RESEARCH

Vol. 16, 2019

ISSN 2319–7757 EISSN 2319–7765

Indian Journal of Engineering

New Generation and Environment Friendly Bio Based Thermal Insulation Materials

Hanifi BINICI[1], **Orhan AKSOGAN**[2], **Rifat RESATOGLU**[3]

1.Ceyhan Construction Company, Baskonus Street, No: 9, Kahramanmaras, Turkey, E-mail: hanifibinici@gmail.com
2.Maltepe University, Department of Civil Engineering, Maltepe 34857, Istanbul, Turkey, E-mail: aksogan@cu.edu.tr
3.Near East University, Nicosia, North Cyprus, E-mail: rifat.resatoglu@neu.edu.tr

Corresponds to:
Rifat RESATOGLU
Near East University,
Nicosia, North Cyprus
E-mail: rifat.resatoglu@neu.edu.tr

Hanifi BINICI
Ceyhan Construction Company,
Baskonus Street, No: 9, Kahramanmaras, Turkey
E-mail: hanifibinici@gmail.com

Article History
Received: 22 January 2019
Accepted: 02 March 2019
Published: April 2019

Citation
Hanifi BINICI, Orhan AKSOGAN, Rifat RESATOGLU. New Generation and Environment Friendly Bio Based Thermal Insulation Materials. *Indian Journal of Engineering*, 2019, 16, 122-134

ABSTRACT
In this study, the properties of insulation materials have been searched using eggshell and nutshell with perlite and sawdust. Eggshell, nutshell which have been ground in different sizes. Sawdust with perlite and epoxy as binding have been used at the

production of composite. Unit weights, ultrasonic sound velocity, thermal insulation coefficient and radiation absorption levels of produced samples in standard sizes have been investigated. Particle size of eggshell increases, radiation retention rate increases depending on the diameter. Similarly, much more sound has been kept. The voids of insulation materials are important. Location of the nutshell in matrix has been caused a decrease in the thermal conductivity. In this study has been showed that insulating materials would be produced from eggshells and nutshells. The thermal conductivity coeffecition of the new generation and environment friendly bio based thermal insulation materials is similar to the values obtain for expanded polystyrene, extruded polystyrene and mineral wool. In this way, wastes as eggshell and nutshell can be decreased and also they can be gained to the economy. Limited experiments have been done in this study. So, more detailed studies is necessary. Environmental, sustainable and economic advantages may result from this practice.

Key Words: Insulation, Eggshell, Nutshell, Perlite, Sawdust

1. INTRODUCTION

In modern society, using radiation with growing aims in the various forms endangers to all lives. Today, using of radiation at basic science, medicine, industry, and military purposes has been reached to the very large dimensions. In the world, radiation rays are used to meet a need in the medicine, scientific research, energy, agriculture and industry and also to diagnose and cure at the more than three thousand nuclear facilities and medical centres (Demir et al., 2010). Radiation is energy which spreads with energy pockets called photon, wave and particle (Price et al., 1957). Three basic issues including time distance and armour must be paid attention in order to be protected from the harmful effects of this energy. Radiation dose will be increase, if the time which is exposed to the radiation of radioactive source string out. Effects from the some strong radioactive materials can be protected only with armouring. Radiation which occurs both natural and artificial ways can be at different varieties sand their effects are different too (Akkurt et al., 2006; Esen and Yilmazer, 2011).

In this context, evaluation of waste materials have gained importance and using of waste materials with different aims have widespread in civil engineering studies. Importance studies have been done to be protected from radiation which affects environment and human health greatly (Topcu, 2003; Binici et al., 2016).

According to data years of 2014, four hundred thousand tones nuts have been produced. On the other hand, 33% of this production have been occurred nutmeat (Binici et al., 2014). After nutmeat is used, lots of nutshells are obtained. Using of these wastes without simple heating methods is necessary. According to data years of 2011 of Turkey Statistical Agency Presidency, number of annual produced egg is equal to one billions and fifty millions approximately. Four millions five hundred thousand eggshells are thrown away in one year. Using as a radiation retention material of eggshell will be a good alternative method because of its chemical structure. Production and consumption of energy is increases ever day due to industrial development. Today, to be doing of nuclear power plants without causing adverse effects on the environment is very important for health of alive and sustainability. So, searching of radiation-proof materials has gained a vital importance in recent years. Because of natural sources decreases with increasing world population, natural sources can be protected with recycle. Also material consumption can be decreased and qualified wastes can be recycling to protect natural sources. So recycle and using natural source effectively are very important (Binici et al., 2016). Energy-saving has gained importance because of economic and strategic causes recently (Binici et al., 2014). In Europe, 40% of total energy are consumed in buildings and approximately half of this amount come to pass by heat through wall. In recent years, new building materials and construction systems have been started to use commonly and lots of benefits have been provided in terms of building physics and comfort. In this context, isolation of building walls providing energy-saving facilities is an open topic to the researches. Nowadays using of both textile and organic fibres have been used as isolation material production (Xiao-yan et al., 2010).

In order to reduce the negative effect on the environment, environmentally friendly materials are being chosen for the construction of buildings more and more frequently (Kolo and Olagunju, 2018). The building insulation materials that are now used more commonly are expanded polystyrene, extruded polystyrene and mineral wool (Hemant Kumar Singh et al. 2015; Angeline Mary et al. 2015). Moreover, in recent years, bio based waste materials are used production of thermal insulation materials.

The radiation insulation properties of these environmentally friendly materials have not yet been examined thoroughly. This paper presents most commonly used linear absorption coefficients by gamma ray saturation levels at 17.7, 26 and 60 keV energies that have been measured. It has been found that it is possible to produce insulation material resistant to sound and against radiation by using egg and nut shell and sawdust. It is seen that samples incorporating egg and nutshell and sawdust could be used at hospitals, military and industrial facilities and shelters which are under radiation hazard. The material with the best radiation absorption coefficient was eggshell.

