TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Textile Engineering

Increase Retention Properties of Aquadesk Materials

Master Thesis

Study programme: N3106 Textile Engineering
Study branch: Nonwoven and Nanomaterials

Author: **Md Tanzir Hasan, B.Sc.**
Thesis Supervisors: Ing. Jiří Chvojka, Ph.D.
Department of Nonwovens and Nanofibrous materials

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1. Russell, S., 2007. *HANDBOOK OF NONWOVENS*. Cambridge, England: WOODHEAD Publishing.
2. Ugbolue, S., 2017. *Polyolefin Fibres*. 2nd ed. Elsevier.
3. Kellie, G., 2016. *Advances in technical nonwovens*. UK: Woodhead.
4. Fangueiro, R. and Rana, S., 2018. *Advances in Natural Fibre Composites*. Springer.
5. Eichhorn, S., Hearle, J. and Jaffe, M., 2009. *Handbook of textile fibre structure*. Cambridge: Woodhead Pub.

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ABSTRACT

Nothing is permanent and doesn't exist on earth without having a change. If we think about the history, we see there was an end of everything. Something new appears and replace the old one. Every problem is bound with a solution. Earth is changing every day and losing the balance from many sides where environment is one of them. To keep the balance equal and friendly something unique must be invented. Green roof is one of that kind. It's an invention which belongs to the group of nonwovens. It's a process which is creating several things for the society also creating several needs.

Amount of our basic needs are increasing day by day as well as the demand of textile industry. But it's not unknown that the increasing amount of textile industry causing pollution. To prevent this the concept of sustainability is growing. Sustainability in nonwovens is one of them. Zero waste materials, green manufacturing, less production of carbon by keeping the low impact are turning it into more sustainable. Due to the alarming environmental impacts such as climate changes in a drastic way, extreme hot & cold temperature as well as unpredictable climate sustainability are getting more attention. Sustainability became inevitable in the industry of manufacturing [1].

This thesis is about to create an aquadesk board which can be used as a base or vegetation board in green roof. It also plays a good role in sustainable nonwoven industry. To create this product there would be no use of chemicals which can impact badly on environment. So, it's an eco-friendly product which can be prepared by using 90% of recycled materials [2]. It's also used as a vegetation board of green roof which can absorb water from rain and any other sources and hold it to use when necessary. The main aim of this diploma thesis is to develop the water retention properties. We must focus on increasing the water retention properties of the new sample. This diploma project will be studying and understanding on this topic.

Key words: Nonwoven, Recycled Polyester, Green roof, Aquadesk, Water retention, Sustainability.

ABSTRAKT

Nic není trvalé a na Zemí neexistuje, aniž by došlo ke změně. Když se zamýšlíme nad historií, vidíme, že k všemu byl konec. někdy se objeví něco nového a nahradí to staré. Každý problém je spojen s řešením. Země se mění každý den a ztrácí rovnováhu z mnoha stran, kde je prostředí jednou z nich. Aby byla rovnováha stejná a přátelská, je třeba vymýšlet něco jedinečného. Zelená střecha je jedním z těchto druhů. Je to vynález, který patří do skupiny netkaných textilií. Jé to proces, který vytváří pro společnost několik věcí a také vytváří několik potřeb.

Množství naších základních potřeb se každým dnem zvyšuje a poptávka po textilním průmyslu. Není však známo, že rostoucí množství textilního průmyslu způsobuje znečištění. Aby se tomu zabránilo, koncept udržitelností roste. Udržitelnost v netkaných textiliích je jedním z nich. Nulové odpadní materiály, zelená výroba, menší produkce uhlíku díky udržení nízkého dopadu ji mění v udržitelnější. Kvůli alarmujícím dopadům na životní prostředí, jako jsou drastické změny klimatu, se extrémní horké, studené teploty a nepředvídatelné udržitelnosti klimatu věnují větší pozornosti. Ve výrobním průmyslu se udržitelnost stala nevyhnutelnou [1].

Tato práce se zabývá vytvořením desky aquadesk, kterou lze použít jako podkladovou nebo vegetační desku v zelené střeše. Hraje také dobrou roli v udržitelném netkaném průmyslu. K vytvoření tohoto produktu by nebylo použití chemikálií, které mohou mít nepříznivý dopad na životní prostředí. Jedná se tedy o ekologický produkt, který lze připravit s použitím 90 % recyklovaných materiálů [2]. Používá se také jako vegetační deska zelené střechy, která dokáže absorbovat vodu z deště a jiných zdrojů a v případě potřeby ji použít. Hlavním cílem této diplomové práce je vyvinout vlastnosti zadržující vodu. Musíme se zaměřit na zvýšení retenčních vlastností nového vzorku. Tento diplomový projekt bude studovat a porozumět tomuto tématu.

