INVESTIGATION OF NATURAL MATERIAL TO REDUCE INDUSTRIAL NOISE

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Abstract

Today with rapid industrialization, industrial noise has become a serious environmental problem in Sri Lanka. The noise which is generated by machines in industry is called as industrial noise. This excessive noise can interfere with communication between supervisors and employees. Continuous exposure to noise can cause fatigue, which often results in accidents and reduces the pace and quality of work. Noise affects negatively on the day today life of surrounding people, who have faced with many problems mentally and physically. Therefore, noise control is one of the major requirements to improve the living environment. Most of the developed countries use practical techniques to minimize the nuisance such as barrier walls, duct silencers, acoustical wall panel, soundproof curtains, sound enclosures for industrial machinery and other similar noise control treatments that are installed near the source to effectively reduce the sound level. However, Sri Lanka has not yet yielded much into this issue as noise reduction methods are costly. Therefore, it is necessary to find out cost effective methods to control industrial noise.

This research was conducted to investigate the potential uses of Salvinia dust as natural sound reduction material, to give a solution for the existing industrial noise problems. Specimens having a size of 75 mm (diameter) x 25 mm (thickness) were made by using Salvinia dust. Salvinia dust was mixed with cement at a ratio of 1:1 and water was added. Noise Reduction Coefficient of these specimens were investigated by using an experimental set-up including signal generator, speaker and noise level meter. Noise reduction ability of the materials was quantified by using Noise Reduction Co-efficient (NRC). Variation of NRC with particle size, mix proportion and sample thickness were also investigated. Effectiveness of Salvinia dust to control industrial noise is discussed in this paper.

Keywords: Noise Reduction Coefficient, Salvinia dust, Impedance tube

1. Introduction

Sri Lanka's economic growth over the last three decades has been fuelled and accompanied by rapid industrialization and urbanization. The industrialization is associated with rapid technological changes and innovations, machines and factories [3]. This growth, which has relied extensively on the country's abundant and diverse natural resources, has degraded land and water quality, caused the loss of natural habitats, and generated increasing levels of noise pollution (i.e., Noise generates to environment from industrial buildings in Colombo city has been increased today over than last decade).

General characteristics of noise are represented by sound pressure level (measured in dB) and frequency (measured in Hz). According to frequency spectrum, industrial noise is divided into discrete frequency noise, broadband noise and shock noise. Discrete frequency noise is the typical noise emitted from various industrial fields: fans, blowers, compressors, internal combustion engines, gears, tires, cutting machines, saws, transformers, etc. Broadband frequency noise is resulted from rapidly passing air. Shock noise is emitted in an instant from explosion, rock blasting, pile driving pneumatic hammer. The frequency of these noises has varied from 1- 8 kHz [10].

The noise level in residential, commercial and industrial areas is exceeding the prescribed limit at all the monitoring places [9]. This kind of industrial noise is generally known as "Annoying Noise". The annoyance can be defined as "a feeling of displeasure associated with any agent or condition, known or believed by an individual or group to adversely affect them" [4]. This has become a nuisance for people in surrounding areas such as residential, hospital, institutional and sacred places. It can cause reduced quality of life and associated psychological issues such as anxiety, emotional stress, nervous complaints, nausea, headaches, instability, argumentativeness, changes in mood, increased social conflicts. Therefore, noise control is one of the major requirements to improve the living environment.

Advanced techniques such as barrier walls, duct silencers, acoustical wall panel, soundproof curtains, and sound enclosures for industrial machinery are available in order to minimize the noise, although these techniques are expensive. In addition, these developed materials consume high CO_2 emission during their manufacturing process (i.e. Glass fibres). However, Sri Lanka has not yet yielded much into this issue possibly because these methods are expensive. Therefore, it is important to investigate an economical and environmental friendly product to minimize noise.

Cost effective noise reduction techniques, probably by using natural materials, will be a sustainable solution to protect people from industrial noise. In this research study, main objective is to investigate a material that has the ability to reduce noise in the frequency of industrial noise (1- 8 kHz).

It has been reported by Kannan (2005) that different materials perform differently, when they are used for acoustical applications. In a previous study by Chaurangani et al, (2011) investigated noise reduction properties of tiles prepared using saw dust and coir fibres. They have found that Noise Reduction Coefficient (NRC) is greater for the tile cast with large particles than that for the tile cast with small particles for both materials. Further, they have found that NRC increases with increasing the tile thickness. Also it was found that tile having grooved surface has shown much higher NRC values than the tile having flat surface.

