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EFFECT OF NANO FILLER ADHESIVE IN SINGLE LAP JOINT BONDED STRUCTURES

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Abstract-This work focuses on developing new adhesive formulations based on epoxy/nanostructures carbon forms. Different types of nanofillers were dispersed into an epoxy matrix for developing toughened epoxy paste aeronautic adhesives. The reinforced adhesives were used for bonding glass fiber/epoxy composite adherents. Data were also compared to the result obtained both for the unfilled adhesive and/or adherents. Single lap joint sample were prepared to measure mechanical strength and adhesion properties of the joints configurations.To analyze the types of failure mode using Acoustic emission testing.

Keywords- *Glass/Epoxy composite, adhesively bonded joints-Graphene nanoplatlets(GNP),Tensile test, Acoustic Emission (AE).*

I. Introduction

Adhesive bonded aircraft structures and joints have demonstrated considerable variation in their reliability of service performance. The failure to recognise the cause of such bond failures has meant the continued use of deficient bonding processes both in manufacture of defective components and the use of poor repair technology. Further, the lack of knowledge of bond failure mechanisms has resulted in inappropriate test methods being used to assist selection of bonding materials and processes[1].This study will address the essential elements of adhesive bonding technology and will present examples of bond failures which characterise the results of inappropriate bonding practices, based on extensive service experiences with bonded panels and repairs[2]. The objective is to encourage better bonding practices by identification of the real causes of adhesive bond failure and to refute many fallacies frequently used to explain unexpected bond failures. Clear identification of the failure mode plays an important role in determining the cause of bond failure[2,3.]

During the past three decades, application of composite materials are continuously increasing from traditional application areas such as military aircraft, commercial aircraft to various engineering fields including automobiles, robotic arms and even architecture. Due to its superior properties, composites have been one of the materials used for repairing the existing structures[3.] It is shown that continuum mechanics can be employed to analyse the behaviour of these model composites and used to predict the minimum flake dimensions and optimum number of layers for good reinforcement[4]. When crack arrests, the bonded joint can sustain a higher load and thus benefits from some of the intrinsic properties of the adherends (e.g.The plasticity of metal adherends) to enhance energy absorption and toughness[5].The basic

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requirements of an on-aircraft surface preparationare Primarily, it must produce a durable bond which mustbe validated using exactly the same procedures andmaterials. It must be succinctly robust and transportable that itcan be performed in non-idealconditions.It should not cause secondary damage to the surrounding structure, such as corrosion.The basic principles for adhesive bonding for repairunder depot or levelmaintenance areessentially thesame as for production[6]. Fibers do not act as an effective reinforcing material when the adhesion is weak. Also, the adhesion between phases can be easily degraded in aggressive environmental conditions such as high temperatures and/or elevated moisture, and by the stress fields to which the material may be exposed. Many efforts have been done to improve polymer-glass fiber adhesion by compatibility enhancement[7]. Composite structures, used to meet the demand for lightweight, high strength/stiffness and corrosion resistant materials in domestic appliances, aircraft industries and fields of engineering composites, have been one of the materials used for repairing the existing structures owing to its superior mechanical properties. Applications of composite materials have been extended to various fields, including aerospace structures, automobiles and robot systems[8]. Next generation aircraft engines and pipelines are common application areas of these adhesives. In order, however, to ensure the safe use of epoxy adhesives in such structures, computational analyses must be conducted to simulate eventual failure mechanisms[9]. The major structural integrity issue is to assure that disbonding of the patch due to environmental degradation will not occur during the required service life. Methods based on a combined safe-life/damage tolerance approach can be applied to the patch system where bond environment durability is not a concern, based on patch system fatigue allowable and knockdown factors. It is proposed that the BWT should be adopted as the principal accelerated test for quality control for bonding surface treatment[10].(Vasanthy and Jeganathan 2007, Vasanthy et.al., 2008, Raajasubramanian et.al., 2011, Jeganathan et.al., 2012, 2014,Sridhar et.al., 2012, Gunaselvi et.al., 2014, Premalatha et.al., 2015, Seshadri et.al., 2015, Shakila et.al., 2015, Ashok et.al., 2016, Satheesh Kumar et.al., 2016).

