PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Sustainable Resources to Improve on Living Green Walls Acoustics: Supply Chain Study

Ghofran SALAH[1]; Anna ROMANOVA[2]

[1] University of Greenwich, United Kingdom

[2] University of Greenwich, United Kingdom

ABSTRACT

Living Green Walls (LGWs) or Vertical Gardens are built and deigned using a selection of plants, growing medium, frames, supports, and irrigation system. LGWs are considered as a natural solution of controlling noise especially in urban environments. A better sound absorption can be achieved through replacing the currently used growing medium by a new material with a higher porosity. A high porosity material allows more sound to entre and dissipate in the material matrix. Coconut fiber can be a considerable alternative for the currently used growing medium, due to its high porosity. It has proven that natural fibers have good sound absorption coefficient at medium and high frequencies (500 – 2000 Hz). The study works on improving the LGWs acoustic using sustainable resource (coconut fiber). In order to increase the sound absorption over the current LGWs and utilize the coconut waste obtained from grinding the coconut waste which naturally exists. Moreover discussing the impact of introducing the coconut to the LGWs Supply Chain. The paper presents analysis based on real data collected from LGWs companies.

Keywords: Sound absorption, Coconut fiber, Supply Chain

1. INTRODUCTION

Urban areas have been expanded rapidly in the last decades. The world population increased from 5.3 billion in 1990 to 7.7 billion in 2019 (1, 2). In 2018 the United Nation website has revealed that 55 % of the world's population lives in urban areas (3). Based on a study done in 2000 it was proved that more than 44 % of the population within the European Union was exposed to road traffic noise levels over 55 dB (4). As the world continues to urbanize, many countries will face challenges in mitigating the sound pollution levels.

Greening these cities is a key element in addressing this noise pollution levels, in order to create a new sustainable urban lifestyle. Searching for an empty land to plant vegetation is nearly impossible in such crowed areas. Hence, Living Green Walls (LGWs) are considered as practical solution. LGWs concept of creating natural surfaces on the walls goes back to the hanging gardens of Babylon that was one of the Seven Wonders of the World at 600 BC (5). Currently LGWs design varies based on the customer requirements. LGWs are offered by different national and international companies. Previous acoustic studies have demonstrated the LGWs within the context of traffic noise mitigation. The studies focused on the sound absorption and sound propagation properties of green walls and vertical greenery systems used on façades (6 – 8). It was found that green vertical systems with 4 m width, 8 m height, and 0.3 m thickness, reduce sound propagation compared to rigid façades with maximum road traffic noise reductions of approximately 10 - 20 dB at mid frequencies around 500 – 1000 Hz. These green vertical systems were on average 1 m above the ground (7, 9).

The configurations of the systems (10), roof thickness (9, 11), and vegetation layer (12), have all been shown to be important factors affecting the sound absorption and sound propagation properties of green systems. In order to absorb the sound well, materials should have high porosity (relative volume of pore space). A porous absorbing material contains cavities, channels or interstices so that

[1] G.M.Salah@greenwich.ac.uk

[2] A.Romanova@greenwich.ac.uk

sound waves are able to enter and be captured by them. When the sound waves are exposed to a porous material, the air molecules at the surface and within the pores of the material are forced to vibrate. This leads to loss of some incident/emitted energy. Because part of the energy is converted into heat by the air molecules due to thermal and viscous losses at the walls of the interior pores and tunnels within the material (13, 14).

Fibrous materials consist of a series of tunnel-like openings that are formed by interstices in material fibers; these fibers may be continuous filaments or discrete elongated pieces that trap emitted sound. They are produced in rolls or in slabs with different thermal, acoustical, and mechanical properties. Fibers can be classified as natural or synthetic (artificial, i.e foam). Natural fibers can be fruit or vegetable (coconut, banana, cotton, kenaf, wood, etc.), animal (wool, fur felt), or mineral (asbestos) (15). Recent measurements carried out on samples of natural fibers. The measurements have shown that similarly to traditional porous materials natural fibers have good sound absorption coefficients, especially at medium and high frequencies (500 – 2000 Hz) (14, 16).