For the current study, “Salvinia dust” was selected due to their high availability in tropical region. Salvinia moss grows in slow moving water bodies such as lakes, ponds, streams, ditches, marshes, rivers, etc. Due to the rapid growth rate of Salvinia moss, surfaces of ponds, reservoirs, and lakes are covered by a floating moss (Figure 1). The plant's growth clogs waterways and blocks sunlight needed by other aquatic plants and especially algae to carry out photosynthesis thereby oxygenating the water [5]. This has caused to kill many aquatic plants, insects or fish trapped underneath its growth. The growth habit of Salvinia is also problematic to human activities including flood mitigation, conservation of endangered species and threatened environments, boating and irrigation. Once removed the plant, it must be dried, burnt or disposed of in a manner that ensures it will not re-entry to the waterway**.** In order to reduce the water pollution, an attempt will be made to utilize Salvinia. As texture of Salvinia consists of fibre, attempt has been made to utilise it in the manufacturing of sound reduction product. As a natural material Salvinia moss is biodegradable and it will make environmental friendly product.

Figure 1- Salvinia moss

In North Central province, most of lakes have covered by the Salvinia moss (Figure 1). In Thabuththegama area, there has begun project make manure by drying (until moss take grey) and powdery Salvinia. It is expected to use that powder (Salvinia dust) as sample constructing material of the current research.

1.1 Objectives

The objectives of the current research study are,

- To utilize Salvinia dust as noise reduction material
- To investigate the effects of mix proportion, particle size and thickness of the product on noise reduction properties

2. Methodology

Methodology includes preparation of specimen, development of experimental set-up and laboratory experiments.

2.1 Preparation of specimens

Specimens with circular shape were prepared by mixing Salvinia dust with cement at different mix proportions. Diameter and thickness of the specimen were 75mm and 25mm, respectively. The plastic mould (gauge 1000 PVC pipe ring) that was used to cast specimen is shown in Figure 2.

Figure 2- Specimen used for noise testing

Initially, a specimen with the mix proportion of 1:1: cement: Salvinia dust was cast by using the mould. The same mould was used to cast all specimens. Specimens were cast with two difference thickness (i.e., 25 mm and 50 mm) in order to determine the effect of thickness on noise reduction property. Salvinia dust particles were selected in two categories: Small and Large. Particles with the size less than 0.85 mm were considered as “Small” while particles with the size between 1.7-2.36 mm were considered as “Large”. These were defined according to available sieve sizes in the laboratory. Specimen cast with different particle size was used to investigate the effect of Salvinia dust particle size on noise reduction property of developed specimen. These specimens were kept in the laboratory for one week for hardening. The mix proportions used in the study are presented in Table 1.

Table 1: Mix proportion of specimens

Sample Identification	*Mix proportion(in weight basis)*		*Thickness (mm)*	*Size of Salvinia dust*
	Cement	*Salvinia dust*		
A(Control)	*1*	*1*	*25*	*Large*
B	*1*	*1*	*50*	*Large*
C	*1*	*1*	*25*	*Small*
D	*2*	*1*	*25*	*Large*

Samples A and B were tested to determine the variation of NRC with the thickness of specimen while samples A and C were tested to determine the variation of NRC with varying the particle size of Salvinia dust. Samples A and D were tested to determine the variation of NRC with mix proportion between Salvinia dust and cement.

2.2 Development of experimental set-up

Experiment set up that was similar to the impedance tube system was developed [1]. This was done mainly because it was reported that the Impedance tube method usually gives accurate measurement for sound absorption coefficients and the impedance according to the standard of ISO 10534-2 [1]. The experimental set-up consisted of speaker at one end, propagation tube and a noise level meter (model: SL-1350) which were interposed the specimen as shown in Figure 3.

