressive strength test is illustrated in the graph given below.

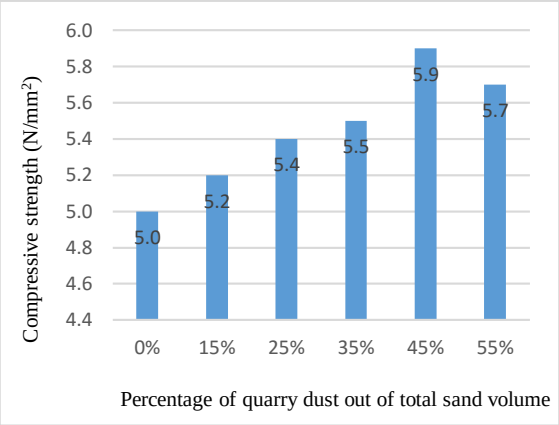

Figure 4. Compressive strength test (28 days)

The mortar mixture with 45% quarry dust and 0.54 Water:Cement ratio has the highest compressive strength and it is 18% greater than the compressive strength of standard mortar mixture. The strength of mortar samples increases when the quantity of quarry dust was increased up to 45% but after that, it has started to decrease. Also, the compressive strength of all samples has increased with the curing period.

In 28 days test results also, the compressive strength of cement mortar samples increases with the quantity of quarry dust and it has increased up to 45% but after that, it has started to reduce.

Therefore using the test results of both 7 and 28 days compressive strength tests it can be concluded that 45% replacement of natural sand by quarry dust will yield the maximum strength for cement mortar and therefore the suitable quantity of quarry dust to replace natural sand is 45% out of its total volume.

Conclusion

The main aim of this research was to come up with a proper waste management method for the quarry dust generated in crusher plants of Sri Lanka as a waste. Usage of quarry dust as a substitute construction material is one of the good methods to dispose of quarry dust properly and this research was done based on this concept.

In this research there were 3 main objectives such as; to find out what are the disposal methods follow by crusher plants for quarry dust disposal, to design a new mortar mixture by substituting sand using stone dust, to examine the variation of properties of mortar with the variation of the quarry dust quantity added.

The first objective was achieved through the Questionnaire. The questionnaire was distributed to 10 randomly selected crusher plants in Kurunegala district. It was found that 40% of crusher plants dispose of quarry dust by selling, to produce various products like concrete blocks, concrete fence posts, concrete, etc. But 60% of crusher plants do not have a proper waste management system. Therefore they have stockpile quarry dust that is generated in crusher plants, for about 1 month or more.

The second and third objectives of the research were achieved through Sieve Analysis Test and Compressive Strength Test (7 and 28 days). It was found that the adequate quantity of quarry dust that can be used to replace the natural sand is 45% through the test results of both 7 and 28 days compressive strength tests. The compressive strength of this test sample was 4.1N/mm^2 and it was 36.67% greater than the standard test sample in the 7 days compressive strength test and in 28 days compressive strength test it was found that the compressive strength of this test sample was 5.9 N/mm^2 and it was 18% greater than the standard test sample. The water: cement ratio of this sample was 0.54. The test results show that the compressive strength of cement mortar increases with the quantity of quarry dust added but after a certain point (45% stone dust) strength starts to decrease. Therefore quarry is suitable for the partial replacement of natural sand and not the full replacement.

Therefore quarry dust is a good alternative to partially substitute natural sand when preparing cement mortar and this will also be a good solution for the scarcity of natural

sand. Also nowadays sand is a very costly material, therefore this will be a good solution to reduce construction costs because it is more cheaper than sand. Also, over-extraction of sand from river beds cause deepening of river beds which lead to the occurrence of bank slides, affecting agriculture, disturbs aquatic plants and organisms etc.

Acknowledgement

I would like to thank my research supervisor Dr. M.B. Samarakoon, who provided necessary guidance throughout this research. Next, my sincere gratitude goes to my research coordinator Dr (Mrs.) N.H.K. Gunasekara, who provided necessary guidance throughout the entire period of this research. I would also wish to pay my gratefulness to the staff of the Laboratory of Building Materials Research and Testing Division of National Building Research Organization who provided great support to conduct necessary laboratory tests. Finally, I would like to thank everyone who helped and encouraged me throughout this research.