Coconut fiber and coir are waste material that remains after the coconut is processed into different products, such as: coconut meat, coconut milk, coconut water, etc. The Coconut fiber and coir are extracted from the inner husk of the coconuts as shown in Figure 1. Coconut natural fiber is characterized by its thickness, coarseness and durability (17). Coconut fiber and coir are by-product which occur in nature,as shown in Figure 2. The coconut fruit yields 40 % coconut husks containing 30 % fiber, with coir making up the rest (18). Coir (also known as coir pith, coir meal, coir dust and coco peat) is a waste product of the coconut fruit (19), consisting of the dust and short fibers derived from the husk of the fruit. This amount of renewable natural resource can be utilized as an alternative for the Black Compost Soil (BCS), to improve on LGWs sustainability.

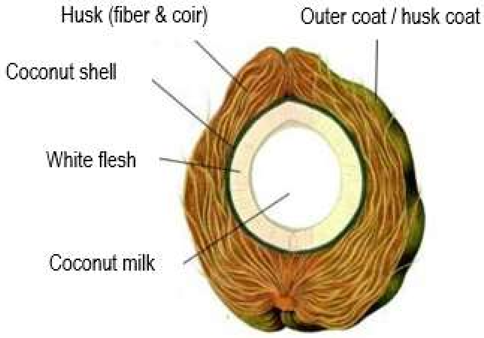

Figure 1- Coconut component schematics (20)

Figure 2- Coconut husk, fiber and coir (21)

Coconut coir pith and BSC can be blended in order to obtain fluffed plant growth media. This mixed growing medium will improve the fluffed yield characteristics and enhanced wettability as compared with the results obtained from using BCS individually. Coir pith is granular in nature and holds water in a matrix equivalent to a “honeycomb” or sponge. Coir pith does not shrink as much as peat moss and peat moss does not wet as well as coir pith (22).

To study the coconut fiber capability of noise absorption an experiment was performed. This experiment will be illustrated in the section 2.

2. Methodology

Two methodologies were applied in this study: (a) in-situ acoustic absorption experiments of traditional Black Compost Soil (BCS) vs. Coconut Fiber (CF), (b) case-study approach and analytical modelling of Supply Chain to establish benefits of the CF for LGWs companies.

2.1 Experimental Methodology

To compare the acoustic absorption of the Black Compost Soil (BCS) vs. Coconut Fiber (CF) an in-situ experiments were carried out at the LGW nursery site. In these experiments a 3 m wide and 2 m tall LGW with only pre-filled soil in the modules was used (see Figure 3). Each compartment of the module measures 80 mm x 100 mm. The moisture content of each of the growth medium’s was kept at 5 %.

The acoustic method described in (23) was used, where instrumentation consisted of ‘An intensity probe, Brüel & Kjær, type 4197 with Brüel & Kjær NEXUS conditioning amplifier type 2690 and parametric transducer (directional loudspeaker HSS-3000 Emitter) with HSS-3000 amplifier. The intensity probe was firmly attached to a telescopic tripod and placed at a height of 0.9 m and 1.7 m away from the measured surface. The orientation of the intensity probe with respect to the wall was perpendicular. The directional loudspeaker was also attached to a tripod and it was placed 4 m away from the wall. The line connecting the center point of the directional loudspeaker and the middle of the intensity probe was also set perpendicular to the wall. See Figure 4 for the set-up schematics. This method offers great precision and hence advantage over the traditional acoustics barrier absorption methods, CEN/TS1793-5:2003 and ISO354-2003, as mentioned in (23).

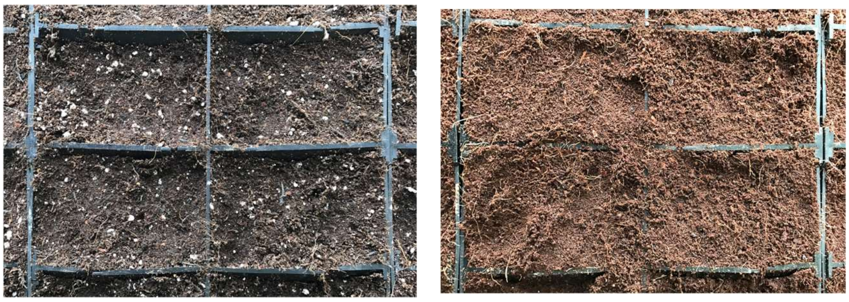

Figure 3 - Black Compost Soil (BCS, left) and Coconut Fiber (CF, right) in plastic modules

