SOUND ABSORPTION CAPACITY OF GARNET PARTIAL REPLACEMENT IN MORTAR

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DEDICATION

To my (Late) grand father
Sardar Shah Muhammad Khan

To my loving parents
Assoc.Prof Nighat Seema & Assoc.Prof Manzoor Hussain Khan

To my sibling & my family members
Engr Muneeb Manzoor, My Sister, Assoc. Professor Nadia Kanwal (Aunt)
& DEO Rehana Shah Muhammad Khan (Aunt)

To my supervisor
Assoc. Prof. Dr. Zaiton Haron

And to all the people around me

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ABSTRACT

Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection in the room. The research aims to develop sound absorbent mortar with inclusion of waste materials in effort to improve the acoustic quality of the room. One method to increase the acoustic quality would be covering part of concrete wall with a new mortar which has high sound absorption. The objective of the research is to determine both non-acoustic properties and evaluate acoustic performance of mortar containing waste garnet as partial garnet aggregate replacement. Three new mortar with i) a series of garnet replacement 10 to 40% of sand to normal mortar (1 sand :3 cement) , ii) a series of perlite mortar (1 cement : 4 perlite) with waste garnet replacement up to 30%, and iii) a series perlite mortar with garnet replacement and cotton fiber were developed to have such high sound absorption. Waste garnet, an industrial waste obtained from the shipyard industries were used for the purpose of greener production.. At 7 days age garnet replacing sand of 20% in normal mortar demonstrated highest average sound absorption of 0.221 which implies that the capacity of 22% in absorbing sound in room, thus not achieving the target of 0.8. The inclusion of garnet in perlite mortar and addition of cotton fiber do not posses good effect in 7 days age of mortar. However, overall, garnet increased the sound absorption of mortar.

ABSTRAK

Bahan penerap bunyi kebiasaan digunakn untuk mengatasi kesan yang tidak diingini disebabkan oleh pemantulan bunyi di dalam billik. Kajian ini bertujuan untuk membangunkan motar yang berungsi untuk menyerap bunyi yang terhasil dengan mengunakan bahan buangan dalam mewujudkan mutu kualiti akustik yang lebih baik di dalam bilik. Salah satu kaedah yang digunakan bagi meningkatkan kualiti akustik dengan menyeliputi bahagian permukaan dinding konkrit dengan motar baru yang mempunyai penyerapan bunyi yang tinggi . Objektif kajian ini adalah untuk menentukan prestasi bukan akustik dan menilai prestasi akustik yang mengunakan motar hasil daripada sisa garnet. Tiga mortar baru dengan i) satu siri penggantian garnet 10 hingga 40% pengunaan pasir kepada mortar biasa (1 pasir: 3 simen), ii) satu siri mortar perlit (1 simen: 4 perlit) dengan penggantian sisa garnet sehingga 30%, dan iii) satu siri perlit mortar dengan penggantian garnet dan serat kapas telah dibangunkan untuk penyerapan bunyi yang tinggi. Sisa garnet adalah sisa industri yang diprolehi daripada industri galangan kapal yang berfungsi untuk menghasilkan prokduksi yang lebih hijau. Pada usia mortar ke-7 hari penggunaan garnet sebanyak 20% menggantikan penggunaan pasir dalam motar yang biasa menunjukkan kapasiti penyerapan sebanyak 0.221 yang mewakili 22% penyerapan dalam bilik tidaklah mencapai sasaran sebanyak 0.8. kemasukan gernet dalam campuran motar perlit dan penambahan serat kapas tidak memberi kesan yang positif dalam tempoh masa 7 hari. Walaupun bergitu, secara keseluruhanya garnet dapat meningkatkan penyerapan bunyi oleh motar

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LIST OF ABBREVIATIONS

BS	-	British Standard
ASTM	-	American Society for Testing and Materials
NMG	-	Normal Mortar Garnet
PMG	-	Perlite Mortar Garnet
PMGCF		Perlite Mortar Garnet Cotton Fiber
PM	-	Perlite Mortar
UTM	-	Universiti Teknologi Malaysia

CHAPTER 1

INTRODUCTION

1.1 Introduction

Good acoustics always provide easy and comfortable environment in the room. Since speaking and hearing are the most important modes of communication in room, a room's acoustic design should be constructed so that the highest possible degree of speech intelligibility is achieved for listeners. Room acoustics are now increasing attention among listeners because the acoustic quality is one of the main factors for an effective listening process (Sarlati *et al.*, 2014). Speech in a room is transferred through a combination of direct and reflected sound from the listeners. Direct sound is a sound which travels straight to its listeners without diverting from its source while reflected sound reflects from some objects like wall before reaching to its listeners. Reflected and direct sound improves the communication environment in the room when combined properly in a quiet room (Haghighi *et al.*, 2012). Acoustic problem in room can also cause serious disorders among the listeners. The common disorders are stress, anxiety, depression etc. These types of disorders can cause harmful effect on the listener's health (Evans *et al.*, 1993).

