CHAPTER 3

DEVELOPMENT OF ADHESIVE BONDED ACOUSTIC NONWOVENS OF COTTON, VISCOSE AND POLYESTER FROM THE CLOTH WASTE COLLECTED FROM GARMENT INDUSTRIES

3.1 INTRODUCTION

Nonwoven is a kind of fabric with orientation or random arrangement of fibers bonded by means of mechanical or chemical bonding. The structure of nonwoven is three-dimensional netted and multi porous, which is very suitable for the application as sound absorption materials with its porosity, plasticity and elasticity. Besides, nonwoven has the advantages of using recycled fibers as basic raw material, many varieties, simple manufacturing technology, high productivity, multiple technologies and various fields of applications.

The garment industry having six cutting tables produces 50 Kg of wastes per day. The thousands and thousands of garment and apparel industries will produce huge amount of cutting waste. These wastes are burned in sizing and processing industries, cleaning materials in workshops and burned in open area polluting the environment. In this chapter, the development of nonwovens by using the recycled fiber of cotton, viscose and polyester which are reclaimed from the waste of garment units and the analysis of their acoustic absorption is discussed in detail.
3.2 MATERIALS

The material for the nonwoven is ‘Trimmed waste’ of garment industries. Garment industries are producing the garments in a high volume, which in turn gives high volume of trimmed waste. Figure 3.1 shows the photographic view of trimmed wastes. These trimmed wastes are used as raw material to develop adhesive bonded nonwoven. This waste can be classified as cotton, viscose and polyester.

![Figure 3.1 Waste collected from garment industries](image)

3.3 METHODS

3.3.1 Method of producing the nonwoven

The wastes from garment units are processed through the sequence of methods as shown in the Figure 3.2. The wastes are cleaned well as they will contain many unwanted materials like papers, sewing thread, lining pieces, broken metal parts, buttons and other contaminants. These contaminations are removed manually. The cleaned material can be cut into small bits with cutting machine of the garment units. The small pieces of the waste are shown in Figure 3.3.
Figure 3.2 Flow chart for the method of development of the nonwoven

Figure 3.3 Material from the cutting machine
3.3.2 Working of the Fabric opener

By the fabric opener, the trimmed wastes are opened into tuft of threads. The chopped pieces of wastes, as in the Figure 3.3, are fed to the feed conveyor. The pair of feed rollers will hold the pieces to opener where they will be opened to yarn bits. When processed twice in this opener the yarn tuft will be opened further to get fibrous stage. The opening and stripping action in this machine contribute to the development of fibrous material as shown in the Figure 3.4. The machine can produce 100 kg of opened fibers per hour.

Figure 3.4 Line diagram of the Fabric opener

Figure 3.5 Photograph of the Fabric opener
3.3.3 Working of the Web former

The fed web in this machine is opened further to achieve very thin layer of fiber as in the Figure 3.6, which are deposited over the circumference of the condensing cages (by the aerodynamic principle of web formation) and thus the thin fibrous layer is delivered. The material from the web former is shown in the Figure 3.7. This web former produces 138 meters of fibrous layer per hour.

Figure 3.6 Line diagram of the Web former

Figure 3.7 The material from the web former
3.3.4 Method of Chemical bonding

The fibrous layer from the web former is sprayed with polyvinyl acetate at a constant pressure and flow as shown in the Figure 3.8. The adhesive add on percentage is taken care of 20%. Precaution is taken to avoid excessive or lesser flow of adhesive through the sprayer. By the calendar roller pressure, the fibrous layer is converted into a nonwoven fabric.

![Figure 3.8 Line diagram of the Chemical bonding device](image)

A. Recycled fiber web  B. Calendar roller  C. Spray gun  D. Compressor  E. Spray gun  F. Adhesive bonded web

**Figure 3.8 Line diagram of the Chemical bonding device**

3.3.5 Method of Drying

The bonded sheets are dried through the drying chamber at 120\(^0\)C; 160\(^0\)C. The preheated fabrics are calendared as shown in the Figure 3.9 and heated again to bind the fabric according to the required thickness.

