CHAPTER 1
INTRODUCTION

1.1 GENERAL INTRODUCTION

The development of lightweight building system has intensified in dwellings. The term lightweight building system has no restriction in material choices. Usage of agricultural waste in lightweight building system has been developed in many countries. Acoustics is most important from the standpoint of hearing and of how sound and vibrations are perceived and experienced. The major aim of sound insulation in building acoustics is in providing the comfort level to the dwellers and setting building codes. The requirements for sound insulation that has been existed were formulated with homogeneous simple construction in mind. It has been found that these requirements do not function in the way they should have been with regard to the lightweight construction.

Sound transmission either airborne or structure borne is a potential problem that occurs in buildings from sources within or from outside. With the expansion of real estate activities in the countries like India, the need to attend sound insulation requirements also assumes greater dimensions. Apart from conventional materials, builders often use hollow blocks and prefabricated ferro cement panels in the construction.
Annoyance of structure borne and airborne sound are the major problems that are faced by structures in buildings. Properly designed and constructed structures are expected to provide a comfortable acoustical environment. There seems to be not much case studies conducted for Indian criteria regarding sound transmission in buildings. Since the development of building materials used in construction emerged with considering the reuse of waste materials and lightweight panels, the properties of these materials are needed to be studied. Not only the strength, yet there is a need for consideration of thermal and acoustical properties of materials that are being used. All significant paths of sound transmission must be considered within the building as well as noise intrusion from outside the building. Since in tropical countries like India, abundant agricultural and agro-industrial wastes are discharged, these wastes can be used as potential material or replacement material in the construction industry. This will have double advantage of reduction in the cost of construction material and also as a means of disposal of waste. It is at this time the above approach is logical, worthy and attributable.

India is the largest coconut producer in the world (Mannan et.al. [1], 2007). Therefore, the mode of using hollow blocks and panels made of coconut shell and oil palm shell as building element with different acoustical parameters such as sound reduction index, coupling loss factors and junction parameters etc., are to be analyzed and studied. The problem of sound transmission is however closely associated with several aspects of building construction, which includes its layout, types of materials used in construction and other building service requirements. The construction industries are provoked with the use of conventional materials and lightweight building materials like hollow blocks and panels made of coconut shell, palm oil shell and rice husk which provide easier and cost effective construction with strength and thermal insulation behaviour too.
The materials used in a lightweight construction differ in their characteristics from those used in traditional constructions. Traditional construction often consists of concrete, steel (as reinforcement) and brick. In contrast, lightweight construction contains mineral wool, plasterboard, straw boards and ferrocement panels. The air between different components can also be viewed as a material that has interesting characteristics of its own due to its viscosity. Since evoke of new lightweight materials made of agricultural waste, the study of acoustical characteristics of these materials are needed.

Two different approaches to describe and compute the acoustics of buildings can be distinguished. The one involves determining the average flow of acoustical energy between separate components often in combination with the use of empirically based knowledge or data. The other approach involves a detailed analysis of the problems from a deterministic point of view, using analytical and numerical methods utilising physical field variables of materials such as sound pressure and vibration velocity. Traditionally prediction models for sound insulation in buildings have been based on the concept of energy balance such as Statistical Energy Analysis. Work based on this concept enhancing the generality and accuracy of sound transmission has been done by Crocker and Price [2] (1969), and Craik [3] (1983).

The influence of laboratories on the result of measured Sound Reduction Index (SRI) is a topic of several research studies earlier. For test elements especially with similar properties, the damping plays a considerable role in transmission property. Cremer has considered this aspect by taking loss factor into account. Subsequently it is also shown that not only the material loss factor should be taken into consideration but the entire damping of the structure should be considered, which is known as the total loss factor.
The prediction models are used to estimate the acoustic performance in terms of sound insulation for the design of buildings. Computer versions of some of these models are very useful to facilitate such computations. Significant input parameters for such models are sound reduction index of the elements and sound transmission with respect to junction elements. Though standardised measurement methods exist for the sound reduction of elements, it is also very useful to have the methodology to calculate or to compute these quantities.

For example, in the case of hollow blocks, the inner hollow space makes the blocks lighter and easier to handle them on site reducing the foundation load. Because of hollow space the gross density of the blocks is reduced resulting in reduced sound insulation. The performance varies with the inner web structure of the blocks affecting the sound reduction index. The bending stiffness values of these blocks influence the critical frequency $f_c$ dip or the coincidence frequency region. The effect of plastering on these walls is considerable. There is also certain amount of uncertainty associated with in-situ and laboratory measurements of insulation of building elements. The deviation can be of the order of 2dB.

There is a lack of published data on the effect of coconut fibers in block walls with sound transmission class (STC) ratings. Much of the literature is for cement blocks, which have, paint finishes and which do not have very high STC ratings. The literature shows no authentic information about sound transmission especially at low frequencies. Measurements reported in the literature typically show up to 100Hz or 125 Hz in case of ISO-140-1 [4] (1995). Low frequency sound is equally annoying and hence structures with high sound transmission loss at low frequencies are also required. Quite often low frequency noise is the cause of complaints in and around a given building.
Cavity walls or double walls are generally employed both as internal partitions as well as high performance walls separating internal to external environment. When properly designed these partitions give reasonably good sound insulation. Sometimes ties are introduced between the cavity walls to have structural stability and subsequently the sound reduction index gets affected.