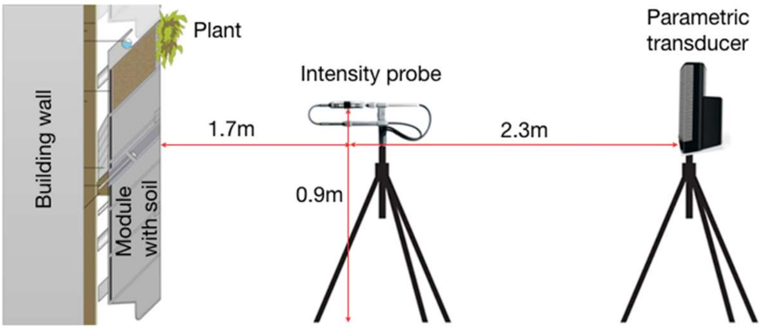

Figure 4 - Acoustics experiment set-up, using Ans Global Ltd LGW system

2.2 Investigation Methodology

An interview was carried out with one of the well-known LGWs companies (Scotscape Ltd.) in the United Kingdom. During the interview a set of questions were asked to Scotscape Ltd., to help in exploring and understanding their supply chain. In large, the questions acquired the information in these categories:

a) The material / components of LGW;
b) Material suppliers, supplier location and means of transportation;
c) The LGW ordering process;
d) Communication link between LGW company and suppliers.

The Scotscape LGW is mainly consists of five main components: modules, irrigation system, plants, BCS, and fixtures. All of these components are sourced from different suppliers. Part of the suppliers are local (based in the UK), except for the modules and plants.

The LGW supply chain process starts with initiating the LGW order by a client. The client contacts the LGW company to arranges a site visit. Then company's employ takes the site's measurements. A quotation is then estimated and sent to the client, to get the approval. After the client approves the offer, the measurements are used to create the LGW design and identify the required material. After that, they order the required material from their suppliers via e-mail. The soil and fixtures (screws, guttering, and timber) are off the shelf from local DIY stores near the company. The orders are shipped to LGW Company. The modules are delivered by ship to UK and then collected by the LGW company by van. The irrigation system is delivered by van from Bristol to the LGW by van. The plants are sourced from Holland by vans. Finally, they ship the material to client's site and install the LGW. A flow diagram was created to show the LGWs material supply chain Figure 5.

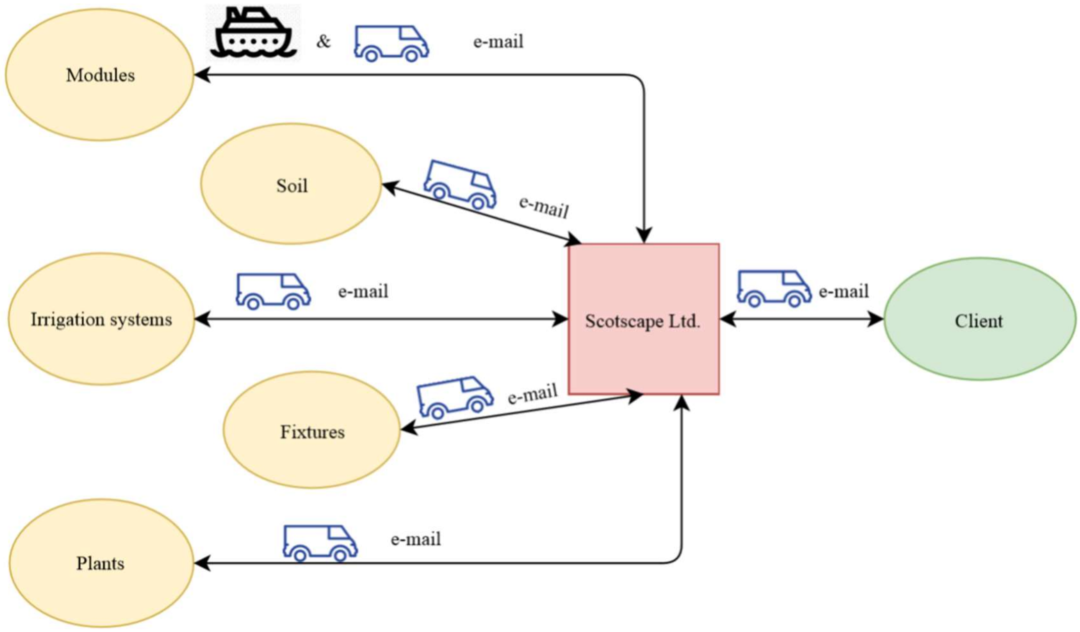

Figure 5 - LGW supply chain flow diagram

3. Data Analysis

After applying both methodologies, the outcomes were analyzed in Section 3.1 & 3.2.