![Figure 3.9 Line diagram of the Drying chamber](image)

A. Conveyor  B. Calendar roller  C. Pre heater  D. Main heater  E. Adhesive sprayed web  F. Nonwovens

**Figure 3.9 Line diagram of the Drying chamber**
The nonwovens of recycled cotton (C), polyester (P) and viscose (V) fiber reclaimed from cutting waste of garment units were produced according to required samples of single layer (C1, P1 and V1), double layer (C2, P2 and V2), and triple layer (C3, P3 and V3). The Figure 3.10 shows the photograph of acoustic cotton nonwoven fabric. Figure 3.11 shows the photograph of recycled viscose acoustic nonwoven and the Figure 3.12 shows the photograph of recycled polyester acoustic nonwoven.

Figure 3.10 Photograph of the acoustic cotton nonwoven

Figure 3.11 Photograph of the acoustic viscose nonwoven
3.4 TESTING METHODS

The nonwoven samples of recycled cotton, polyester and viscose fiber reclaimed from cutting waste of garment units produced according to required samples of single layer, double layer and triple layer were tested for sound absorption and physical properties like thickness, areal density and air permeability.

3.4.1 Sound absorption Coefficient by Impedance Tube method

The sound absorption coefficients of the nonwovens were tested by the impedance tube method based on ASTM E 1050 at Marmara University, Turkey. A sound source (loud speaker) is mounted at one end of the impedance tube and at the other end the nonwoven is placed. The loud speaker generates broadband, stationary random sound. This sound propagates as planner waves in the tube, hits the sample and gets absorbed. Thus a standing wave interference pattern results due to superimposition of forward and backward travelling waves inside the tube. The sound pressure at two fixed location is measured and by using the two-channel digital frequency analyzer. From the results it will be possible to determine the
complex reflection coefficient, the sound absorption coefficient and the normal acoustic impedance of the nonwoven.

The usable frequency range depends on the diameter of the tube and spacing between the microphone positions. The small tube setup with 29 mm diameter measures the parameters of sound in the frequency range from 500Hz to 6.4 KHz. Whereas, the larger tube setup with 100 mm diameter measures the parameters of sound in the frequency range from 50Hz to 1.6 KHz.

![Impedance Tube method](image)

Source – Brüel & Kjær

**Figure 3.13 Impedance Tube method (ASTM E 1050)**

### 3.4.2 Sound resistance Testing Method

A sound of particular decibel is created by the sound source and the receipt decibels have been measured by the decibel meter with and without sample. The sound insulation by the fabric samples can be calculated by the following derivation (equation -13) derived by Surajit Senguptha et al (2010).
3.4.2.1 Design and development of sound insulation measuring instrument

A simple testing apparatus as in Figure 3.14 has been fabricated to measure the sound insulation property of the textile materials. It consists of a box 100cm X 100cm made out of wood with removable top lid. In the left hand side of the box a sound source (S) which will produce definite decibel of sound is fixed and in the right hand side the decibel meter (R) is fixed coaxially opposite to sound generator to measure the sound intensity.

Figure 3.14 Testing apparatus for measuring sound resistance

The sound resistance or insulation by the fabric samples can be calculated by the following derivation derived by Teli et al (2007) and Surajit Senguptha et al (2010)

\[
SR \% = \frac{d_{B_{wos}} - d_{B_{ws}}}{d_{B_{wos}}} \times 100
\]  

(13)
Where;

SR - sound reduction

dB wos - sound level without sample and
dB ws - the sound level with sample

The samples were placed in three different positions: 25 cm, 50 cm and 75 cm from the sound source and measured for sound resistance with three decibel values of 60 dB, 70 dB and 80 dB. The average sound resistance percentage of these three decibel values were calculated and compared for all the samples.