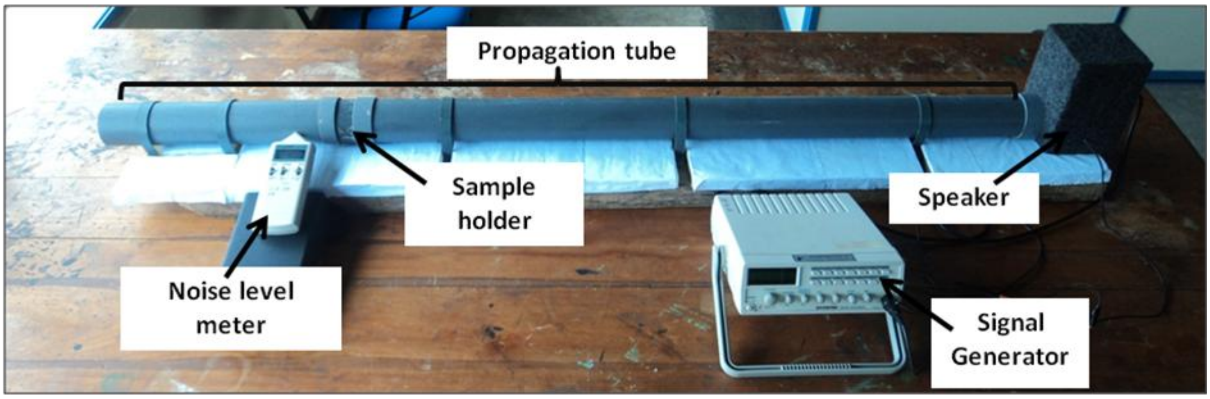

Figure 3- Impedance tube system for Sound absorption measurement

The tube was sufficiently rigid to avoid transmission of noise into the tube from outside and vibration excitation by the sound source or from background sources (e.g. doors closing). ISO 10534-2 recommended the wall thickness should be 5% of the tube diameter and the length of the tube at least 10 - 15 times the tube diameter. In preparation of experiment set-up, these guidelines were used. However, in the standards (ISO 10534-2), the tube material was not specified. Therefore, in the current study, PVC pipe was used as a propagation tube. The mould (i.e., gauge 1000 PVC pipe) was selected as a rigid. This was necessary to assure that no sound would leak into or out of the tube where the sample cover and the tube meet. Therefore, PVC rings were used as sample covers. According to the standards, the sample cover must fit snugly into the impedance tube, not so tightly that it bulges in the centre, nor so loosely that there is space between its edge and the sample cover. Therefore, PVC pipe sockets were used to fit the sample cover to the propagation tube (Figure 3).

Sound energy was provided over a frequency range of 400-8000 Hz. It was usually important for the sound source to have a high power rating (i.e., 50 to 100 watts) so that high intensity sound may be generated inside the tube for certain types of testing.

This experimental set-up is well developed one than the previous experimental set-up which was used by Chaturangani et al (2011). In the previous experimental set-up, sensor of noise level meter was placed without a proper cover for eliminating the effect of surrounding noise on the measurements. In the current experimental set-up, the sensor of noise level meter was placed inside the tube, so that effects of the surrounding noise on the measurements were minimised.

2.3 Laboratory experiment

Apparatus was prepared as shown in Figure 3. Noise levels were measured without placing the specimen in a frequency range 400 – 8000 Hz; beginning from 400 Hz and gradually increased by 400 Hz up to 8000 Hz. Above procedure was repeated with placing the specimen and noise levels were measured. Sin waves without changing amplitude (p-p 21.9V) were provided as input wave by using the signal generator (Figure 4).