As it is clear from previous studies, evaluation of wastes at our world carries a big importance. The aim of the studies in this context is to produce suitable insulation material using insulation material. Productions of an insulation material having lower thermal conductivity have been aimed with study. By this means, the people living there will benefit from waste, via serial production, employment will be created and national economy will be also benefitted. Alternative sources have been came into prominence because of natural sources are used fast. Studies on thermal insulation are limited, so literature will be contributed with done these studies. Thermal insulation coefficient, ultra sound velocity and radioactive permeability properties of produced samples have been investigated.

2. MATERIAL AND METHOD

2.1. Material

2.1.1. Nutshell

Nutshell keeps fresh to the nuts. It is a layer which having single rigid structure in the nut fruits. Nuts with the shell are cracked by separating into calibres. After this process, nutmeat and nutshell have been separated. Nutshell is both economic and nature friendly according to the other fuels. Giving off heat at high calorie because of structure and consisting of grains is very important properties of nutshell whose value is unknown completely.

2.1.2. Eggshell

In the study, the eggshells obtained from a patisserie were ground to resize by 0-1 mm used for further process. Chemical components of eggshell are given in Table 1.

Table 1 The chemical content of egg (Binici et al., 2015).

Compounds	(%)
Calcium carbonate	94-97
Magnesium	0.2-1.0
Calcium phosphate	0,2-1,0
Organic materials	2-3.3
Sodium, potassium, iron, copper, manganese	0.1

2.1.3. Perlite

Perlite is the name given as siliceous rock. At the study, Perlites which are between at 0 and 3 mm sizes have been used.

2.1.4. Sawdust

Sawdust are wastes obtained from Kahramanmaras wood warehouse in Turkey during grating of woods or trees, machining of lathes or sieving. These wastes have been used as admixture material in the insulation material.

2.1.5. Epoxy

Epoxy is a chemical resin from the thermosetting group. Its resistance to the water, acid and alkali is good and it doesn't loss this property with time. Generally epoxies having two components transit from liquid state to solid state like the other thermoset plastics and then they reach final hardness in the one-two weeks. Epoxy combination with glass or carbon fibre have excellent mechanical durability. Epoxy is a material which is commonly used in the field of construction too. Epoxy is used in the filling of cracks and placing of steel reinforcement which will be added into reinforced concrete.

2.2. Method

Eggshell have been dried at a cool and shade place. After the shells have been ground and passed through determined sieves, they have been classified in three different sizes. Eggshells and nutshell which are 0-1 mm size have been used. Epoxy has been used a binder material in the samples. The mixture proportion of samples used are given in Table 2. At the initial stage, the optimization of the epoxy content to be used in the samples took into account the characteristics of the available raw materials and the existing laboratory infrastructure. The following formulas were used in determining the mixing ratios.

Eggshell/epoxy=Nutshell/epoxy=Perlite/epoxy= 0.5......................(1)

Sawdust/epoxy=0.6...(2)

Other mix group/epoxy= 0.55..(3)

In order to ensure the adhesion of the particles and manufacture the samples with adequate strength (0.2 MPa). The work also considered the experience accumulated from previous studies in similar fields. Samples with twenty six different mixing ratios were produced (Table 2). After impregnating with binder, the mortar obtained was poured, with its own weight, into steel moulds of 160 x 160 x 40 mm dimensions to obtain four samples of 40 × 40 × 160 mm dimensions in each mould. After being poured in moulds, the mortar was compacted with a hydraulic press at 5 MPa and 100°C for 10 min and, then, kept in there for approximately 24 hours (Fig.1).

Table 2 The mixture proportion of samples (g)

Samples	Components				
	Nutshell	Eggshell	Perlite	Sawdust	Epoxy
N1	300	-	-	-	200
N2	200	-	-	-	135
E1	-	350	-	-	235
E2	-	300	-	-	200
P1	-	-	300	-	200
P2	-	-	200	-	135
S1	-	-	-	270	170
S2	-	-	-	240	150
NE1	160	140	-	-	200
NE2	140	160	-	-	200
NP1	160	-	140	-	200
NP2	140	-	160	-	200
NS1	160	--	-	140	195
NS2	140	-	-	160	195
EP1	-	180	170	-	235
EP2	-	170	180	-	235
ES1	-	180	-	170	225
`ES2	A	`2Q	Q	180	225
PS1	-	-	160	140	195
PS2	-	-	140	160	195
NEP1	100	100	100	-	200
NEP2	90	120	90	-	200
NES1	100	100	-	100	195
NES2	90	120	-	90	195
NEPS1	75	75	75	75	195
NEPS2	70	90	70	70	195

In this work the preparation of waste bio-based insulation materials using shells obtained via egg and nut grounds wastes has been optimized. In a first stage, the effect of different ratios of raw materials content to mixture ratio (0.5, 0.55 and 0.6) and of two distinct percentages of materials on the extent of the chemical reaction was studied. In this investigation, it can be searched that different percentages epoxy were used to assess their effect on the unite weight, water absorption, thermal conductivity and mechanical properties of the insulation materials, including their recovery time.

Figure 1 The view of samples

2.3. Unite weights and water absorption

Weights and volumes of produced samples have been found. Transmitted sound waves into material whose transition time from one surface to the other surface of the material have been measured and wave velocity has been calculated. The relationship between the compressive strength and the other properties of the materials with calculating supersonic wave velocity have been obtained approximately (ASTM C 67-03, 2003; ASTM C 597, 1994).

2.4. Ultrasonic pulse velocity

Ultrasonic pulse velocity measurements allow the continuous monitoring of the setting of insulation composite samples, which is important to determine for instance the formwork removal time. However, aspects such as the cause of the low initial velocity, the relation between the velocity and the setting times and the effect of raw materials type or epoxy amount additives are still under discussion. Therefore, different sample compositions with egg and nutshell, perlite and sawdust were tested by ultrasonic measurements. The ultrasonic method gives a more complete picture of the setting. The change of ultrasonic velocity in time is sensitive to the differences in setting behaviour of the tested samples.

In this experiment, smooth surfaces of samples have been determined and two caps of pundit device have been lubricated with grease. Those two caps (heading) were fixed to the face of samples in a manner which they are going to be reciprocal to each other. And then, readings of pundit device have been made. The smallest of these readings has been taken and ultra sound velocity has been determined (Fig. 2.).