The rooms do not need a great deal of sound diffusion and designed mostly for listening to speech. But the absorptive and reflective attributes are significantly essential of the room. The absorption and reflection of sounds can interfere when not controlled correctly in room listening (Haghighi *et al.*, 2012).Acoustic quality of sound always plays a vital role in listener's performance as well as learning environment in the room. Furthermore, poor quality of acoustic in room influences on the hearing loss among the listeners. Today much importance is given to the acoustical environment. Noise control and its principles play an important role in creating an acoustically pleasing environment. This can be achieved when the intensity of sound is brought down to a level that is not harmful to human ears (Seddeq, 2010).

Good porous materials have the property that they absorb the sound and help in reducing in poor acoustic quality in room. Materials that reduce the acoustic energy of a sound wave as the wave passes through it by the phenomenon of absorption are called sound absorptive materials. They are commonly used to soften the acoustic environment of a closed volume by reducing the amplitude of the reflected waves (Seddeq, 2009).Acoustical material plays a number of roles that are important in acoustic engineering such as the control of room acoustics, industrial noise control, studio acoustics and automotive acoustics. Sound absorptive materials are generally used to counteract the undesirable effects of sound reflection by hard, rigid and interior surfaces and thus help to reduce the reverberant noise levels (Seddeq, 2009).

Sound absorbing materials have been developed as an engineering control to reduce reverberation and overall sound levels. Managing the acoustic problem in a room is not easy task. Many acoustic parameters are taken into account such as noise criteria, speech intelligibility, and reverberation time. Of these reverberation time is the main factor that is the length of reverberation time that will create comfortable or anger to a person. Reverberation time is defined as the length of time required for sound to decay 60 decimals from its initial level. Reverberation time depends on several factors, such as the volume, sound frequency, and sound absorption level in the classroom (Harun and Said 2007). The World Health Organization has also given some suggestions for schools to reduce noise and reverberation in the room through important classroom acoustics standard, ANSI S12.60-2002 (World Health

Organization. 1999). The standard recommendation to limit the reverberation time to maximum value of 1.0 sec. The process of reverberation starts with the production of sound at a point within a room. The acoustic pressure wave expands radially outward, reaching walls and other surfaces where energy is both absorbed and reflected. Reflection off large, uniform, rigid surfaces produces a reflection the way a mirror reflects light, but reflection off non-uniform surfaces is a complicated process, generally leading to a diffusion of the sound in various directions.

The performance of sound absorbing materials is evaluated by the sound absorption coefficient (α) (Seddeq, 2010). Alpha (α) is defined as the measure of the acoustical energy absorbed by the material upon incidence and is usually expressed as a decimal varying between 0 and 1.0. The four factors that affect the sound absorption coefficient: 1) Nature of the material itself. 2) Frequency of the sound .3) the angle at which the sound wave strikes the surface of the material. 4) Air gap (Haris, 1979).

Other the other hand, noise pollution is the problem which needs to be solved by many developing and developed societies. Noise pollution is increasing and has a significant impact on human quality of life where it can produce negative effects on people's health (Maderuelo *et al.*,2003) .Noise is defined as 'unwanted sound', is perceived as an environmental stressor and nuisance. Exposure to a continuous noise may lead to a hearing problem. Hearing impairments due to noise are a direct consequence of the effects of sound energy on the inner ear. It is generally believed that noise disturbs activities and communication, causing annoyance. In some cases, annoyance may lead to stress responses, then symptoms and possibly illness. Alternatively, noise may influence health directly and not through annoyance. The response to noise may depend on characteristics of the sound, including intensity, frequency, and complexity of sound, duration and the meaning of the noise (Stansfeld and Matheson, 2003).

There are many products in a great number of commercial and environmental noise control applications, including building, automotive and business services areas and traffic noise abatement to try to minimize this problem. The products usually used to deal with this problem are in the form of a foam, glass wool or fiberglass. However, these materials lack sufficient structural strength and require expensive protection when exposed to the elements and abusive treatment (Maderuelo *et al.,* 2003).Recently; granular materials have been studied for different acoustic treatment due to their sound absorptive and sound insulating properties. Properties of granular materials are of great importance in many areas of acoustics and noise control. These products, combined with cementitious, polyurethane or epoxy binders, show a good degree of structural strength and durability with high values of acoustic absorption. Some of these granular materials studied are rubber crumbs, flint particles, hemp and expanded clays (Maderuelo *et al.,* 2003).

Noise exposure causes a number of predictable short-term physiological responses mediated through the autonomic nervous system. Exposure to noise causes physiological activation including increase in heart rate and blood pressure, peripheral vasoconstriction and thus increased peripheral vascular resistance (Stansfeld and Matheson, 2003). Noise exposure has also been an indicator of exposure to other factors, both physical and psychosocial, which are also associated with high blood pressure. Unless these other risk factors are controlled, spurious associations between noise and blood pressure may arise. Noise exposure creates annoyance which then leads on to more serious psychological effects. This pathway remains unconfirmed; rather it seems that noise causes annoyance and, independently, mental ill-health also increases annoyance (Stansfeld and Matheson, 2003).