Klíčová slova: Netkaný materiál, Recyklovaný polyester, zelená střecha, Aquadesk, Zadržování vody, Udržitelnost.

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Pes: Polyester
RPes: Recycled Polyester
WT%: Water Retention percentage
g: Mass (gram)
m: Time (minute)
SEM: Scanning electron microscopy
Rpm: Revolutions per minute
Temp: Temperature (°C)
h: Hour (h)
GSM: Gram per square meter

1. INTRODUCTION

Environment and population are changing proportionally. More population and a smaller number of basic needs. We need a well-balanced environment to sustain in this world. Due to huge amount of population and large number of basic needs world is changing behavior now. Some countries are destroying natures to build new industries to fulfill human's basic need. As a result, it decreased the amount of oxygen we need [3]. It produces more heat than we need. So far Global warming became a hot topic for last few years. So, world needs a second thought to change the climate and make it friendly for human being. Green roof is one of those advance measures who can play a good role to protect our environment and provide us necessary basic elements. It's an advance product by green textiles. Mostly it's made by aqua desk materials [2]. It has so many benefits. It could be economical, ecological, or societal. It can be easily managed and doesn't need any extra land.

It is possible to plant useful vegetables or fruits or flower on this green roof. Sometimes that helps financially. As this board absorbs water from rain and let less water goes to sewage system what can easily reduce the amount of water in sewage system to prevent late flood. Plants in green roof also can help to reduce the amount of CO_2 from environment by producing more O_2. It can also help to maintain a good heat amount because normally plant absorbs sunlight what can be helpful to maintain the friendly level of heat and keep the weather pleasant. Even if there is any solar panel on roof in that case green roof helps to increase the working capability of solar panel by reducing the amount of heat of roof [2]. In dense and highly populated urban centers are indispensable to give comfort. Because of ground speculation in city centers, planted surfaces are disappearing. To reduce the high thermal loads good thermal protection is useful. Planted roofs on the top of building roofs can also prevent this by offering the protection. It's an easy and acceptable ecological solution which offer not only the reduction of the thermal loads but also to the improvement of highly dense built-in centers [4]. Green roof has a positive effect on human's behavior of working and living. It offers relaxation which helps to reduce stress. It works also on

social unity. People with less aggression and stress make a good neighborhood and reduce violence [2].

Current study is focused on increase the water retention properties of aquadesk materials. This board has an important role on vegetations. It absorbs the water and keep it until its necessary. The vegetation part of green roof has much dependency on this character of aquadesk board. So, in case of water retention ability's if it increases it can add more properties and more working rate. As a result, that can be effective on producing the maximum capacities and to get a better result as well as advantages which will be described during the experiment and study. In this diploma project the main goal will be by changing the materials and the percentage of specific materials how it's possible to increase the water retention properties which might have a significant role in retention, drainage and as a vegetation layer on green roof.

2. THESIS SIGNIFICANT SCOPE, BACKGROUND AND OBJECTIVE

2.1. Background of the study

Changes of world environment is increasing proportionally with the number of population and basic needs of human. There should be something which can protect our environment as well as can provide us some benefits at the same time. Aquadesk works as a vegetation layer for green roof. It has a greater absorbency and retention properties also good mechanical and other essential properties as well. Retention properties of aquadesk has a good role on growing system of green roof. As aquadesk is friendly to environment so it adds noting odd to green roof. It doesn't have any chemical reactions as its totally made without using any chemical. Green world concepts are one of the important issues in compare with the present situation of our world. Where we are destroying our nature to make cities and industries. So green roof came forwards to safe this world not consuming any land but using the roof top. The properties of aquadesk board have a great role on it. To Grow trees on green roof needs enough water. Aquadesk board does the work. It absorbs water and save it to grow plant or trees on green roof like a vegetation board. Mechanical properties of aquadesk also helps in that case. Also, this board helps to save the water from rain for further use and that helps to drainage system to prevent any kind of flood or other disaster because it helps to reduce the excessive water [2].

Investigations are still going on green roof to make it more friendly to environment and add more quality by improving few parts of it. By adding varieties of materials can improve the retention properties of layers. Like dual substrate layer of green roof are effective at retaining water from rain. It sinks for organic, heavy metals or nitrogen in every cases. It doesn't show any first flush effect. But still some more research going on it to improve of its functions. Mostly this dual substrate layer used in urban areas [5].

2.2. Objective of the study

The objective of the study is

1. To earn the exact knowledge about the various processes, techniques and methods used to make aquadesk board.
2. The selection of most suitable technique of nonwoven for the development of aquadesk.
3. To know about the raw materials varieties of aquadesk board which can make a difference between the performances of different boards where there will be different ratio of raw materials for every board than each other.
4. The objective of the study is to get some knowledge about water retention properties of different aquadesk board and check the greater water absorbency level of those boards and find out the best one also the percentage of each raw materials used for it. Also, to add some super absorbent materials how we can try to make water retention properties more.