Figure 2 Ultrasonic pulse Velocity set up

2.5. Thermal insulation coefficient

Because energy efficiency in buildings will be evaluated not only based upon heating demand, but also according to the primary energy demand, the ecological properties of the building materials for the whole assessment has become essential. The demand for eko- building materials is rising sharply, especially insulating materials from renewable resources. The application of natural materials has become increasingly important as a consequence of the increasing need to conserve energy, use natural materials, incorporate architecture and construction into sustainable development processes, and the recently promulgated discussions on appropriate disposal of used insulation materials such as polystyrene.

Due to the fact that natural materials are more sensitive to moisture, decomposition factors such as temperature, material moisture content, attacks by microorganisms, and possible decomposition of the material or shorter durability, it is necessary to evaluate the degradation rate of builtin materials and also determine their real in situ hydrothermal properties according to their moisture content, and volume changes.

Thermal insulation coefficient of produced composite insulating material have been measured with KEM brand, QTM-500 model thermal conductivity measuring device at USKIM.

2.6. Radiation absorption coefficient

In today's world there are many unresolved problems (Portola, 2015; Torosyan, 2015; Orlova, 2015), one of which is to find engineering solutions for protection against to exposure to ionizing radiation, for example, in the case of a nuclear explosion or leakage on the radiation-hazardous facility. It is known that an important spread factor of radiation is the atmosphere, in particular, cloudiness (Andersen, 2016; Tuesday, 2016; Allen and Sherwood, 2010).

In areas where people are likely to encounter ionizing radiation, it is often necessary to provide shielding to reduce exposure to gamma radiation. Common forms of shielding include rigid materials with limited portability, such as high density concrete, lead bricks, steel plates and cooling pools filled with water. The gamma attenuation of these materials has been widely studied (William et al., 1991). In addition to these classic, well characterized shielding materials, composite materials are becoming increasingly available from shielding manufacturers. These composite materials range from simple advances, such as lead wool blankets with protective plastic covers, to more advanced materials, such as custom moulded components constructed from high density metals dispersed in organic materials. When evaluating the merits of these composite materials relative to the more classic forms of shielding, it is important to understand the basic principles that lead to gamma ray attenuation. Put simply, shielding, or the attenuation of gamma radiation, occurs through the interaction of the gamma radiation with matter. The degree to which gamma radiation is attenuated is dependent upon the energy of the incident gamma radiation, the atomic number and density of the elements in the shielding material, and the thickness of the shielding. Composite materials may offer additional benefits in chemical resistance, physical durability, and portability. This experimental study has been done at Physics Department Radiation Laboratory in KSU. Am-241 radioactive isotopes have been used as a radiation source. The radiation test was performed on selected samples.

3. RESULTS AND DISCUSSION

Obtained results have been compared according to the results of experiments.

3.1. Unite weights and water absorption

Sound permeability test of all samples have been experimented and obtained values are given in Table 3. Ultrasonic sound velocity of sample have been found lower increasing void ratio of sample. Samples whose weights per unit of volume are between 1.01-1.08 gr/cm^3 have been produced grain. On the other hand, N1 sample whose specific bulk density is largest and it has been produced as laminar. This situation has been explained with void structure. Ultrasonıc sound velocity of sample N6 has been found lowest. Sample N2 has been produced as laminar and its ultrasonic sound velocity has been found highest. These results have been explained forming more voids at matrix phase. Also, sample N6 which contains perlite has been given much more positive results and this has been explained with structure of perlite. The results showed that the board with a density of 110–135 kg/m^3 had the water absorption values ranging from 23 to 34 %, which was close to that of the expanded perlite and vermiculite within the same density range in the prior study (La Rosa and Recca, 2014).

Table 3 Unit weight of samples and water absorption

Samples	Unit Weight (g/cm^3)	Water absorption (%)
N1	1,22	19,4
N2	1,26	20,1
E1	1,32	22,2
E2	1,35	23,1

P1	1,11	28,1
P2	1,18	28,5
S1	1,12	19,4
S2	1,19	23,1
NE1	1,22	21,1
NE2	1,28	21,8
NP1	1,14	24,6
NP2	1,19	26,4
NS1	1,16	19,7
NS2	1.19	22,4
EP1	1,25	22,1
EP2	1,31	23,8
ES1	1,16	21,8
ES2	1,21	22,3
PS1	1,13	27,4
PS2	1,17	27,1
NEP1	1.21	19,2
NEP2	1,24	19,8
NES1	1,27	20,4
NES2	1,33	21,3
NEPS1	1,23	18,5
NEPS2	1,29	19,2

Obtained results were similar in the literature similar work (Binici and Aksogan, 2014). These results suggest other potential applications for these materials beyond heat insulation in areas where damping properties can be an added value.