The most widespread and well documented subjective response to noise is annoyance, which may include fear and mild anger, related to a belief that one is being avoidably harmed. Noise is also seen as intrusive into personal privacy, while its meaning for any individual is important in determining whether that person will be annoyed by it. Annoyance reactions are often associated with the degree of characteristics affecting the unwantedness of noise is its loudness or perceived intensity. Loudness comprises the intensity of sound, the total distribution of sound and its duration. The evidence is mixed on the importance of both the duration and the frequency components of sound and also the number of events involved in determining annoyance. High frequency noise has been found to be more annoying than low frequency noise. Vibrations are perceived as a complement to loud noise in most community surveys of noise and are found to be important factors in determining annoyance, particularly because they are commonly experienced through other senses as well as hearing (Stansfeld and Matheson, 2003).

1.2 Problem Statement

There is an acoustics problem in the room especially when the person speaks in the room, the listeners can not listen exact meaning which is delivered. This is due to multiple reflections as a result of reflective wall around the room. This will cause communication problem between speakers and listeners. In addition this will also develop serious disorders like stress, anxiety which will cause disturbance for the healthy environment.

1.3 Aim and Objective

The research aims to develop sound absorbent mortar with inclusion of waste materials in effort to improve the acoustic quality of the room. The objectives are;

1. To determine mechanical strength of new mortars.
2. To evaluate the acoustic performance of the mortars.

1.4 Scope of the Study

The scope of this study will include aspects as below:

i. Non-acoustical laboratory experiments: The test was conducted for strength of mortar, compressive strength, flexural strength, water absorption, density.

ii. Acoustical laboratory experiment: Impedance tube testing was used for sound absorption coefficient and noise reduction coefficient.

The scope of study was focused on the use of garnet as a fine aggregate replacement in an optimum mix proportion of normal mortar garnet, perlite mortar garnet and perlite mortar garnet cotton fiber in order to get the maximum sound absorbing and noise reduction coefficient. Apart from this the compressive strength, flexural strength, water absorption and density were also taken into account.

Table 4.13 shows the value of NRC of perlite garnet cotton fiber mortar samples. With the addition of cotton fiber in the samples the value of noise reduction coefficient was reduced as compared to garnet mortar samples.

Table 4.13: NRC of Garnet Perlite Cotton Fiber Mortar Samples

Absorption Frequency[Hz]	PMGCF 1%	PMGCF 2%
250	0.116	0.097
500	0.273	0.366
1000	0.161	0.243
2000	0.026	0.032
Noise Reduction Coefficient (NRC)	0.144	0.185

It can be seen that for 7 days age, NMG has best acoustic performance. Perlite mortar shows lower absorption due the experiment is carried out at 7 day where the water content in the mortar is still high. According to Seddeq perlite has higher when performed at 28 days. However, overall, garnet increased the sound absorption of normal concrete mortar with NRC less than 0.1. In series of PMG, after replacing 20 % garnet with perlite the NRC was 0.16. This value was going to slightly increased when cotton fiber was introduced.

4.5 Summary

It was found that partial replacement of garnet in mortar effect non-acoustical performance as well as acoustic performance of mortar. The compressive strength was increased when 30 % garnet was replaced, but it was going to be decreased when 40 % replacement took place. The flexural strength was going to be decreased when 30 % replacement took place. Similarly partial replacement of garnet was also effected on the water absorption and density of the samples. Moreover in acoustic performance, the partial replacement of garnet with sand has maximum noise reduction coefficient value that is 0.22 as compared to other two samples.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter will discuss about the conclusions and recommendations from the study of performance of partial replacement of garnet in perlite mortar, normal mortar and in cotton fiber mortar. The chapter will also discuss about the aim and objectives of the study that was full filled

5.2 Determination of mechanical strength of new mortars

Three mortar with i) a series of garnet replacement 10 to 40% of sand to normal mortar (1sand :3 cement) , ii) a series of perlite mortar (1 cement : 4 perlite) with waste garnet replacement up to 40%, and iii) a series perlite mortar with garnet replacement and cotton fiber were developed to obtain mechanical strength. It was found at 30% the Compressive Strength of normal mortar with replacement of garnet mortar and perlite mortar with garnet replacement the compressive strength is can be used for mortar inside building and perlite with garnet replacement 10% and 20% with cotton fiber 1 and 1.5% can be considered for potential use. While the flexural strength of normal mortar garnet was maximum as compared to PMG and PMGCF.

5.3 Evaluation of acoustic performance of the mortars

For the purpose of noise comfort in building, garnet replacing sand of 20% in normal mortar demonstrated highest average sound absorption of 0.221 that can imply that the capacity of 22% in absorbing sound in room and not achieving the target of 0.8. The inclusion of garnet in perlite mortar and addition of cotton fiber also do not posses good effect in 7 days age of mortar. Perlite has porous which is an important aspect for materials to absorb sound however at 7 days the pores contain much water that make it unable to absorb sound effectively

5.4 Recommendation

Since the scope and time for this study was limited. In order for the future researchers in order to obtain the clear picture of sound absorbing mortar by using garnet, the following recommendations should be taken into account. For 28 days of curing the result may different for sound absorbing capacity of morar.It was recommended that when garnet is mixed with cotton fiber it will give better capacity of sound absorption of mortar.

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