3.4.3 Methods of testing physical properties

The standard test procedure followed for determining the physical properties of the nonwoven samples are ASTM D 5736 for thickness of the fabric, ASTM D 6242 for areal density in grams per square meter ASTM D 737 for its air permeability. To ascertain the ratio of fiber to fabric volume, packing factor was calculated from the following equation

Fabric packing factor = Fabric density/ Fiber specific gravity.

Fiber specific gravity values of 1.54, 1.39 and 1.52 were taken for cotton, polyester and viscose respectively. The specific gravity of the PVAc is 1.44.

In order to study the influence of fiber type, number of layers, areal density, bulk density, porosity and air permeability on sound absorption, the samples of recycled fiber nonwovens with single layer, double layer and triple layer were produced and measured with the above parameters.
3.5 RESULTS AND DISCUSSIONS

The physical properties of the adhesive bonded nonwoven of recycled cotton, viscose and polyester fibers are measured and average values of ten samples are given in Table 3.1. The samples of cotton single layer, double layer and triple layer are tabulated as C1, C2 and C3. Similarly the viscose and polyester samples are tabulated as V1, V2, V3 and P1, P2, P3.

Table 3.1 Physical properties of the nonwovens

<table>
<thead>
<tr>
<th>S.No</th>
<th>Sample</th>
<th>Fabric thickness (mm)</th>
<th>Areal density (g/m²)</th>
<th>Bulk density (g/cm³)</th>
<th>Fabric packing factor</th>
<th>Porosity</th>
<th>Air permeability (cc/s/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C1</td>
<td>2.1</td>
<td>330.50</td>
<td>0.157</td>
<td>0.103</td>
<td>0.897</td>
<td>98.01</td>
</tr>
<tr>
<td>2</td>
<td>C2</td>
<td>3.91</td>
<td>653.00</td>
<td>0.167</td>
<td>0.109</td>
<td>0.891</td>
<td>69.28</td>
</tr>
<tr>
<td>3</td>
<td>C3</td>
<td>5.51</td>
<td>980.77</td>
<td>0.178</td>
<td>0.116</td>
<td>0.884</td>
<td>37.18</td>
</tr>
<tr>
<td>4</td>
<td>V1</td>
<td>2.08</td>
<td>323.11</td>
<td>0.155</td>
<td>0.102</td>
<td>0.898</td>
<td>106.81</td>
</tr>
<tr>
<td>5</td>
<td>V2</td>
<td>4.01</td>
<td>648.01</td>
<td>0.162</td>
<td>0.107</td>
<td>0.893</td>
<td>81.03</td>
</tr>
<tr>
<td>6</td>
<td>V3</td>
<td>5.68</td>
<td>960.21</td>
<td>0.169</td>
<td>0.112</td>
<td>0.888</td>
<td>39.72</td>
</tr>
<tr>
<td>7</td>
<td>P1</td>
<td>2.31</td>
<td>321.19</td>
<td>0.139</td>
<td>0.101</td>
<td>0.899</td>
<td>91.08</td>
</tr>
<tr>
<td>8</td>
<td>P2</td>
<td>4.44</td>
<td>639.00</td>
<td>0.144</td>
<td>0.105</td>
<td>0.895</td>
<td>56.14</td>
</tr>
<tr>
<td>9</td>
<td>P3</td>
<td>6.4</td>
<td>948.03</td>
<td>0.149</td>
<td>0.108</td>
<td>0.892</td>
<td>34.51</td>
</tr>
</tbody>
</table>

From the Table 3.1, it is observed that the single layered cotton, viscose, polyester recycled fiber nonwovens shows similar results in fabric packing factor and porosity. When the layers are increased the fabric packing factor also increased. This may due to the increase in thickness and areal density of the fabrics. The area covered by the increased fiber content increases the packing factor and decreases the porosity.
While comparing the Air permeability of the samples, the samples C2,C3,V2,V3,P2 and P3 show 30%, 60% , 23%, 61% , 38% and 62% lower values than that of their corresponding single layer samples. These comparisons reveal that the increase in fiber content of the nonwovens decreases the air permeability.