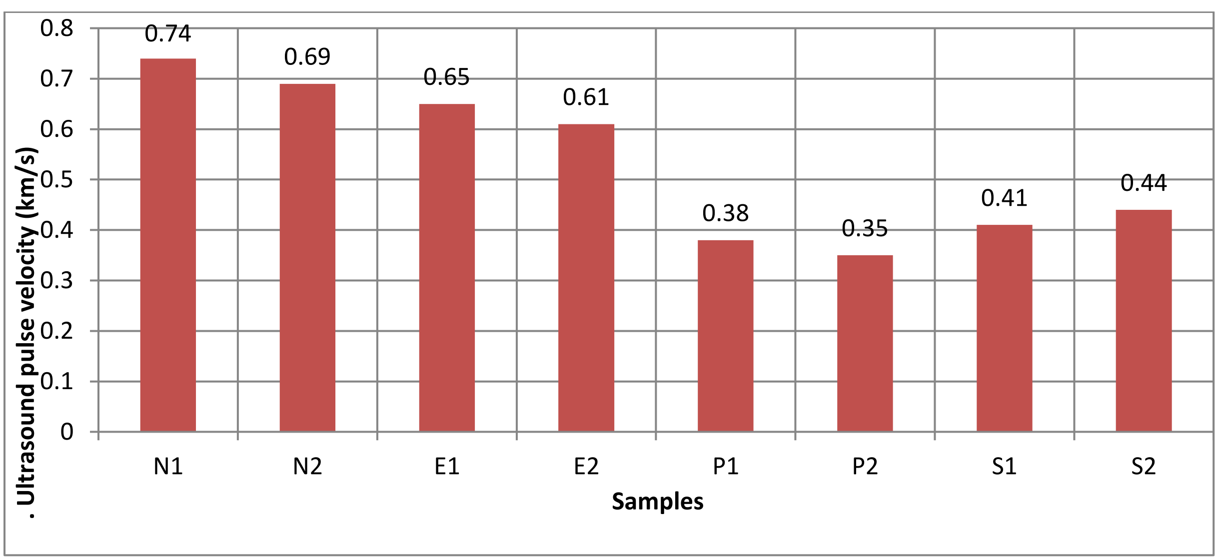


Figure 3 Ultrasonic pulse velocity of single group samples

3.2. Ultrasonic pulse velocity

Ultrasonic pulse velocity of single group samples are given in Fig. 3, Ultrasonic pulse velocity of double group samples are given in Fig. 4 and Ultrasonic pulse velocity of triple and quad group samples are given in Fig.5. Ultrasonic pulse velocity and thermal conductivity were found to decrease with increasing raw materials/epoxy ratio but increase with increasing samples unites weight.

Moreover, higher composite unite weight also resulted in less shrinkage. The experimental results prove that insulation composites made from egg and nutshell, perlite and sawdust dredged silt can help enhance insulation of composites.

Ultrasonic pulse velocity of the single layered sample are quite different. Ultrasonic pulse velocity rates of the N and E added samples were found to be 34 percent lower than the P and S added samples. This can be explained by the fact that the pore structures of the N and E added samples are denser and filled than the P and S added samples. While the Ultrasonic pulse velocity rates of the N and E-added samples were a group, on the other hand the P and S-added samples became a new group. In both groups, the Ultrasonic pulse velocity in itself are similar to one another.

In double groups, the sample with the highest Ultrasonic pulse velocity rate is the sample NS, while the sample with the lowest is the sample PS. This group of samples is close to Ultrasonic pulse velocity. The Ultrasonic pulse velocity of the double groups were found to be 10 percent lower than the single ones. This situation is explained by the fact that the materials in both groups are mostly have pore structures.