II. EXPERIMENTAL DETAILS

Materials and Methods

GNP were procured from Javanthee Enterprises Pvt. Ltd. And also the resin and hardener are(GY-257),(2963) from Araldite Pvt. Ltd. Commercial High strength Bi-directional E-Glass fibre was used in current study.Epoxy resin was used to form matrix material. By using the vacuum infusion bagging method to form a two different thickness of laminate plate, adding the GNP to the normal epoxy mixer ultrasonic heater is used[2]. Three different single lap joint were done, in the ratio of (0.25%wt,0.5%wt) and the another one is normal epoxy resin[1].(Manikandan et.al., 2016, Sethuraman et.al., 2016, Senthil Thambi et.al., 2016).

Composite Fabrication

Composite panels were prepared through aVacuum Bagging Process. The Vacuum Infusion Process (VIP) is a technique that uses vacuum pressure to drive resin into a laminate[5]. In the ratio of (100:45) resin and the hardener were mixed. Figer 1 shows the 30mmX30mm fiber

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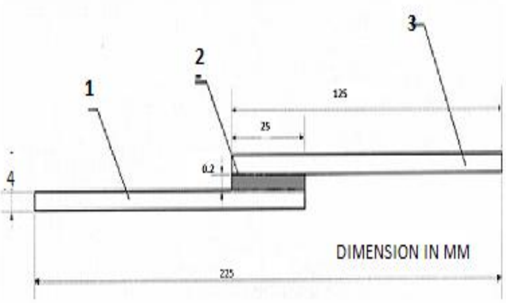
sheet is used in this process.Vacuum Bagging Equipment and Techniques for Room-Temp Applications.So, the curing process is also normal and the duration is 24 hrs.

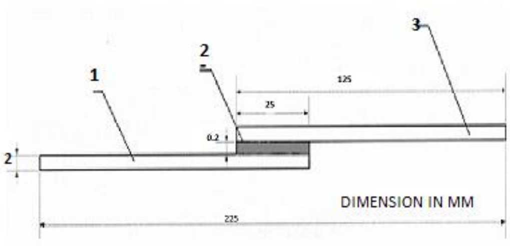
Figure 1 vacuum bagging process

Mechanical Characterization

GNP and the normal epoxy resin mixer ratio is (0.25%wt,0.5%wt) table 1. The tensile tests were performed on samples asper ASTM D638 standard using computer controlled Universal Testing Machine. And also to analyz the failure modes of the specimen by using Acoustic Emission(AE) testing method. Tests were carried out on six series of sample, each one characterized by different combination between adherents and adhesive formulations.ASTM D5868-01 standard tensile specimens of size 125x25x2mm and 125x25x4mm were cut using water-jet cutting to avoid machining defects and to maintain good surface finish from the fabricated laminates as shown in figure2(a),(b).The adherend surfaces cleaned with acetone were bonded for single lap joint specimen Figure 3.



Fiber 2 (a) 4mm thickness single lap joint



Fiber 2 (b) 2mm thickness single lap joint

Figure 3 2mm,4mm single lap joint specimen.

Table 1 GNP mixing ratio

Designation	Composition
S1	Glass fiber + Epoxy
S2	Glass fiber + Epoxy+(0.25% GNP)
S3	Glassfiber+ Epoxy+(0.5% GNP)

Results and Discussion

Tensile properties

Figure 4 testing the specimen in universal testing machine.

Figure 5, 6 shows the load–displacement curves of the glass fibre reinforced with neat and modified epoxymatrix under the uniaxial tensile testing. For the 2mm thickness and 4mm

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thickness single lab joint specimen. One can observe from Table.2.1 and Table.2.2 that the tensile strength value increasedfrom5kN to7KN. It clearly indicates that ratio of GNP and the epoxy resin,exhibited better ultimatestrength when one compared with other fillers.