The air permeability results of samples V1 and P1 show 10% and 7% higher than that of C1. This may be due the individual fiber properties and their bonding behavior.

3.5.1 Sound absorption performance of C1, C2 and C3

Different recycled fibers of natural and synthetic fibers have different properties especially in consideration to the surface and inner bonding properties. These properties influence the density of the nonwovens, which in turn affect the sound absorption by the fabric.

![Figure 3.15 Sound absorption coefficient of single layer (C1), double layer (C2) and triple layer (C3) nonwovens of recycled Cotton](image)

Figure 3.15 Sound absorption coefficient of single layer (C1), double layer (C2) and triple layer (C3) nonwovens of recycled Cotton
Figure 3.15 shows the sound absorption coefficients of recycled fiber adhesive bonded nonwoven made out of cotton. The evaluation has been done with the single layer, double layer, and triple layer.

From Figure 3.15 it can be observed that while the frequency increases the sound absorption coefficient (SAC) of all the samples C1, C2 and C3 also increases. Similarly, while thickness increases the sound absorbing performance also increases.

At the highest frequency of 6400 Hz, the SAC values of C1, C2 and C3 are 0.51, 0.61 and 0.84. The calculated average SAC values of C1, C2 and C3 which are 0.25, 0.33 and 0.48 also reveal the same. The performance of samples C1 and C2 shows equal values from 0 to 2000 Hz; this may be due to the lower frequency, the small increase in thickness or fiber content of this nonwoven does not influence the sound absorption.

The linear equation of C1 is $Y = 9E - 05X - 0.0425$ with $R^2$ value of 0.9794, C2 is $Y=0.0001X - 0.0519$ with $R^2$ value of 0.9562 and C3 is $Y=0.0001X + 0.0322$ with $R^2$ value of 0.9581. The sound absorbing performance of C1, C2 and C3 shows good correlation.

### 3.5.2 Sound absorption performance of V1, V2 and V3

Figure 3.16 shows the sound absorption coefficients of recycled fiber adhesive bonded nonwoven made out of viscose. The evaluation has been done with the single layer, double layer, and triple layer.

At the highest frequency of 6400 Hz, the SAC value of V1, V2 and V3 are 0.48, 0.58 and 0.86. The calculated average SAC values of V1, V2 and V3 are 0.21, 0.31 and 0.47. The performance of samples V1 and V2 shows equal values from 0 to 2500 Hz; this may be due to lower frequency. The
small increase in thickness or fiber content of this nonwoven does not influence the sound absorption.

Figure 3.16 Sound absorption coefficient of single layer (V1), double layer (V2) and triple layer (V3) nonwovens of Viscose

The linear equation of V1 is \( Y = 8 \times 10^{-5}X - 0.0297 \) with \( R^2 \) value of 0.9846, V2 is \( Y = 0.0001X - 0.0562 \) with \( R^2 \) value of 0.9598 and V3 is \( Y = 0.0001X + 0.0208 \) with \( R^2 \) value of 0.9638. The sound absorbing performance of V1, V2 and V3 shows good correlation.

### 3.5.3 Sound absorption performance of P1, P2 and P3

Figure 3.17 shows the sound absorption coefficients of recycled fiber adhesive bonded nonwoven made out of polyester. The evaluation has been done with the single layer, double layer, and triple layer.
Figure 3.17 Sound absorption coefficient of single layer (P1), double layer (P2), and triple layer (P3) nonwovens of Polyester

From Figure 3.17 it can be observed that similar to cotton and viscose nonwovens, while the frequency increases the sound absorption coefficient (SAC) of all the polyester samples also increases. Similarly while thickness increases the sound absorbing performance also increases. At the highest frequency of 6400 Hz the SAC value of P1, P2 and P3 are 0.61, 0.85 and 0.93. The calculated average SAC values of P1, P2 and P3 which are 0.30, 0.41 and 0.51 also reveal the same. The performance of samples P1 and P2 shows more or less equal values up to 1250 Hz.