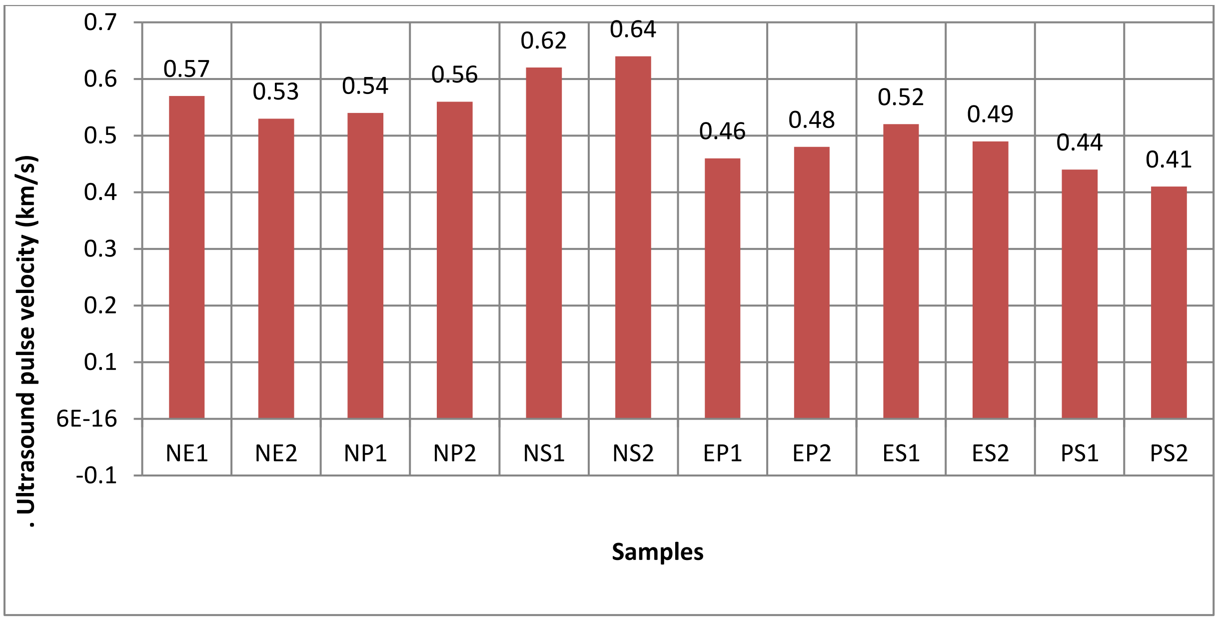


Figure 4 Ultrasonic pulse velocity of double group samples

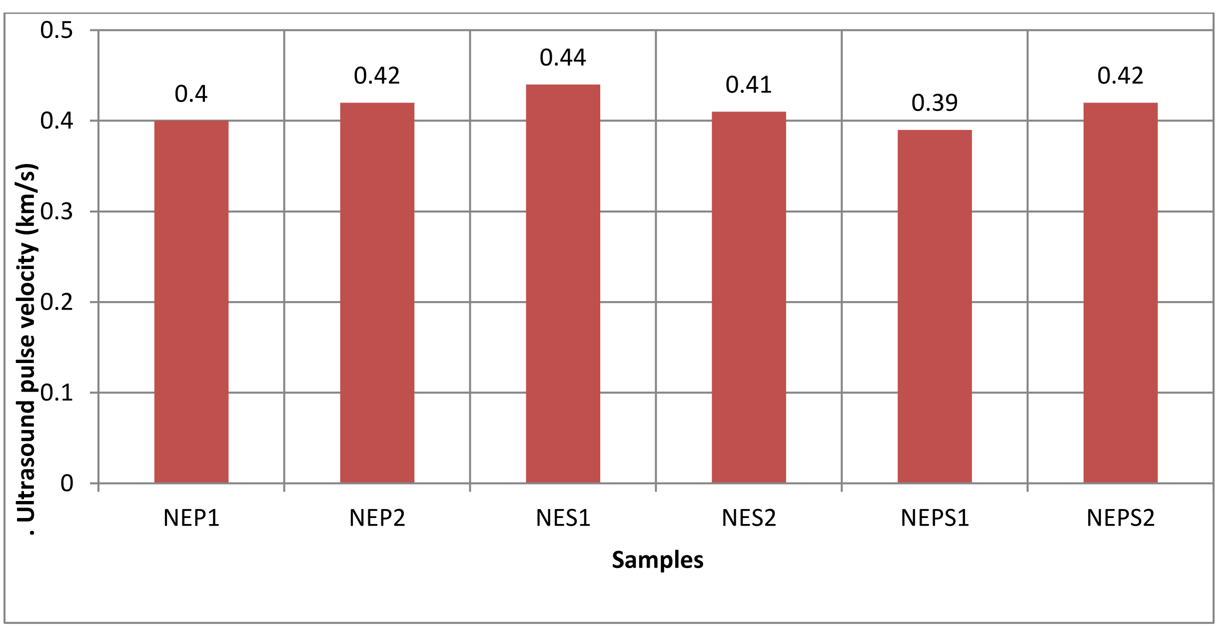


Figure 5 Ultrasonic pulse velocity of triple and quad group samples

The Ultrasonic pulse velocity of the triple and quadruple groups are close to each other. In addition, Ultrasonic pulse velocity of quadruple groups were found to be smaller than triple groups. Ultrasonic pulse velocity of these groups were found to be 25 percent smaller than in single groups.

3.3. Thermal conductivity coefficient

Due to the fact that natural materials are more sensitive to moisture, decomposition factors such as temperature, material moisture content, attacks by microorganisms, and possible decomposition of the material or shorter durability, it is necessary to evaluate the degradation rate of builtin materials and also determine their real in situ hydrothermal properties according to their moisture content, and volume changes. Thermal insulation coefficient of samples has been given in Figures 6-8. Thermal coefficients of all samples have been showed diversity. Thermal insulation coefficient of a material must be smaller than 0.1 to be used as an insulation material according to TS 805.The samples have ensure this condition. These results have explained that enough voids in samples have not been occurred and very intensive structure have been obtained. The thermal conductivity coefficient of specimens decreased as the amount of egg and nutshells increased in concrete. The minimum thermal conductivity value was 0.039 W/m K, observed at specimens P1. From this result, it was concluded that perlite used in the mixture showed better insulation properties (i.e. lower thermal coefficient). Due to the low unit weight and thermal conductivity values of new generation and environment friendly thermal insulation composites.

The sample P in the single group has the smallest the thermal conductivity coefficient. Generally, the thermal heat transfer coefficient of the P and S group samples was found to be smaller than the N and E group samples. This can be explained by independent space structures in the P and S group samples. The thermal heat transfer coefficient of the P and S group samples was found to be 40 percent smaller than the N and E group samples.

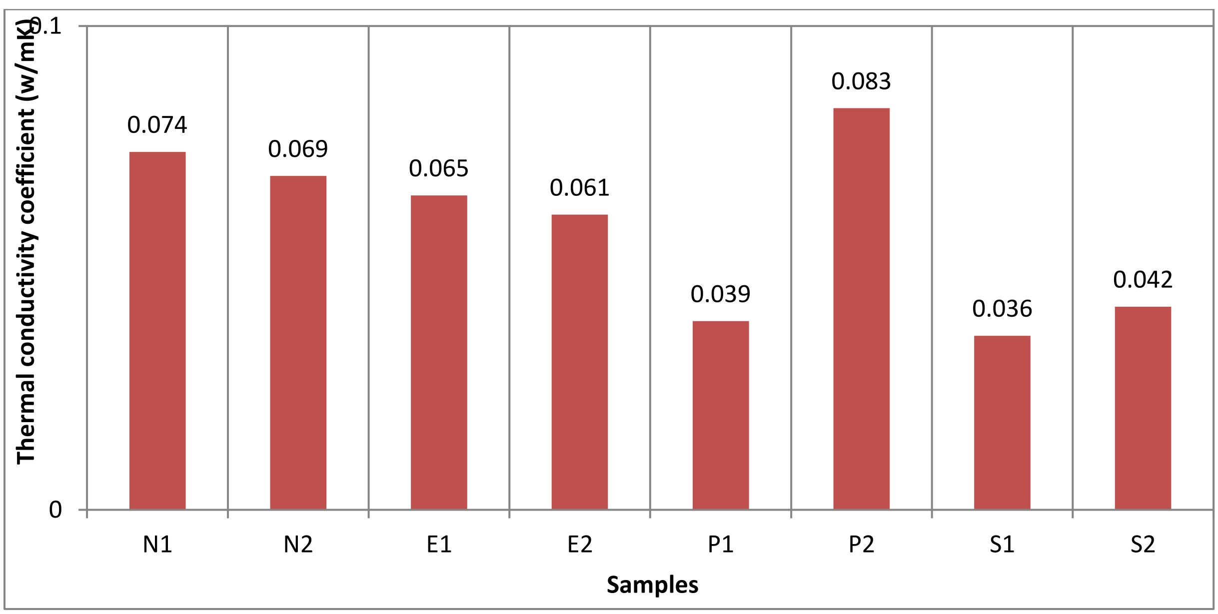


Figure 6 Thermal conductivity coefficient of single group samples

Generally, the thermal conductivity coefficient of double groups is found to be smaller than in single groups. This is explained by the gaps in the matrix structures of the double groups. The variation in the thermal conductivity coefficients of the samples in the individual groups is similar to the others.

The thermal conductivity coefficient of the triple and quadruple group samples was found to be smaller than the other examples. This is explained by the formation of new gaps in matrix structures of this group of samples. Generally, the thermal conductivity coefficient of samples in the triple and quadruple groups was found to be 33 and 26 percent lower than that of the single and double group samples, respectively.