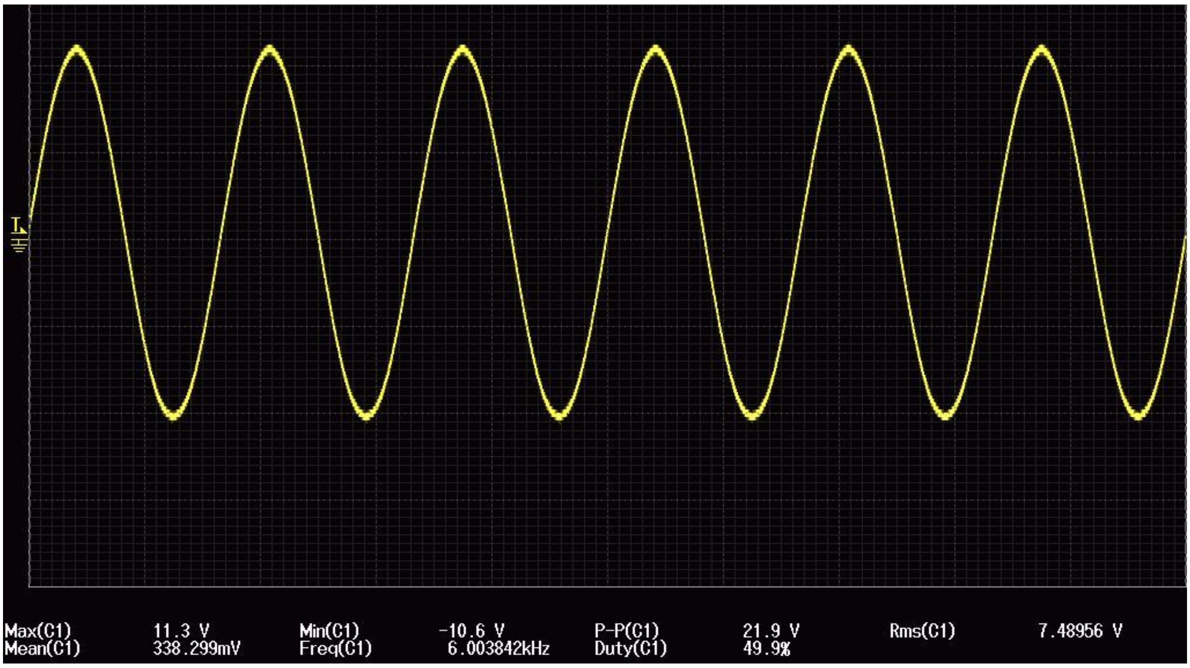

Figure 4- Characteristics of input waveform

In the current study, Noise Reduction Coefficient (NRC) was used to quantify the effect of noise reduction at each frequency. Noise Reduction Coefficient (NRC) was determined as the ratio between the noise reductions due to the specimen to the incident noise level without placing the specimen (Eq.1).

Noise Reduction Co-efficient = Intensity of reduced noise (dB)/intensity of incident noise (dB)

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Here, the noise reduction was the difference between the noise level measurement without placing the panel (i.e., a in dB) and with placing the panel (i.e., b in dB) as given by Eq. (2).

$$\text{Noise Reduction Coefficient (NRC)} = (a - b)/a \quad \text{------------------------------------ (2)}$$

3. RESULTS

Variation of Noise Reduction Co-efficient (NRC) for different thickness, different particle sizes and different mix proportions were investigated and effect of thickness, particle sizes and mix proportions on NRC values are presented in this section.

3.1 Effect of thickness

Figure 5 shows the Noise Reduction Coefficient for the Salvinia specimen having thicknesses of 25mm and 50mm while keeping other variables (large particle size, mix proportion of cement: Salvinia dust = 1:1) constant. It can be clearly seen that NRC of 50mm thick specimen is higher than that of 25 mm thick specimen in the frequency range 0.4 - 3.2 kHz. In the frequency range of 1.2 – 5.6 kHz the NRC for the 50 mm specimen varies between 0.2 - 0.4.

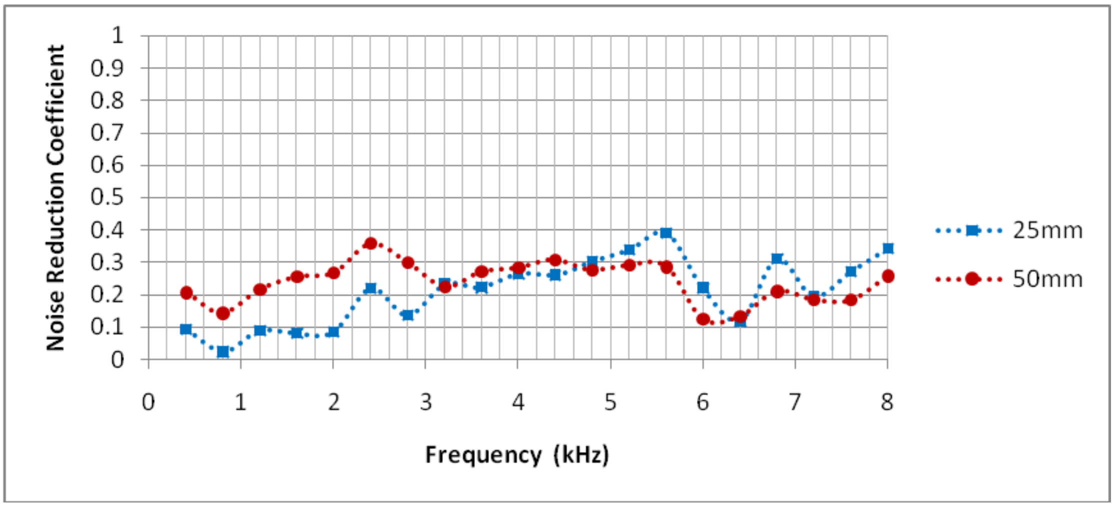

Figure 5- Effect of thickness on Noise Reduction Coefficient (Samples A & B)