The linear equations of P1 is \( Y = 0.0001X - 0.0578 \) with \( R^2 \) value of 0.9718, P2 is \( Y = 0.0002X - 0.0659 \) with \( R^2 \) value of 0.9777 and P3 is \( Y = 0.0001X + 0.0026 \) with \( R^2 \) value of 0.9828. The sound absorbing performance of P1, P2 and P3 shows good correlation.
3.5.4 Influence of thickness on sound absorption

While increasing the number of layers of nonwoven fabrics of recycled fibers the sound absorption coefficient also increases. The Figure 3.18 shows the influence of thickness on the SAC values of single, double and triple layers of nonwovens.

![Figure 3.18 Influence of thickness on Sound absorption coefficient of the nonwovens](image)

From the Figure 3.18, it is observed that the nonwoven C1 which has 2.1 mm thickness is having the average SAC of 0.25, whereas with the increase of 1.81 mm thickness in C2 shows increase of average SAC of 0.08 and the fabric C3 with increase of thickness 3.41mm performs with average SAC of 0.23 higher than C1.

The viscose fabric V1 with thickness of 2.08mm performs with average SAC of 0.21. The increase of thickness of V2 by 1.93mm shows increase of average SAC of 0.10 and the fabric V3 which has the thickness of 3.6 mm higher than V1 shows average SAC of 0.26 higher than V1.
Similarly, the polyester nonwoven P1 with the thickness of 2.31 mm results with average SAC of 0.30, The increase in the thickness by 2.13mm by P2 shows average SAC of 0.11 higher than P1 and the fabric P3 with increase of 4.09mm in thickness shows average SAC of 0.21 higher than P1. All these results reveal that the increase in thickness of the nonwoven fabric increases the sound absorption. This same trend was observed by Sezgin Ersoy et al (2008).

### 3.5.5 Influence of areal density on Sound absorption

Figure 3.19 shows, when there is an increase in areal density there is an increase in sound absorption coefficient for cotton, viscose and polyester nonwovens. Hence, there may be correlation between these two parameters for all nonwovens. The cotton, viscose and polyester shows good correlation having $R^2$ value of 0.97, 0.9826 and 0.9992 with the equations $Y =0.115X +0.1223$, $Y=0.13X+0.07$ and $Y=0.105X+0.1967$ respectively.

![Figure 3.19 Influence of areal density on Sound absorption coefficient of the nonwovens](image)

<table>
<thead>
<tr>
<th>Areal density (g/m²)</th>
<th>0.3305</th>
<th>0.653</th>
<th>0.9807</th>
<th>0.3231</th>
<th>0.6480</th>
<th>0.9602</th>
<th>0.3211</th>
<th>0.639</th>
<th>0.9480</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average sound absorption coefficient</td>
<td>0.25</td>
<td>0.33</td>
<td>0.48</td>
<td>0.21</td>
<td>0.31</td>
<td>0.47</td>
<td>0.3</td>
<td>0.41</td>
<td>0.51</td>
</tr>
</tbody>
</table>
3.5.6 Influence of bulk density on Sound absorption

The influence of bulk density on SAC of nonwovens as shown in the Figure 3.20 reveals that the increase in bulk density directly increases the SAC. Double layered cotton nonwoven which has the difference in bulk density of 0.01 g/cm$^3$ with the single layered cotton nonwoven depicts 24% increase in SAC. Triple layered cotton nonwoven having the difference in bulk density of 0.021 g/cm$^3$ depicts 47% increase in mean SAC. Double layered viscose nonwoven having the difference in bulk density of 0.007 g/cm$^3$ with single layer depicts 32% increase in mean SAC. Triple layered with difference of bulk density 0.014 shows 55% increase in mean SAC. Polyester double layered nonwoven having the difference of bulk density 0.005 g/cm$^3$ with single layer depicts increase in mean SAC of 26% and triple layer with difference of bulk density 0.01 g/cm$^3$ depicts 47% of increase in mean SAC.