3.1 Experiment Analysis

The intensity probe was used to record the instantaneous intensity, where time window analysis (of 3 x 10 s repetitions) and further Fourier analysis were carried out to determine the acoustic absorption coefficient (23) for both BSC and CF. Figure 6 below represents averaged acoustic absorption coefficient for BSC, CF as well as 100 mm thick Melamine sample (good porous absorbent material with known acoustical properties) and 18 mm Plywood (known for good reflection properties as a non-porous material) to benchmark the results. It is seen that the absorption coefficient of the CF is between 12 – 20 % higher in frequency ranges 300 – 5000 Hz.

This parameter will change with the fluctuation of the moisture content of the growth medium, however the moisture content in the range of 0 - 20 % has been reported to be most effective at facilitating adequate sound absorption. At higher concentration of moisture, the growth medium becomes mostly reflective as pores are filled with water that tends to behave like a glass surface.

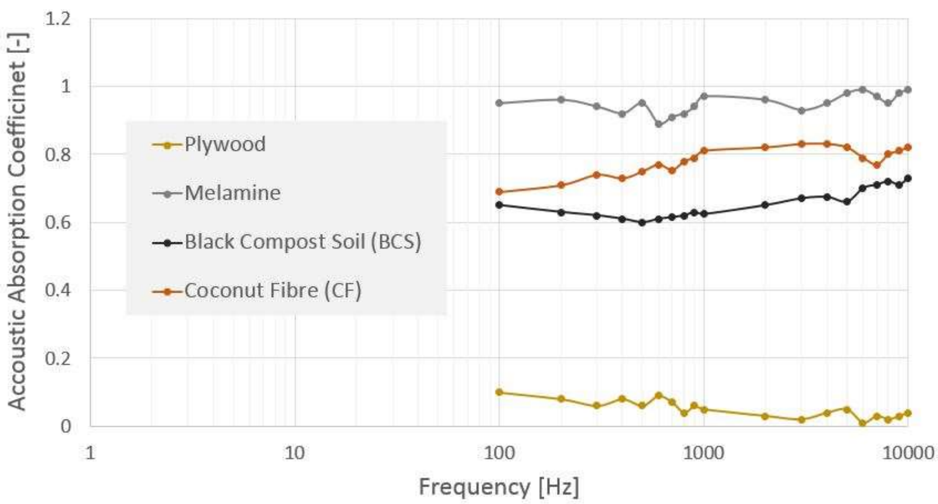

Figure 6 - Acoustics absorption coefficient for 100 - 10000 Hz

3.2 Questionnaire Analysis

Carbon emission was calculated for each component based on the material weight and means of transportation, taking into consideration the fuel type, distance travelled, material weight and vehicle weight. Table 1, columns left to right, shows the LGW components, materials, material weight in kg/m^2, transportation type, distance (km) from the supplier to the LGW company, emission factor (km/m^2) and the carbon emission (CO_2/m^2).

Based on (24), the average volume of a van = 17 m^3 and the fuel type is diesel. The average capacity of ship is 58 containers, the one container is 33 m^3 (25, 26) and the fuel type is diesel. The carbon emission was calculated manually. Taking into consideration that the load utilization percentage for a van is 85 % (27), and for a ship is 70 % (28). The emission factor for the van is 0.2568 ton kg CO_2 (29) and 0.01592 ton kg CO_2 (29) for the ship.

The LGW components, material, weights, and the mean of transportation were deduced from the data collected by the questionnaire. The distance was calculated using Google Maps, based on the supplier and LGW company location as provided by questionnaire answers. The van carbon emission was calculated using equations 1 - 5. The ship carbon emission was calculated using equations 6 - 10.