The results showed that the samples with a unite weight of 1,11–1,35 g/cm^3 had the thermal conductivity values ranging from 0.039 to 0.083 W/m K, which was close to that of the expanded perlite and vermiculite within the same unite weight range. The thermal conductivity values had a strong linear correlation with the sample unite weight. From this date it can be concluded that as an environment-friendly and renewable material, the egg and nutshell are particularly suitable for ceiling and wall applications to save energy (Nuno et al., 2015; Binici and Aksogan, 2016). The reduced thermal conductivity provides a better thermal insulation system that consumes less energy for cooling and heating in the use phase. In the present study, thermal conductivity coefficient were carried out for various materials that are intended for use as external walls for buildings.

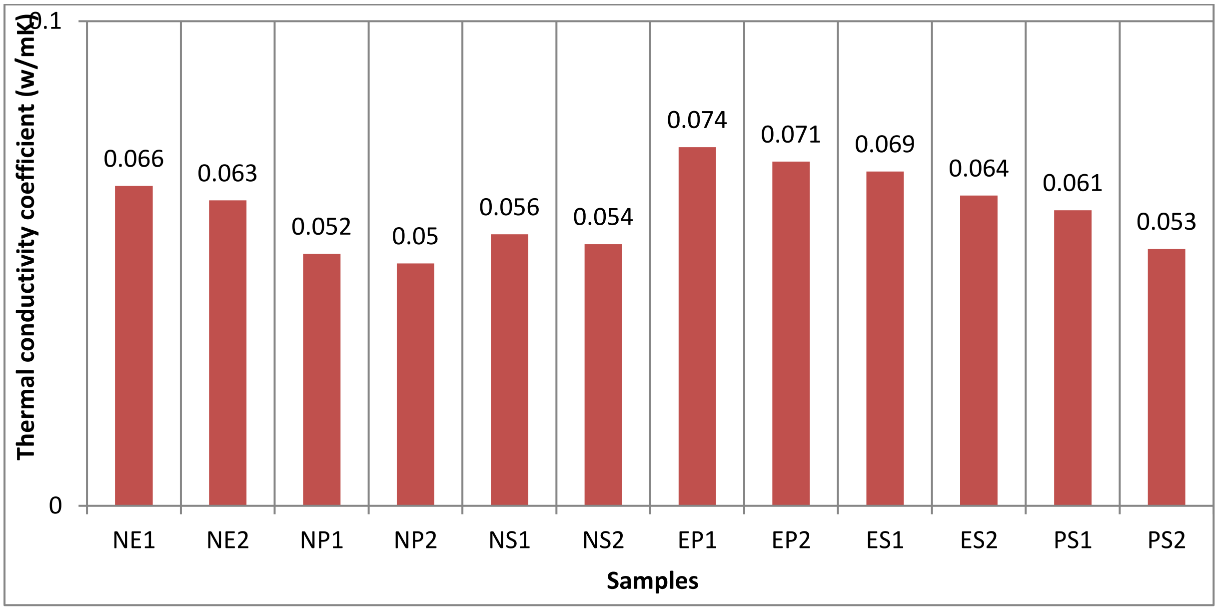


Figure 7 Thermal conductivity coefficient of double group samples

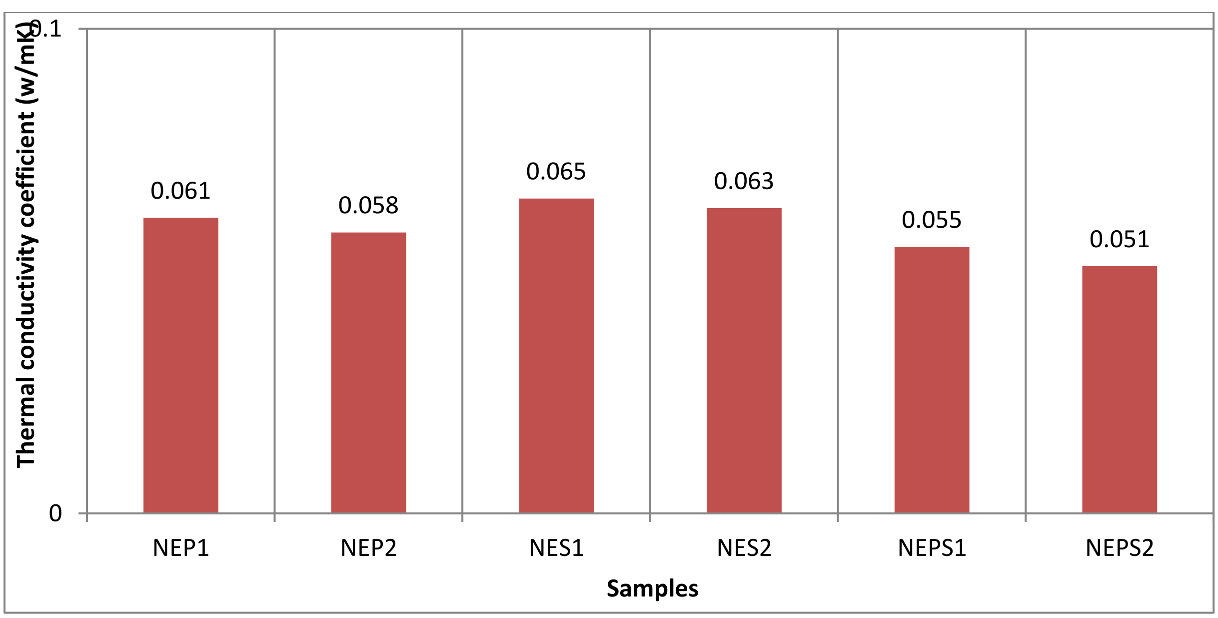
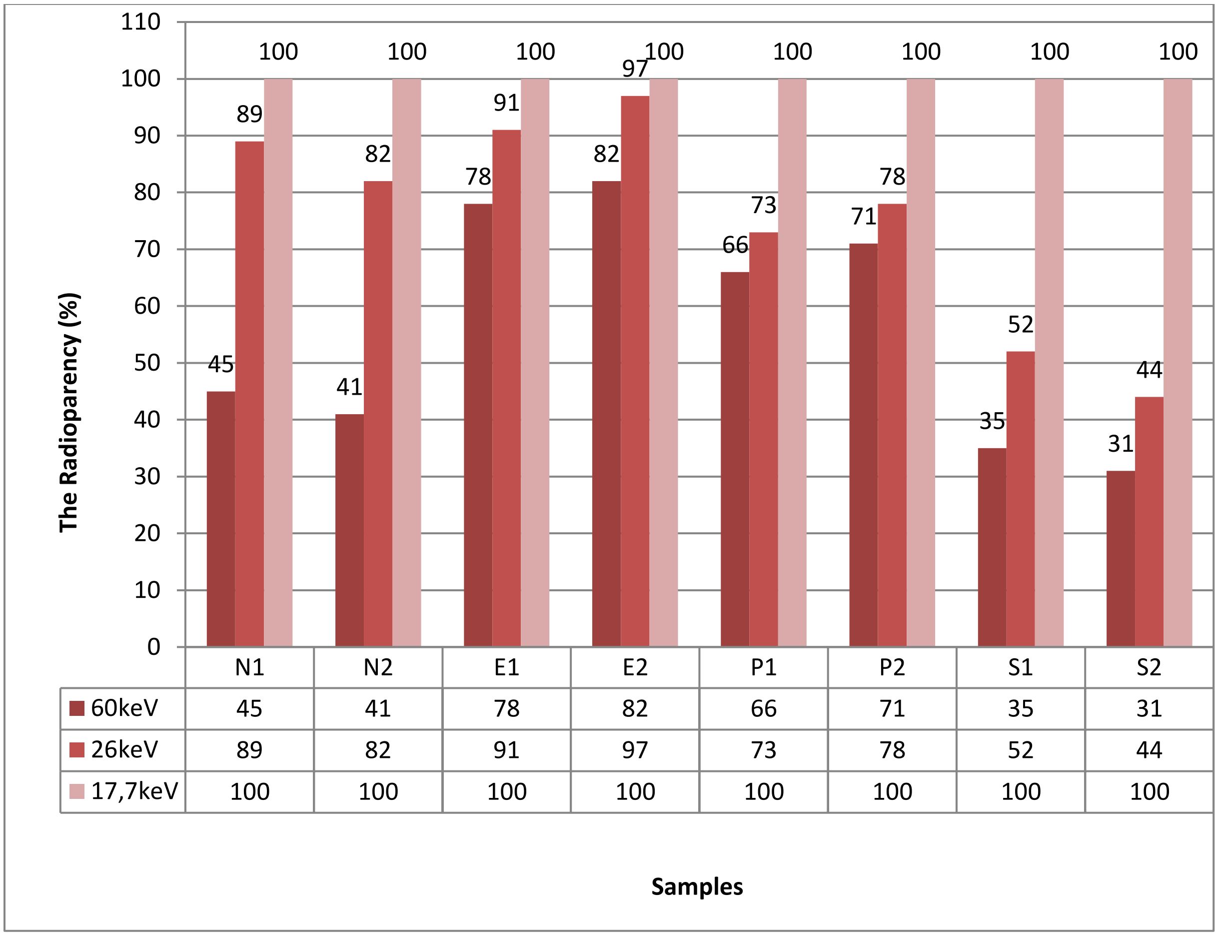