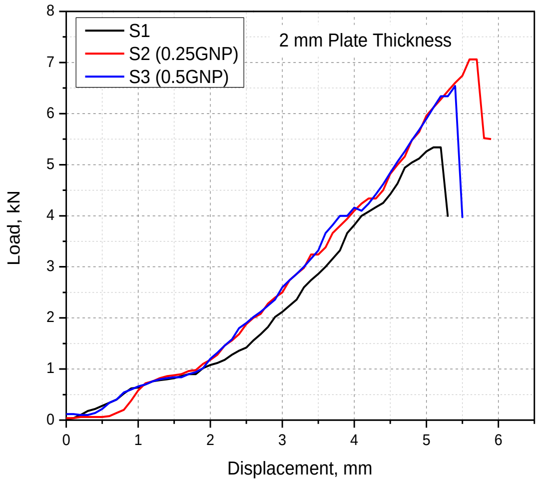

Figure5 (2mm)Typical Load VsDisplacement curves obtained from tensile test

Table 2.1 (2mm) load factor

SPECIMEN	ULTIMATE LOAD(KN)
S1(Glass fiber + Epoxy)	5.4
S2 (Glass fiber + Epoxy+(0.25% GNP)	7.06
S3(Glassfiber+ Epoxy+(0.5% GNP)	6.54

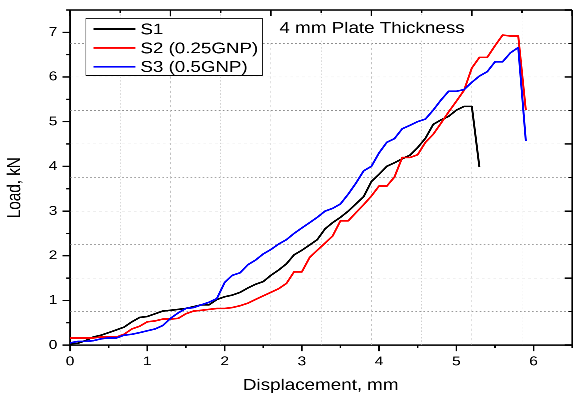

Figure6 (4mm)Typical Load Vs Displacement curves obtained from tensile tests

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Table 2.2 (4mm) load factor

SPECIMEN	ULTIMATE LOAD(KN)
S1(Glass fiber + Epoxy)	5.04
S2 (Glass fiber + Epoxy+(0.25% GNP)	7.1
S3(Glassfiber+ Epoxy+(0.5% GNP)	6.9

Acoustic emission Testing

The failure modes in GFRP composite adhesively bonded joints are identified using various AE parameters such as The range of peak frequency pertaining to the below failure modes of composite laminates obtained from different orientation during the conduct oftensile test with acoustic emission monitoring are obtained. The relevant frequency ranges are: 80-110 kHz corresponding to matrix failure (Adhesive), 130-200 kHz to fiber matrix failure (thin layer cohesive failure), and 230-250 kHz to fiber tear failure I and 250-300 kHz to fiber failure respectively as shown in the figure 7 and table

Table 3 Frequency range and failure modes of bonded lap joints for two different thickness (2mm,4mm) plates.

Frequency range		80-110KHZ	130-200KHZ	200-250KHZ	250-280KHZ
Failure modes		matrix	Fiber-matrix	Fiber-tear	fiber
S1	2	3.9%	74.50%	4.06%	12.50%
	4	4.5%	69.06%	3.82%	8.04%
S2	2	2.7%	84.44%	2.10%	18.06%
	4	3.6%	73.07%	1.70%	7.45%
S3	2	2.10%	76.56%	2.9%	9.89%
	4	3.80%	64%	2%	5.42%