Figure 3.20 Influence of bulk density on Sound absorption coefficient of the nonwovens
3.5.7 Influence of air permeability on Sound absorption

While increasing the number of layers of the adhesive bonded nonwoven fabrics of recycled cotton, viscose and polyester fabrics the air permeability decreases as in the Figure 3.21.

<table>
<thead>
<tr>
<th>Air permeability (cc/s/cm²)</th>
<th>98.01</th>
<th>69.28</th>
<th>37.18</th>
<th>106.8</th>
<th>81.03</th>
<th>39.72</th>
<th>91.08</th>
<th>56.14</th>
<th>34.51</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average sound absorption coefficient</td>
<td>25</td>
<td>33</td>
<td>48</td>
<td>21</td>
<td>31</td>
<td>47</td>
<td>30</td>
<td>41</td>
<td>51</td>
</tr>
</tbody>
</table>

Figure 3.21 Influence of air permeability on sound absorption percentage of the nonwovens

Figure 3.22 Correlation between Sound absorption and air permeability of the nonwovens
As the layer increases, it not only increases the areal density and bulk density of the combined samples, but also increases the short fiber content which will occupy the air voids. The Figure 3.22 shows a good correlation having $R^2$ value of 0.9783 with the equation $Y= -0.0038X +0.6205$, it is a significant negative correlation between sound absorption and air permeability. The above said results are in line with the findings of Teli, M.D et al (2007) and Surajit Senguptha (2010).

3.5.8 Influence of porosity on Sound absorption

Similar to air permeability lower level the porosity higher level the sound absorption must be. The Figure 3.23 shows the influence of porosity on sound absorption. Less porosity and less air permeability of the samples permit the sound frequency lesser amount at low frequency level, but at higher frequency, the sound enters the fine pores and experiences friction between the fibers and adhesives, thus performs with higher absorption of sound energy.

![Figure 3.23 Influence of porosity on Sound absorption coefficient of the nonwovens](image)

<table>
<thead>
<tr>
<th>Porosity</th>
<th>0.897</th>
<th>0.891</th>
<th>0.884</th>
<th>0.898</th>
<th>0.893</th>
<th>0.888</th>
<th>0.899</th>
<th>0.895</th>
<th>0.892</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average sound absorption coefficient</td>
<td>0.25</td>
<td>0.33</td>
<td>0.48</td>
<td>0.21</td>
<td>0.31</td>
<td>0.47</td>
<td>0.3</td>
<td>0.41</td>
<td>0.51</td>
</tr>
</tbody>
</table>
3.5.9 Influence of woven backing cloth on Sound absorption

The nonwovens of cotton, viscose and polyester single layer (C1B, V1B & P1B), double layer (C2B, V2B & P2B) and triple layer (C3B, V3B & P3B) backing with a woven plain fabric of 20 s warp and 20 s weft tested for sound absorption, the results are shown in Figure 3.24. The double layer polyester nonwoven depicts the highest SAC of 1, but the nonwoven with three layers of cotton, viscose and polyester backing with woven cloth shows insignificant values \( R^2 < 0.9 \). This is because of the thickness is more, the backing cloth reduces the absorbing performance. This results are correlating with the research findings of Sezgin Ersoy et al (2008)

![Sound absorption performance of nonwovens made up of recycled cotton, viscose and polyester backing with cotton woven fabric](image)

**Figure 3.24** Sound absorption performance of nonwovens made up of recycled cotton, viscose and polyester backing with cotton woven fabric