Figure 8 Thermal conductivity coefficient of triple and quad group samples

All input components are varied in the tests. The impact of epoxy content changes in relation to the rate of change of other properties was the focus of the investigation. The tests results show that the correct combination of natural materials is absolutely comparable with convectional materials.

3.4. Radioparencyrates

The Radioparency results of the selected samples have been given in Figure 9.



	N1	N2	E1	E2	P1	P2	S1	S2
60keV	45	41	78	82	66	71	35	31
26keV	89	82	91	97	73	78	52	44
17,7keV	100	100	100	100	100	100	100	100

Figure 9 The Radioparency results

All groups totally absorbed 17, 7 keV energized rays. It is seen that these group samples 26 and 60 energized rays absorbed by E group samples at most. It is seen that samples E1 and E2 are the most waste eggshell incorporating sample. Using waste eggshell is effective on radiation absorption. Radioparency of samples N and P under 60keV energized rays is 80%. This difference between two samples based on samples is perlite based composite and it has higher porosity than other samples. As the amount of nutshell and sawdust additive increases, the ratio of radial absorption is decreased. On the other hand, as the amount of eggshell and perlite additive increases, the ratio of radial absorption is increased. All samples could be used as a radiation shielding material at this thickness because average radiation energy of the devices used at health sector is lover than 70 keV. This material can be used at higher radiation energy levels by increasing the eggshell amount and the thickness. It is thought that high level of calcium carbonate ($CaCO_3$) in the eggshell is effective on radiation absorption. For buildings applications; an optimum material solution would have the essential structural properties of materials but with lower thermal conductivity and radiation against materials. The use of the eco-insulation materials in building structure seems to bring several advantages in terms of innovation, good insulation properties and light-weight structures. The new generation and environment friendly bio based thermal insulation materials results show that when the eco-materials is used, the environmental performance is lower compared to other traditional materials, in the manufacture phase. Nevertheless, impacts due to material transportation and installation could be lowered due to the light weight and handling of the eco-materials and these results are supported prior study (Binici et al., 2014; Binici et al., 2015).

4. CONCLUSION

Based on the experimental investigation reported in the paper the following conclusions can be drawn:

1-Eggshell's grain increases, rate of radiation retention has been increased.

2-To increase rate of eggshell have affected to increase retention of radiation.

3-Voids in the insulation material are important. So, if samples whose rate of nutshell is higher, Coefficient of heat transmission of samples is lower.
4-Because of much more voids have been formed with increasing particle size of eggshell, retention rate of sample has increased.
5-Location of the nutshell in matrix caused a decrease in the thermal conductivity.
6-Weight per unit of volume of grained composites have been found lower than laminar composites.
7-Ultrasonic sound transmission speeds of grained composites have been found smaller than laminar composites. This condition has been explained with relationship voids from each other in the composite.

Recycling of such wastes as a sustainable construction material appears to be viable solution not only to pollution problem but also an economical option to design of green buildings. In view of utilization of industrial and agricultural waste material for developing sustainable construction material, the present paper reviews various waste materials in different compositions that were added to the raw material at different levels to develop new insulation materials. Various physico-mechanical and thermal properties of the samples incorporating different waste materials are reviewed and recommendations are suggested as the outcome of the study.