For van:

$$Total\ weight\ (ton) = empty\ weight\ of\ van + 85\ \%\ capacity\ of\ material \tag{1}$$

$$Total\ weight\ (ton) \times emission\ faction\ (\frac{ton\ kg\ CO_2}{km}) = Total\ emission\ (\frac{kg\ CO_2}{km}) \tag{2}$$

$$Total\ emission\ per\ box\ \left(\frac{kg\ CO_2}{km}\right) = \frac{totalemission}{no.of\ boxes}\frac{kgCO_2}{km \times box} \tag{3}$$

$$Total\ carbon\ emission\ \left(\frac{kg\ CO_2}{km \times m^2}\right) = \frac{total\ emission}{no.of\ boxes}\left(\frac{kgCO_2}{km \times box}\right) \div total\ material\ per\ box\ \frac{m^2}{box} \tag{4}$$

$$Total\ carbon\ emission\ \left(\frac{kg\ CO_2}{m^2}\right) = Total\ carbon\ emission\ \left(\frac{kg\ CO_2}{km \times m^2}\right) \times total\ distance\ (km) \tag{5}$$

For ship:

$$Total\ weight\ (ton) = empty\ weight\ of\ container + 70\ \%\ capacity\ of\ material \tag{6}$$

$$Total\ weight\ (ton) \times emission\ faction\ (\frac{ton\ kg\ CO_2}{km}) = Total\ emission\ (\frac{kg\ CO_2}{km}) \tag{7}$$

$$Total\ emission\ per\ box\ \left(\frac{kg\ CO_2}{km}\right) = \frac{totalemission}{no.of\ boxes}\frac{kgCO_2}{km \times box} \tag{8}$$

$$Total\ carbon\ emission\ \left(\frac{kg\ CO_2}{km \times m^2}\right) = \frac{total\ emission}{no.of\ boxes}\left(\frac{kgCO_2}{km \times box}\right) \div total\ material\ per\ box\ \frac{m^2}{box} \tag{9}$$

$$Total\ carbon\ emission\ \left(\frac{kg\ CO_2}{m^2}\right) = Total\ carbon\ emission\ \left(\frac{kg\ CO_2}{km \times m^2}\right) \times total\ distance\ (km) \tag{10}$$

Table1 - Living Green Wall material carbon emission calculation

Living Green Wall (LGW) Materials						
Components	Material	Weight (kg/m^2)	Transportation Mean	Distance (km)	Emission Factor(km/m^2)	Carbon Emission (kgCO_2/m^2)
Modules	Fabric + Powder Coated Steel Strip	2.4	Ship +Van	1952 by ship 885 by van	0.075 for ship 0.002 for van	147 for ship 1.77 for van
Irrigation System	Pipes + Calber Tap Timer + Drip Line	0.6	Van	174	0.003	0.52
Plants	Selected Plants	8	Van	280	0.009	2.52
Soil	Black Compost Soil	18	Van	8.05	0.031	0.25
Fixtures	Screws, etc.	5.57	Van	8.05	0.007	0.06

The coir can reduce the weight of the LGW, hence the carbon emission. The coir density is around 0.8 g/cm^3 (30), and soil is around1.6 g/cm^3 (31). A bulk weight of 5 kg of coir gives 70 L of fine coconut fiber potting soil (32), this makes its transportation weight low. It will contribute in reducing the modules and plants transportation weight and carbon emission. Because the modules were designed to hold the BCS which is heavier than the coir. The plant transportation weight and emissions will be reduced, by changing the soil to coir in the plant pots. The coir transportation carbon emission = 0.002 km/m^2 and 0.016 kg CO_2/m^2, assuming that coir is sourced from the same DIY store.

Coir pith proves a greater advantage of allowing good aeration around the roots of plants. It has the unique property of retaining water for longer duration of time. This property of the coir pith may facilitate the continuous and prolonged availability of water for the plants grown in pots (33). Coir can minimize the water consumption in the LGW. As a result, it acts as an ideal potting medium. By changing the growing medium weight, the rest of LGW components weight can be changed.

4. DISCUSSION

The results of the questionnaire analysis show that CF can be a sustainable alternative to the BCF. CF has proved to be a promising growing medium (5). The results of the analysis show that CF can be a sustainable alternative to the BCF in LGWs. CF as a growing medium can increase the sound absorption by 20 % compared to BCS, due to high porosity of CF. Desk study calculations proved that CF can reduce the carbon emission of overall SCM process. The calculations considered the material flow from the supplier to the LGW company. On average CF carbon emission of 0.016 kg CO_2/m^2 and BCS carbon emission of 0.25 kg CO_2/m^2 was achieved. The coconut fiber compared to black soil compost can give the LGW company advantages, such as: (a) minimizing the overall LGW material weight and load on the buildings due to low bulk weight (b) CF will reduce the water usage in LGW system, because it has higher water retention than BCS (c) CF can act as a natural pesticide controller (d) CF origins are sustainable as are considered to be a waste/byproduct in the countries of growth (e) and lastly can contribute in reducing noise by 20 % in 300 - 5000 Hz frequency range.