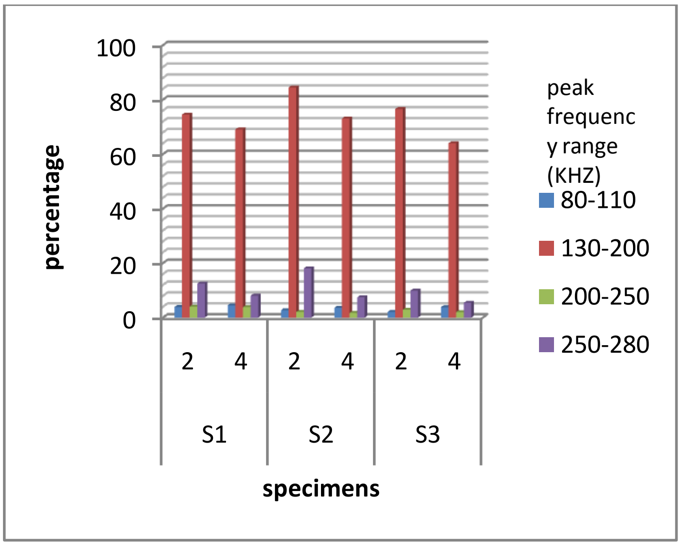

Figure 7percentage of Frequency range of bonded lap joints for two different thickness (2mm,4mm) plates.

Conclusion

In the present paper, the addition of GNP into an epoxy adhesive formulation caused a improvement in the bonded strength of the joints. The response of single lap joints with composite adherend subjected to tensile load was investigated for two different thickness laminates.To analyze the types of failure mode using Acoustic emission testing.

In this case the most relevant enhancement in mechanical performances were achieved by using lower nanofiller(0.25wt/wt%)content in epoxy matrix adherents for 2mm and 4mm thickness lab joints, comparing to the higher nanofiller(0.5wt/wt%) content in epoxy matrix.

The precisely composite bonded joints analysis method must beable to predict failure modes in GFRP composite, and also identified using various AE parameters.

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References

1. U.vietri,L.Guadagno,M.Raimondo, “Nano filled epoxy adhesive for structural aeronautic materials”. 2014:20:3453-3456
2. K.MohamedBak,M.Dinesh, K.Kalaichelvan, “Effect of adhesive thickness area of single lab joint in composite laminate using acoustic emission technique”. 2014:02:567-21
3. Hsiao KT, Alms J, Advani G, “Use of epoxy/multi walled carbon nano tubes as adhesive to join graphite fiber reinforced polymer composites nanotechnology”. 2003:14:791-3