3.2 Effect of particle size

Figure 6 shows the variation of NRC with the Salvinia dust particle size while keeping other variables (thickness of 25mm, mix proportion of cement: Salvinia dust = 1:1) constant. Effect of particle size on NRC was well clear in high frequencies (i.e., above 4.0 kHz), although the effect was not well clear in low frequencies (i.e., below 4.0 kHz). In the frequencies above 3.2 kHz, NRC is generally greater for the specimen cast with large particles than that for the specimen cast with small particles. For the specimen with small Salvinia dust particles, NRC increases up to 0.33. In the measured frequency range, the NRC values varied mostly between 0.2 - 0.4.

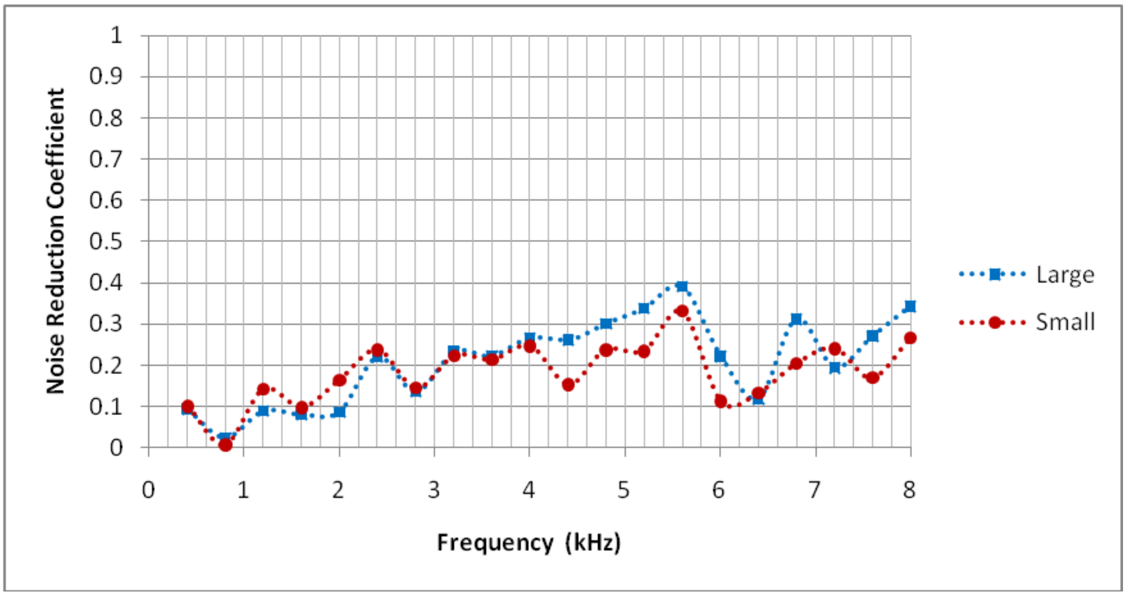

Figure 6: Effect of particle size on Noise Reduction Coefficient (Samples A & C)

3.3 Effect of mix proportion

Figure 7 shows the variation of NRC with mix proportions. Specimen thickness (i.e., 25mm) and size of Salvinia dust particle (i.e., large) were kept constant for the two specimens. It can be observed, for all investigated frequencies (i.e., 0.4-8 kHz), the NRC values of specimen having cement: Salvinia dust = 2: 1 mix ratio is higher than that of the other specimen. Specimen with the mix proportion, cement: Salvinia dust = 2: 1 shows maximum NRC of 0.43 at 5.6 kHz.