The concept of environmentally friendly, sustainable, recycled, and green building materials is currently an important feature in the marketing of sound-absorbing materials. These new directions will hopefully encourage the use of cheap renewable natural materials.

CF has proved to be a promising growing medium with higher and improved crop quality (34, 35). It offers a high moisture to air retention capacity, which enables easy growth and well spread root system. Some plants may need adding nutrients to the CF, it depends on the nutrients that is required for each plant type.

Finally, CF average retail cost is £ 150 per ton (36) and the soil average retail cost is £82.99 per ton (37), where 1 ton of dried compacted CF can expand to 10 tons of growth medium by exposing to air and adding minimal water. This is due to the CF structure phenomenon, it comprises of thin hollow shells or tubes, that allow the CF to absorb ten times of its own weight in water.

5. CONCLUSIONS

Living Green Walls is considered as a natural solution to control the sound pollution in urban areas. The LGW sound absorption capability can be maximized by 20 % using CF that showed higher sound absorption over the current used growing medium (BCS). CF yields higher and improved crop quality and offers a high moisture and air retention capacity, which enables easy growth and well spread root system.

Coconut fiber can reduce the carbon emission and lower the LGW cost, which in turn improves the sustainability of LGW. CF will also reduce the amount of energy (water and possibility the electricity) used to maintain LGWs. It should be noted that the study only considered the material flow from the supplier to LGW companies. Further detailed study can be performed to include the energy consumption at all stages: from production to installation.

ACKNOWLEDGEMENTS

The authors would like to thank the University of Greenwich for the fund towards this conference. The authors would like to thank Scotscape Ltd. for it is collaboration especially Niall Mc Evoy the business development manager for his invaluable help in getting the required information.