3.5.10 Sound resistance performance of the nonwovens

The nonwovens while tested for the sound resistance with 60 dB, 70 dB and 80 dB showed that the increase in number of layer, increases the
sound resistance. The average sound resistance percentage values for the three
decibel values were shown in the figure 3.25. The single layer nonwovens of
recycled cotton, viscose and polyester showed approximately 11%, 22% and
28% sound resistance with fabric to source distance of 25cm, 50 cm and
75 cm. The double layer nonwovens of cotton, viscose and polyester showed
approximately 15%, 30% and 38% sound resistance with fabric to source
distance of 25cm, 50 cm and 75cm. The triple layer nonwovens of cotton,
viscose and polyester showed approximately 18%, 43% and 56% sound
resistance with fabric to source distance of 25cm, 50 cm and 75cm. These
results also reveal that the sound resistance also increases as the distance
between the fabric and the source increases.

![Sound resistance performance of nonwovens made up of recycled cotton, viscose and polyester](image)

**Figure 3.25** Sound resistance performance of nonwovens made up of recycled cotton, viscose and polyester

### 3.5.11 Multi variable ANOVA analysis

The sound absorption and sound resistance values of the nonwovens
made up of recycled cotton, viscose and polyester with different thickness
was analyzed using statistical tool of multivariable ANOVA. From the results
it is observed that there is significant differences found between the samples of cotton, viscose and polyester at 95% confidence level, shows $F_{\text{actual}} > F_{\text{critical}}$ (130.2105 > 6.944272). It is due to the different structural properties of the recycled fibers. Likewise the other fabric properties like aerial density, bulk density, air permeability and porosity were analyzed and found significant differences between the samples because of the types of the fibers (natural, regenerated and synthetic), type of adhesive and method development of nonwoven.

### 3.6 CONCLUSIONS

The automotive and building interiors made up of recycled fibers are in potential market growth. The recycled fiber nonwovens as acoustic absorbing materials are developed by using the fibers recycled from the waste fabrics of cotton, viscose and polyester collected from the garment industries. The nonwovens are tested for acoustic absorption by ASTM E 1050. It is observed that polyester fiber nonwoven has the highest absorption coefficient in lowest frequency levels and highest frequency levels. Hence it is concluded that the nonwoven made of recycled polyester with its closer structure and higher sound absorbing percentage of 93% is much suited for interiors in buildings and automotives. The cotton and viscose nonwovens are also having sound absorption of 84% and 86% at 6400Hz. The major applications of these developed nonwoven products may be suggested for floor coverings and wall coverings.

The developed nonwovens while tested for the sound resistance with 60 dB, 70 dB and 80 dB by the novel sound insulation tester reveal that these nonwovens also can be used as sound insulators to reduce the unwanted and uncontrolled noise from outside environment.
From this chapter the following conclusions were derived;

- The recycled fiber nonwoven exhibits higher efficiency of sound absorption due to the following factors: effect of fiber diameter, shortened length of fibers, and variable pore geometry of the fabric. The average sound absorption values of C3, V3 and P3 were 0.48, 0.47 and 0.51.

- By increasing the number of layers for Nonwoven fabrics of recycled fibers the sound absorption coefficient also increases.

- When there is an increase in areal density there is an increase in sound absorption.

- The influence of bulk density on SAC of nonwovens reveals that the increase in bulk density directly increases the SAC.

- There is a significant negative correlation between sound absorption and air permeability.

- Similar to air permeability, lower the porosity level higher the sound absorption.

- The double layer polyester nonwoven backing with woven cotton fabric nonwoven depicts the highest SAC of 1, but the nonwoven with three layers of cotton, viscose and polyester backing with woven cloth shows insignificant values i.e. $R^2 < 0.9$.

- The sound resistance property of the polyester, cotton and viscose with three layered nonwovens at 75 cm distance from the source was 61%, 56% and 53% respectively.
• The sound resistance of the nonwovens increases as the distance between fabric and the sound source increases.

• When the decibel increases, the resistance decreases.

• The increase in number of layers increases the sound resistance of the nonwovens.

• The sound resistance performance of developed nonwoven of cotton, viscose and polyester reveals that there is a negative correlation between sound resistance and aerial density of the nonwovens.