This study shows that insulation materials would be produced from eggshell and nutshell. In this way, these wastes can be gained to the economy and damage of these wastes can be decreased to the environment. In this study, limited experimental studies have been done. Doing more detailed studies is necessary.

Acknowledgement
The authors would like to thank Prof.Dr. Adnan KUCUKONDER for his invaluable contribution to the present study.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCE

1. Akkurt, I., Basyigit, C., Kilincarslan, S., Mavi, B., &Akkurt, A. (2006). Radiation shielding of mortars containing different aggregates. *Cement Mortar Composite,* 28 (16), 153–7.
2. Allen, R.J., & Sherwood, S.C., (2010). Aerosol-cloud semi-direct effect and land-sea temperature contrast in a GCM. *Geophysical Research Letters,* 37 (10), 35-43.
3. Andersen, P.A. (2016). Environmental variables associated with vacationers' sun protection at warm weather resorts in North America. *Environmental Research,* 146(16), 200-206.
4. Angeline Mary M, Vigneshkumar C, Saravanamuthu K, Ponmalar N, Vijaya AM. Eco-friendly building materials for low cost construction in rural and urban areas. *Climate Change*, 2015, 1(3), 161-167
5. ASTM C 597, (1994). Standard Test Method for Pulse Velocity through Concrete, Annual Book of ASTM Standard.
6. ASTM C 67-03, (2003). Standard test methods for sampling and testing brick and structural clay tile. Philadelphia, PA: American Society for testing and Materials.
7. Binici, H., & Aksogan, O. (2017). Eco-friendly insulation material production with waste olive seeds, ground PVC and wood chips. *Journal of Building Engineering.*5 (20), 260–266.
8. Binici, H., & Aksogan, O. (2017). Insulation material production from onion skin and peanut shell fibres, fly ash, pumice, perlite, barite, cement and gypsum. *Materials Today Communications,* 10 (27), 14–24.
9. Binici, H., Aksogan, O., Sevinc, A.H, & Canpolat, E. (2015). Mechanical and radioactivity shielding performances of mortars made with cement, sand and eggshells. *Construction and Building Materials*, 93 (25), 1145–1150.
10. Binici, H., Aksogan, O., Sevinc, A.H., & Kucukonder, A. (2014). Mechanical and radioactivity shielding performances of mortars made with colemanite, barite, ground basaltic pumice and ground blast furnace slag. *Construction and Building Materials,* 50 (14), 177-183.
11. Binici, H., Aksogan, O., & Demirhan, C. (2016). Mechanical, thermal and acoustical characterizations of an insulation composite made of bio-based materials. *Sustainable Cities and Society,* 20 (20), 17–26.
12. Binici, H., Amany, S., & Sohail, H. (2016). Thermal, Sound And Radiation Properties Of Insulation Materials Made With Sawdust, Wheat, Sunflower, Ashes of Corn Stalks And Egg White. *European Journal of Engineering and Technology,* 4(23), 11-17.
13. Binici, H., Eken, M., Dolaz, M., Aksogan, O., & Kara, M. (2014). An environmentally friendly thermal insulation materials from sunflower stalk, textile waste and stubble fibres. *Construction and Building Materials*, 5(24), 24-33.
14. Demir, F., Budak, G., Sahin, R., Karabulut, A., Oltulu, M., & Serifoglu, K. (2010). Radiation transmission of heavyweight and normal-weight mortars containing colemanite for 6 MV

and 18 MV X-rays using linear accelerator. *Ann Nuclear Energy*, 37 (201), 339–44.

15. Esen, Y., & Yilmazer, B. (2011). An investigation of X-ray and ratio izotop energy absorption of heavy weight concretes containing barite. *Construction and Building Materials*, 34 (11), 169–175.
16. Hemant Kumar Singh, Ravi Prakash, Shukla KK. Economic and environmental benefits of roof insulation in composite climate of India. *Climate Change*, 2015, 1(4), 397-403
17. Kolo YW, Olagunju RE. Assessment of passive cooling techniques in all lecture theatres of Federal University of Technology Minna, Niger state. *Discovery*, 2018, 54(273), 342-352
18. La Rosa, A.D., & Recca, A. (2014). Environmental impacts and thermal insulation performance of innovative composite solutions for building applications. *Construction and Building Materials*, 55(14), 406–414.
19. Nuno, V.G., Belinda,S., Carmen,S.R.F., Rui,S., Carlos,P.N., & Ana,B.Ti. (2015). Bio-based polyurethane foams toward applications beyond thermal insulation. *Materials & Design*. 76(15), 77–85.
20. Orlova, K.N. (2015). Analysis of air pollution from industrial plants by lichen indication on example of small town, *IOP Conference Series: Materials Science and Engineering.VI International Scientific Practical Conference on Innovative Technologies and Economics in Engineering* (pp.10-17). Yurga, Russia.
21. Portola, V.A. (2015). Applied Mechanics and Materials. *Scientific Journal,* 770 (215), 690-694.
22. Price, B.T., Horton, C.C., & Spinney, K.T. (1975). *Radiation Shielding*, Pergamon Press. London New York.
23. Topcu, IB. (2003). Properties of heavy weight mortar produced with barite, *Cement and Concrete Research*. 33 (23), 815–22.
24. Torosyan, V.F. (May 2015). Updating of sewage-purification facilities of electroplating enterprises with counter flow ion-exchange filters*, IOP Conference Series: Materials Science and Engineering. VI International Scientific Practical Conference on Innovative Technologies and Economics in Engineering* (pp. 32-38) Yurga, Russia.
25. Tuesday, M. (2016). Simulation of bulk aerosol direct radiative effects and its climatic feedbacks in South Africa using RegCM4. *Journal of Atmospheric and Solar-Terrestrial Physics,* 142(26), 1-19.
26. William, D., Ehmann D & Diane, E. (1991). *Vance, Radiochemistry and Nuclear Methods of Analysis*. John Wiley and Sons, New York.
27. Xiao-yan, Z., Fei, Z., Hua-guan, L., & Cheng-long, L. (2010). An environment-friendly thermal insulation material from cotton stalk fibres. Energy and Buildings, 42(10), 1070–1074).