ISSN:0975-3583,0976-2833 VOL7,ISSUE04, 2016

4. k.B. Katnam, L.F.M Da Silva, "T.M.Young bonded repair of composite aircraft structures". 2013:23:1016-003
5. BabakHaghpanah, Shihungchiu, AshkanVaziri, "Adhesively bonded lap joints with extreme interface geometry"2010:03:123:876
6. S. K. Garkhail, R. W. H. Heijenrath1 and T. Peijs "Mechanical Properties of Mat-Reinforced Thermoplastics based on Polypropylene" 351–372, 2000.
7. A. S. Singha and Vijay Kumar Thakur "Mechanical properties of fiber reinforced polymer composites" (2008) 791–799.
8. A. Lakshumu Naidu, D. Raghuveer, P. Suman "Studies on Characterization and Mechanical Behavior of Reinforced Epoxy Composites" June 2013.
9. T. MunikencheGowdaa, A.C.B. Naidua, Rajput Chhayab, "Some mechanical properties of fabric-reinforced polyester composites" Part A 30 (1999) 277–284.
10. Mubarak Khan, SushantaGhoshal, Ruhul Khan, ShamimAraPervin and Ahmed Mustafa, "Preparation And Characterization Of Fiber Reinforced : Effect Of Additive" 2008.
11. Vasanthy M and M. Jeganathan. 2007. Ambient air quality in terms of NOx in and around Ariyalur, Perambalur DT, Tamil Nadu. Jr. of Industrial pollution Control., 23(1):141-144.
12. Vasanthy. M ,A.Geetha, M. Jeganathan,and A.Anitha. 2007. A study on drinking water quality in Ariyalur area. J.Nature Environment and Pollution Technology. 8(1):253-256.
13. Ramanathan R ,M. Jeganathan, and T. Jeyakavitha. 2006. Impact of cement dust on azadirachtain dicaleaves – ameasure of air pollution in and Around Ariyalur. J. Industrial Pollution Control. 22 (2): 273-276.
14. Vasanthy M and M. Jeganathan. 2007. Ambient air quality in terms of NOx in and around Ariyalur, Perambalur DT, Tamil Nadu. Pollution Research., 27(1):165-167.
15. Vasanthy M and M. Jeganathan. 2008.Monitoring of air quality in terms of respirable particulate matter – A case study. Jr. of Industrial pollution Control.,24(1):53 - 55.
16. Vasanthy M, A.Geetha, M. Jeganathan, and M. Buvaneswari. 2008. Phytoremediation of aqueous dye solution using blue devil (Eichhornia crassipes). J. Current Science. 9 (2): 903-906.
17. Raajasubramanian D, P. Sundaramoorthy, L. Baskaran, K. Sankar Ganesh, AL.A. Chidambaram and M. Jeganathan. 2011. Effect of cement dust pollution on germination and growth of groundnut (Arachis hypogaea L.). IRMJ-Ecology. International Multidisciplinary Research Journal 2011, 1/1:25-30 : ISSN: 2231-6302: Available Online: http://irjs.info/.
18. Raajasubramanian D, P. Sundaramoorthy, L. Baskaran, K. Sankar Ganesh, AL.A. Chidambaram and M. Jeganathan. 2011. Cement dust pollution on growth and yield attributes of groundnut. (Arachis hypogaea L.). IRMJ-Ecology. International Multidisciplinary Research Journal 2011, 1/1:31-36.ISSN: 2231-6302. Available Online: http://irjs.info/
19. Jeganathan M, K. Sridhar and J.Abbas Mohaideen. 2012. Analysis of meterological conditions of Ariyalur and construction of wind roses for the period of 5 years from January 2002. J.Ecotoxicol.Environ.Monit., 22(4): 375-384.
20. Sridhar K, J.Abbas Mohaideen M. Jeganathan and P Jayakumar. 2012. Monitoring of air quality in terms of respirable particulate matter at Ariyalur, Tamilnadu. J.Ecotoxicol.Environ.Monit., 22(5): 401-406.
21. Jeganathan M, K Maharajan C Sivasubramaniyan and A Manisekar. 2014. Impact of cement dust pollution on floral morphology and chlorophyll of healianthus annus plant – a case study. J.Ecotoxicol.Environ.Monit., 24(1): 29-34.

22. Jeganathan M, C Sivasubramaniyan A Manisekar and M Vasanthy. 2014. Determination of cement kiln exhaust on air quality of ariyalur in terms of suspended particulate matter – a case study. IJPBA. 5(3): 1235-1243. ISSN:0976-3333.
23. Jeganathan M, S Gunaselvi K C Pazhani and M Vasanthy. 2014. Impact of cement dust pollution on floral morphology and chlorophyll of healianthus annus.plant a case study. IJPBA. 5(3): 1231-1234. ISSN:0976-3333.
24. Gunaselvi S, K C Pazhani and M. Jeganathan. 2014. Energy conservation and environmental management on uncertainty reduction in pollution by combustion of swirl burners. J. Ecotoxicol. Environ.Monit., 24(1): 1-11.
25. Jeganathan M, G Nageswari and M Vasanthy. 2014. A Survey of traditional medicinal plant of Ariyalur District in Tamilnadu. IJPBA. 5(3): 1244-1248. ISSN:0976-3333.
26. Premalatha P, C. Sivasubramanian, P Satheeshkumar, M. Jeganathan and M. Balakumari.2015. Effect of cement dust pollution on certain physical and biochemical parameters of castor plant (ricinus communis). IAJMR.1(2): 181-185.ISSN: 2454-1370.
27. Premalatha P, C. Sivasubramanian, P Satheeshkumar, M. Jeganathan and M. Balakumari.2015. Estimation of physico-chemical parameters on silver beach marine water of cuddalore district. Life Science Archives. 1(2): 196-199.ISSN: 2454-1354.
28. Seshadri V, C. Sivasubramanian P. Satheeshkumar M. Jeganathan and Balakumari.2015. Comparative macronutrient, micronutrient and biochemical constituents analysis of arachis hypogaea. IAJMR.1(2): 186-190.ISSN: 2454-1370.
29. Seshadri V, C. Sivasubramanian P. Satheeshkumar M. Jeganathan and Balakumari.2015. A detailed study on the effect of air pollution on certain physical and bio chemical parameters of mangifera indica plant.Life Science Archives. 1(2): 200-203.ISSN: 2454-1354.
30. Shakila N, C. Sivasubramanian, P. Satheeshkumar, M. Jeganathan and Balakumari.2015. Effect of municipal sewage water on soil chemical composition- A executive summary. IAJMR.1(2): 191-195.ISSN: 2454-1370.
31. Shakila N, C. Sivasubramanian, P. Satheeshkumar, M. Jeganathan and Balakumari.2015. Bacterial enumeration in surface and bottom waters of two different fresh water aquatic eco systems in Ariyalur, Tamillnadu. Life Science Archives. 1(2): 204-207.ISSN: 2454-1354.
32. Ashok J, S. Senthamil kumar, P. Satheesh kumar and M. Jeganathan. 2016. Analysis of meteorological conditions of ariyalur district. Life Science Archives. 2(3): 579-585.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.
33. Ashok J, S. Senthamil Kumar, P. Satheesh Kumar and M. Jeganathan. 2016. Analysis of meteorological conditions of cuddalore district. IAJMR.2 (3): 603-608.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.
34. Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. South Indian vernacular architecture -A executive summary. IAJMR.2 (4): 655-661.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.
35. Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. Green buildings - A review. Life Science Archives. 2(3): 586-590.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.
36. Satheesh Kumar P, C. Sivasubramanian, M. Jeganathan and J. Ashok. 2016. Indoor outdoor green plantation in buildings - A case study. IAJMR.2 (3): 649-654.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.
37. Manikandan R, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. Assessment of ground water quality in Cuddalore district, Tamilnadu, India. Life Science Archives. 2(4): 628-636.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.