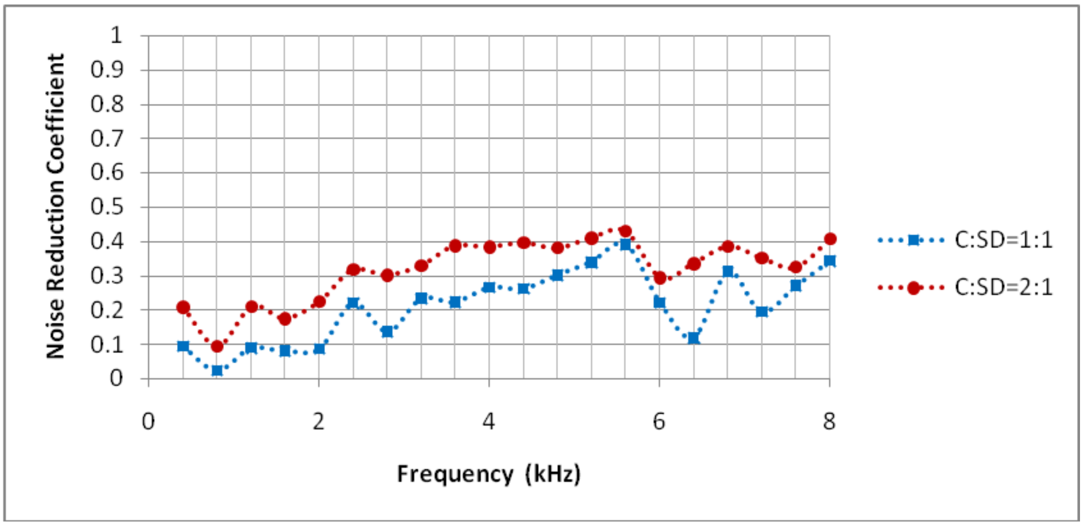

Figure 7: Effect of mix proportion on Noise Reduction Coefficient (Samples A & D)

DISCUSSION

3.1 Effect of Thickness

It can be seen that there is a general increase of NRC with the increasing of thickness in the frequencies below 4.4 kHz (Figure 5). This trend has been observed in previous studies. In a study by Ibrahim et al, (1978) observed noise absorption increases only at low frequencies (i.e., below 4 kHz***)***, as the material gets thicker. In a study by Chaturangani et al (2011) observed similar effect of thickness on NRC in the frequency range of 1.0 – 5.75 kHz for the panel developed with saw dust.

At higher frequencies (i.e., over 4 kHz***)*** effect of thickness on noise reduction was not well clear as for the frequencies below 4 kHz (Figure 5). Similar to the current study, Ibrahim et al, (1978) also observed thickness has insignificant effect on sound absorption at higher frequencies (i.e., over 4 kHz). When the thickness of the sample increases, elongation of the passage way also increases through the pores. Therefore, the ability to dissipate energy might have increased. It might contribute to increase the noise reduction component.

3.2 Effect of particle size

It was found that the specimen cast using large particles has generally greater NRC than that for the specimen cast with small particles (Figure 6) at frequencies above 4 kHz. This might be attributed by the energy dissipation through friction. To allow sound dissipation by friction, the sound wave has to enter the porous material. This means, there should be enough pores on the surface of the material for the sound to pass through and get dampened. With increment of the particle size, the porosity (void ratio) increases. It might contribute to increase Noise Reduction Co-efficient.

3.3 Effect of mix proportion

NRC increases with the increasing of mix ratio (Figure 7). In a previous study, Mingzhang et al, (1993) investigated the effect of air flow resistance towards Noise Absorption Co-efficient (NAC) and found that when sound enters these materials, its amplitude is decreased by friction as the waves try to move through the tortuous passages. Therefore, the acoustic energy is converted into heat. This friction quantity, which can be expressed by resistance of the material to airflow, is called airflow resistance.

In the measured frequency range, the NRC of specimen having cement: Salvinia dust = 2: 1 mix ratio was higher than that of the other specimen, having less mix proportion, mainly the amount of cement. High cement ratio might contribute to increase flow resistivity, consequently causes to increase the NRC.

CONCLUSIONS

In this research the Noise Reduction Coefficient (NRC) of the specimen cast by using Salvinia dust was investigated. It was found that NRC increases with increasing the specimen thickness in the frequency range 0.4 - 3.2 kHz. With the increase of Salvinia dust particle size NRC has increased. For the specimen having large particle of Salvinia dust, the NRC values has varied between 0.2- 0.4. Increase of the mix proportion yields to increase the NRC generally. Salvinia dust, which is natural material, can be effectively used to manufacture a product with appreciable noise reduction properties. However, durability and strength of the product should be further investigated.

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