REFERENCES

1. World Population Review. 2019 World Population by Country [Internet]. 2019 [cited 2019 May 10]. Available from: http://worldpopulationreview.com/
2. United Nations population estimates and projections. World Population Prospects - Population Division - United Nations [Internet]. 2017 [cited 2019 May 10]. Available from: https://population.un.org/wpp/DataQuery/
3. United Nations Department of Economic and Social Affairs. News [Internet]. 2018 [cited 2019 May 10]. Available from: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html
4. L. den Boer, A. Schroten. Traffic noise reduction in Europe [Internet]. 2007 [cited 2019 May 10]. Available from: www.transportenvironment.org/sites/te/files/media/2008-02_traffic_noise_ce_delft_report.pdf
5. Salah GMJA, Romanova A. COCONUT FIBRE AS AN ALTERNATIVE GROWTH COMPOUND FOR LIVING GREEN WALLS. In: The Second Medway Engineering Conference on Systems Efficiency, Sustainability and Modelling [Internet]. 2017 [cited 2019 May 10]. Available from: https://gala.gre.ac.uk/id/eprint/17422/8/17422 ROMANOVA_Living_Green_Walls_2017.pdf
6. Azkorra Z, Pérez G, Coma J, Cabeza LF, Bures S, Álvaro JE, et al. Evaluation of green walls as a passive acoustic insulation system for buildings. Appl Acoust [Internet]. 2015 Mar 1 [cited 2017 Mar 11];89:46–56. Available from: https://www.sciencedirect.com/science/article/pii/S0003682X14002333
7. Wong NH, Kwang Tan AY, Tan PY, Chiang K, Wong NC. Acoustics evaluation of vertical greenery systems for building walls. Build Environ [Internet]. 2010 Feb 1 [cited 2017 Mar 11];45(2):411–20. Available from: https://www.sciencedirect.com/science/article/pii/S0360132309001632
8. Pérez G, Coma J, Barreneche C, de Gracia A, Urrestarazu M, Burés S, et al. Acoustic insulation capacity of Vertical Greenery Systems for buildings. Appl Acoust [Internet]. 2016 Sep 1 [cited 2017 Mar 11];110:218–26. Available from: https://www.sciencedirect.com/science/article/pii/S0003682X16300731
9. Van Renterghem T, Botteldooren D. Numerical evaluation of sound propagating over green roofs. J Sound Vib [Internet]. 2008 Nov 11 [cited 2017 Mar 11];317(3–5):781–99. Available from: https://www.sciencedirect.com/science/article/pii/S0022460X08002654
10. Yang HS, Kang J, Choi MS. Acoustic effects of green roof systems on a low-profiled structure at street level. Build Environ [Internet]. 2012 Apr [cited 2017 Mar 11];50:44–55. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0360132311003532
11. Pittaluga I, Schenone C, Borelli D. Sound absorption of different green roof systems. In: Proceedings of Meetings on Acoustics [Internet]. Acoustical Society of America; 2012 [cited 2017 Mar 11]. p. 015005. Available from: http://asa.scitation.org/doi/abs/10.1121/1.3685875
12. Horoshenkov K V., Khan A, Benkreira H. Acoustic properties of low growing plants. J Acoust Soc Am [Internet]. 2013 May 6 [cited 2017 Mar 11];133(5):2554–65. Available from: http://asa.scitation.org/doi/10.1121/1.4798671
13. Crocker MJ, Arenas JP. Use of Sound-Absorbing Materials. In: Malcolm J. Crocker, editor. Handbook of Noise and Vibration Control [Internet]. Hoboken, NJ, USA: John Wiley & Sons, Inc.; [cited 2017 Mar 12]. p. 696–713. Available from: http://doi.wiley.com/10.1002/9780470209707.ch57
14. Jorge P. Arenas, Jorge P. Arenas. Recent trends in porous sound-absorbing materials. Sound Vib [Internet]. 2010 [cited 2017 Mar 12];44:12–8. Available from: www.SandV.com
15. Chandramohan D, Marimuthu & K. A REVIEW ON NATURAL FIBERS. IJRRAS [Internet]. 2011 [cited 2017 Mar 12];8(2):194–206. Available from: www.arpapress.com/Volumes/Vol8Issue2/IJRRAS_8_2_09.pdf
16. Berardi U, Iannace G. Acoustic characterization of natural fibers for sound absorption applications. Build Environ [Internet]. 2015 Dec 1 [cited 2017 Mar 12];94:840–52. Available from: https://www.sciencedirect.com/science/article/pii/S036013231530007X
17. Bakiya MP, Kamaraj C, Lakshmi S. Study on the Effect of Coir Fibre in the Bituminous Concrete Mix. IJSTE-International J Sci Technol Eng | [Internet]. 2016;2(12):90–4. Available from: www.ijste.org
18. Zafar S. Uses of Coconut Wastes [Internet]. 2015 [cited 2017 Feb 13]. Available from: https://www.bioenergyconsult.com/tag/uses-of-coconut-wastes/
19. Arenas M, Vavrina CS, Cornell JA, Hanlon EA, Hochmuth GJ. Coir as an Alternative to Peat in Media for Tomato Transplant Production. HORTSCIENCE [Internet]. 2002;37(2):309–12. Available from: https://swfrec.ifas.ufl.edu/docs/pdf/veg-hort/transplant/trans_media1.pdf
20. Apse W. All About Palm Trees: A Photographic and Botanical Appreciation [Internet]. 2017 [cited 2017 Feb 22]. Available from: https://owlcation.com/stem/about-palm-trees