38. Manikandan R, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. A study on water quality assessment of Ariyalur district, Tamilnadu, India. IAJMR.2 (4): 687-692.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.
39. Sethuraman G, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. Assessment of air quality in Ariyalur, Tamilnadu, India. Life Science Archives. 2(4): 637-640.ISSN: 2454-1354. DOI: 10.21276/lsa.2016.2.3.9.
40. Sethuraman G, M. Jeganathan, P. Satheesh Kumar and J. Ashok. 2016. A study on air quality assessment of Neyveli, Tamilnadu, India. IAJMR.2 (4): 693-697.ISSN: 2454-1370. DOI: 10.21276/iajmr.2016.2.3.3.
41. Malarvannan J, C. Sivasubramanian, R. Sivasankar, M. Jeganathan and M. Balakumari. 2016. Shading of building as a preventive measure for passive cooling and energy conservation – A case study. Indo – Asian Journal of Multidisciplinary Research (IAJMR): ISSN: 2454-1370. Volume – 2; Issue - 6; Year – 2016; Page: 906 – 910. DOI: 10.21276.iajmr.2016.2.6.10.
42. Malarvannan J, C. Sivasubramanian, R. Sivasankar, M. Jeganathan and M. Balakumari. 2016. Assessment of water resource consumption in building construction in tamilnadu, India. Life Science Archives (LSA) ISSN: 2454-1354 Volume – 2; Issue - 6; Year – 2016; Page: 827 – 831 DOI: 10.21276/lsa.2016.2.6.7.
43. Sivasankar R, C. Sivasubramanian, J. Malarvannan, M. Jeganathan and M. Balakumari. 2016. A Study on water conservation aspects of green buildings. Life Science Archives (LSA),ISSN: 2454-1354. Volume – 2; Issue - 6; Year – 2016; Page: 832 – 836, DOI: 10.21276/lsa.2016.2.6.8.
44. Ashok J , S. Senthamil Kumar , P. Satheesh Kumar and M. Jeganathan. 2016. Analysis and design of heat resistant in building structures. Life Science Archives (LSA), ISSN: 2454-1354. Volume – 2; Issue - 6; Year – 2016; Page: 842 – 847. DOI: 10.21276/lsa.2016.2.6.10.