References

Amnon, K; Hadassa, B. (2006) 'Effect of high levels of fines content on concrete properties', 103(ACI Material Journal), p. pp 474-481.

Appukutty, P; Murugasan, R. (2009) 'Substitution of quarry dust to sand for mortar in brick masonry works', *International Journal on Design and Manufacturing Technologies*, 3(1), pp. 59–63.

ASTM Standard C33. (2003) 'Standard Specification for Concrete Aggregates', ASTM International, Western Conshohocken, PA 19428-2959.www.astm.org.

ASTM Standard C109. (2003) 'Standard Test Method for Comprehenssive Strength of Hydraulic Cement Mortar (Using 2-in or [50mm] Cube Specimens)', ASTM International, Western Conshohocken, PA 19428-2959.www.astm.org.

ASTM Standard C117. (2003) 'Standard Test Method for Materials Finer than 75µm (No.200) Sieve in Mineral Aggregates Washing', ASTM International, Western Conshohocken, PA 19428-2959.www.astm.org.

ASTM Standard C136. (2003) 'Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates', ASTM International, Western Conshohocken, PA 19428-2959.www.astm.org.

Balamurugan, G; Perumal, P. (2013) 'Use of Quarry Dust to Replace Sand in Concrete – An Experimental Study', *International Journal of Scientific and Research Publications*, 3(12), pp. 10–13.

Departmnet of Census and Statiscs (2014) *National Accounts of Sri Lanka 2013*. Available at: http://www.statistics.gov.lk/national_accounts/Annual2013/index.pdf.

Ibrahim, W. (2007) *Towards a sustainable quarry industry in Malaysia : some issues and challenges in Malaysia [online]*. Available at: http://www.opender.com (Accessed: 14 September 2019).

Ilangovana, R., Mahendrana, N. and Nagamanib, K. (2008) 'Strength and durability properties of concrete containing quarry rock dust as fine aggregate', 3(5), pp. 20–26.

Jayawardena, U.DE S; Disssanayake, D. M. . (2006) 'Use of quarry dust instead of river sand for future constructions in Sri lanka', *LAEG2006 Paper number 38*, (38), pp. 1–4.

Jayawardena, U. D. S. and Dissanayake, D. M. . (2008) 'Identification of the most suitable rock types for manufacture of quarry dust in Sri Lanka', 36(3), pp. 215–218.

Mahzuz, H.M.A; Ahmed, A.A.M; Yusuf, M. . (2011) 'Use of stone powder in concrete and mortar as an alternative of sand', *African*

Journal of Environmental Science and Technology, 5(5), pp. 381–388.

Muhammad, I; Rasheed, F. (2010) *Health and environment related issues in stone crushing in Pakistan*.

Raj, M. and Chinnadurai, S. (2009) 'Modeling of fugitive dust emission and control measures in stone crushing industry', (August 2014). doi: 10.1039/b818362g.

Rajapaksha, R. W. C. N. and Sooriyaarachchi, H. P. (2009) 'Feasibility of Quarry Dust to Replace River Sand as Fine Aggregate of Concrete', 42(04), pp. 30–37.

Sankh, A.C; Biradar, P.M; Naghathan, S.J; Ishwargol, M. . (2014) 'Recent Trends in Replacement of Natural Sand With Different Alternatives', *ISOR Journal of Mechanical and Civil Engineering (ISOR-JMCE)*, pp. 59–66.

Wells, J. (2000) 'Environmental concerns and responses in small scale stone quarries in Nairobi'. Available at: http://www.igentaconnect.com/content

Author Biographies

R.M.N.S. Rathnayake

Recent graduate from Department of Civil Engineering. General Sir John Kotelawala Defence University, Sri Lanka.

Dr. M.B. Samarakoon

PhD (Saitama), M.Eng. (AIT), B.Sc.Eng. (Hons) (Peradeniya), Senior Lecturer in General Sir John Kotelawala Defence University, Ratmalana, Sri Lanka.