21. Greer S, Chairperson M, Bradley WL. Converting Coconut Husks into Binderless Particle Board [Internet]. Baylor University; 2008 [cited 2017 Apr 12]. Available from: https://cdn.instructables.com/ORIG/FIZ/94CL/IBKMKPF2/FIZ94CLIBKMKPF2.pdf
22. William E. KuseyDouglas George DellmoreWilliam E. KuseyDouglas George Dellmore. Compressed mixtures of coconut coir pith and peat moss and processes for the preparation thereof [Internet]. United States; US6189260B1, 2001 [cited 2017 May 17]. Available from: https://patents.google.com/patent/US6189260B1/en
23. Romanova A, Horoshenkov K V., Hurrell A. An application of a parametric transducer to measure acoustic absorption of a living green wall. Appl Acoust [Internet]. 2019 Feb 1 [cited 2019 May 28];145:89–97. Available from: https://www.sciencedirect.com/science/article/pii/S0003682X18305504
24. Department for Transport. A Simplified Guide to Lorry Types and Weights [Internet]. United Kingdom; 2003 [cited 2019 May 21]. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/211948/simplified-guide-to-lorry-types-and-weights.pdf
25. Jim Gordon. Approximately how many tons can the average large cargo ship carry? - Quora [Internet]. 2013 [cited 2019 May 23]. Available from: https://www.quora.com/Approximately-how-many-tons-can-the-average-large-cargo-ship-carry
26. Shippo. Shipping Containers Sizes [Internet]. 2018 [cited 2019 May 23]. Available from: https://www.shippo.co.uk/faqs/what-container-s-right-for-me/
27. KPI Library. % of truckload capacity utilized [Internet]. 2007 [cited 2019 May 23]. Available from: http://kpilibrary.com/kpis/of-truckload-capacity-utilized
28. Network for Transport Measures. 7.4 Load capacity utilisation [Internet]. 2017 [cited 2019 May 23]. Available from: https://www.transportmeasures.org/en/wiki/manuals/sea/load-capacity-utilisation/
29. GOV.UK. Greenhouse gas reporting: conversion factors 2018 [Internet]. 2018 [cited 2019 May 23]. Available from: https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2018
30. Ali M. Coconut Fibre-A Versatile Material and its Applications in Engineering. ournal Civ Eng Constr Technol [Internet]. 2011 [cited 2017 May 21];2(9):189–97. Available from: http://www.claisse.info/Proceedings.htm
31. StructX. Densities of Different Soil Types [Internet]. 2016 [cited 2017 May 21]. Available from: https://structx.com/Soil_Properties_002.html
32. Humusziegel. coconut potting soil - unfertilised - pressed coir fibre - 70L: Amazon.co.uk: Garden & Outdoors [Internet]. 2019 [cited 2019 May 24]. Available from: https://www.amazon.co.uk/70L-Coconut-flowering-ground-source/dp/B00HGU24II/ref=asc_df_B00HGU24II/?tag=googshopuk-21&linkCode=df0&hvadid=309904185356&hvpos=1o3&hvnetw=g&hvrand=9629846766849812872&hvpone=&hvptwo=&hvqmt=&hvdev=c&hvdvcmdl=&hvlocint=&hvlocphy=
33. Paramanandham J., Ronald Ross P., Abbiramy K.S., M. Muthulingam. International journal of chemtech research. Int J ChemTech Res [Internet]. 2014 [cited 2017 May 21];6(12):5049–52. Available from: https://www.researchgate.net/publication/288212188_Studies_on_the_moisture_retention_capacity_of_coir_pith_as_a_function_of_time
34. Khandaker M, Kotzen B. The potential for combining living wall and vertical farming systems with aquaponics with special emphasis on substrates. Aquac Res [Internet]. 2018 Apr 1 [cited 2019 May 28];49(4):1454–68. Available from: http://doi.wiley.com/10.1111/are.13601
35. Tomislav Vinković, Dario Iljkic, Nada Parađiković. Tomato Cultivation on Coconut Husks Substrate. Acta Agric Serbica [Internet]. 2007 [cited 2019 May 28];12(23):55–60. Available from: https://www.researchgate.net/publication/265634878_Tomato_Cultivation_on_Coconut_Husks_Substrate
36. Alibaba. Soil Solution Coconut Coir Pith - Buy Grade A Coco Peat,Coco Peat Blocks Retail Packing,Coconut Coir Peat / Cocopeat For Exporters Product on Alibaba.com [Internet]. 2019 [cited 2019 May 28]. Available from: https://www.alibaba.com/product-detail/Soil-Solution-Coconut-coir-pith_50039928270.html?spm=a2700.7724838.2017115.199.702e2652ZTX6Ve
37. Quality Garden Supplies Ltd. Buy Multi-Purpose Topsoil - Garden Topsoil Bulk Bag [Internet]. 2019 [cited 2019 May 28]. Available from: https://www.qualitygardensupplies.co.uk/component/ecwid/Topsoil-Multi-purpose-1-Tonne-Bulk-Bag-p675177?gclid=Cj0KCQjwuLPnBRDjARIsACDzGL3zx8pHylzHOVFjqLZnopA5wuNYuBcHQVad8fL5knGIqX4msBQ6tckaAlqvEALw_wcB