When Statistical Energy Analysis (SEA) has been introduced as it required two separate aspects such as room acoustics and coupled modes of the structure or room. Statistical Energy Analysis is a point of view in dealing with vibration of complex resonant structures. It enables the calculation of energy flow between connected resonant structures such as plates; beam and so on, and between plates and reverberant sound field in an enclosure. Study of room acoustics through a statistical methodology considering the average properties of the enclosure could be studied without going into calculation of each and every mode of the room. Lots of studies on power flow between coupled oscillators have been studied. The flow is from the system with the higher modal energy to that of the lower modal energy. This is similar to the thermodynamical analogy of heat transfer between two connected bodies of different temperatures, when the heat flow is from the body of higher temperature to that of lower temperature.

Composite structures generally consist of a number of elements such as plates, beams and stiffeners. The modal density of a complex structure is approximately that of the sum of the modal densities of its elements. If the power input, the various coupling loss factors and the power dissipated in each element are known, the power balance equations will yield the vibrational energy in the various elements of the structure.
The flanking transmission problems are needed to be considered in order to build successfully usable lightweight building techniques. Flanking component of the propagated energy plays a predominant role in minimising the sound reduction index (SRI). The difference between a direct and flanking path is quite often arbitrary especially where direct paths involve several structural members with structural connections. Flanking paths can assume many forms involving both air and structure borne sound transmission. Airborne flanking transmission is difficult to generalise and the transmission can be through holes and cracks, through doors or through cracks around windows or along circulation spaces such as corridors.

1.2 MOTIVATION OF THE WORK

Noise problems in buildings have considerably increased with increased demands of various types of buildings catering to different functional requirements. Many new materials either prefabricated or lightweight or specially designed materials are used in Indian construction industry. Many environmental factors of noise control have to be complied with, to have acoustical comfort in different types of environments. Hence this study has been envisaged to investigate the acoustical behavior of materials which could be employed for creating safer noise environments in buildings.

In view of escalating sound transmission problems faced today and also considering the rapid depletion of conventional materials on structural elements, the use of aggregates of solid waste materials from different sources are highly desirable, alternate materials that can be used are coconut shells (CS) and oil palm shell, which are basically agricultural solid waste. Use of coconut shell in concrete element directly without studying its rheological properties and behavior with concrete is not advisable. Therefore, mode of using coconut shells in building
elements behavior of coconut shell blocks in different elements with different acoustical parameters such as sound reduction index, coupling loss factors and junction parameters etc., in short and long term have to be analyzed and studied.

1.3 OBJECTIVES AND SCOPE OF THE WORK

The principle objective of the work is to study the transmission behavior of newer types of materials used in construction industry with respect to acoustic insulation properties. The objective is also to evaluate the acoustical performance as one of the principle functional requirements to be satisfied in buildings.

The scope of the work could be described as follows:

(i) To design and construct a transmission loss suite and to study the transmission properties of building elements.

(ii) To conduct a detailed investigation through experimental procedure, the behavior of sound insulation and sound transmission behavior of panels and hollow blocks made of using agricultural waste materials like coconut shell with respect to acoustic insulation and transmission properties.

(iii) To model the systems through Statistical Energy Analysis modeling and

(iv) To carry out a real time investigation model using Odeon and compare with experimental results
1.4 ORGANISATION OF THE THESIS

The thesis is presented in six chapters. The Introduction forms the first chapter. The remaining five chapters of the thesis are organised as detailed below.

A detailed literature review is covered in Chapter 2. The topics include the details of Statistical Energy Analysis (SEA) procedures involving the transmission and power flow in panels and also energy flow in coupled oscillators. The general performance of the panels and sound radiation efficiency of the plates and beams is also reviewed. Performance of sound transmission in case of tie beams and panels are also critically reviewed. A brief review of sound transmission in buildings using SEA has been reviewed. A review is done in the developments of lightweight materials and structures for sound transmission performance.

Chapter 3 gives the procedure for the design and construction of transmission loss suite and experimental procedures to evaluate physical parameters such as longitudinal wave velocity, loss factor, and sound reduction index. Maximum achievable sound reduction index ($R_{w\text{max}}$) of the TL suite has been described.

Chapter 4 describes the results of the sound transmission experiments conducted in the transmission loss suite for various materials. Sound reduction indices for hollow blocks, ferrocement and other structural elements have been discussed and associated variations of loss factors of these elements are also reported.
The Visual Basic program for evaluation of sound reduction index using Statistical Energy Analysis has been described. The results have been compared later with experimental investigations.

Chapter 5 presents real time investigations by simulation model using ODEON for sound transmission behavior in transmission loss suite. The transmission behavior has been analyzed in the low frequency regions for some typical configurations are also included in this study. Evaluation of direct and flanking transmission have been computed. The differences between predicted and measured values of SRI have been projected.

Chapter 6 presents the summary and conclusions based on the work mentioned earlier. The scope for further work as an outcome of the present investigation is also presented in this chapter.