3. LITERATURE REVIEW

In this part of the thesis, we will deliberately explain about the research done which is relevant to this topic on using various textile materials uses in Aquadesk. As its one of the departments of nonwoven geotextiles so that will be focus on this part. The discussion about the methods, materials will be presented here also some techniques will be mentioned. Also, it will be discussed here about how to improvise the materials more to find out some advances from there.

3.1. Research

By going through "**Home-Aquadesk "**by the aquadesk manufacturing company in Czech Republic "**RETEX"** it was understandable that the summary is with the change the environment its necessary to do something which can be effective for both mankind and ecosystem. Aquadesk is a board where plant can grow to make a green roof to protect environment. 90% of the raw materials of aquadesk comes from recycled polyester. No use of any chemical makes it more environment friendly. Aquadesk board or green roof works to balance the rainwater which can prevent the chance of flood by excessive amount of water. Planting trees on aquadesk board also helps to balance the amount of co_2 and o_2 to protect environment from toxic gases. It also helps the building by its mechanical resistance properties, and it provides thermal insulation. It's a geo textile which can be also called as a green textile because of the behaviors of aquadesk towards environment. [2]

From the chapter called **"Properties of recycled polymer, page 1-14"** of the book named "**Recycled Polyester"** it expresses that non-degradable plastic waste from the increasing industrialization and population are became a biggest threat for environment. Plastic has a toxic and non-degradable nature which can damage the living organisms also can destroy the eco-system. Report says 4.8-12.7 million tons of plastics produced by industry and mankind are coming to environment. Around the world up to 1 million plastic water bottles are being used and thrown away every day. Most of the plastic waste are coming from waste polyester bottles, old garments, and industrial polyester waste. These wastes are getting recycled by two major ways such as mechanical and chemical. Aquadesk is prepared by those recycled polyester with no chemical materials. As there is not so much difference between raw polyester and recycled polyester in compare with strength, durability, versatility and performances but while producing recycled polyesters the emission of co_2 gas became less so not so harmful for environment. Production of recycled polyesters also reduce the amount of petroleum fuels which is the major threat comes from polyester production. Recycled polyesters enhanced the mechanical and thermal properties. By reading this chapter I gained the knowledge about the various fantabulous properties of recycled polyesters and so many characteristics and advantages of recycled polyesters which is

much more important because recycled polyester is one of the most important raw materials to make aquadesk board [6].

From the book "**Green roof ecosystems"** in the **chapter 1 page 1-25** it's understandable that green roof is one of the important ways to ignore environmental stress. Aquadesk board is the base of green roof so refers to the backbone of it. Green roof is about to happen as a "sustainable building practice" in cities throughout the world to get rid from environmental threat because of pollution. Green roof has benefits from both public and private sides. Cycle energy and nutrients can be created by green roof ecology. Green roof also capable to model an ecosystem and green roof may provide a ground to test ecological concepts and various purposes to go further. Green roof also called as a vegetated green roof or eco roofs. Which is consisting of membranes, engineered substrates as the growing medium assemblages of plants which is placed on top of the building or few others structure. When our environment became a big concern and threat for our livelihood then green roof is one of the advance inventions. Green roof is structured because of advanced building materials, designing technique and prominent ideas about how to make a friendly environment and develop our built environment much more sustainable and humane [7].
From the article "**How green are the green roofs? Lifecycle analysis of green roof materials by Building and environment (2012)" and page (57-65)** its expressed that green roof has classifications according to the purpose and characteristics and they are intensive and extensive roof based green roof. Green roof has multiple layers with a variable thickness according to the type of roofs. Weather also makes some differences about how the layer would be. From top to bottom basic layers has different sections like root barrier, drainage, filter, growing, medium, and the vegetation layer. There are few new technologies which is enabled to use the low-density polyethylene and polypropylene polyester materials by reducing their weights which helps to reduce the overall weight of green roofs. To compare as a long-term product green roof is one of them because green roof is a sustainable product. But according to some research on low density polyethylene and polypropylene it has some negative effect on environment, so it needs to replace by something more environment friendly and sustainable products [8].

From the article "**Analysis of the green roof thermal properties and investigation of its energy performance, page (719-729)"** of the journal **Energy & Buildings** it comes green roof has some

both ecological and social advantages. As green roof has positive act upon the climate of the area also it has positive act upon the interior climate of the building beneath them. To get a passive cooling system for the interior of the building green roof protects the building roof from solar radiation. During summer season green roof reduce the thermal fluctuation of the outer surface of the roof where green roof is attached and it increases their thermal capacity which can keep the building beneath it cool from hot weather as well as the same functions to keep the place beneath green roof warm during winter. As it's helping to reduce the amount of thermal deduction so for that green roof saves the energy consumptions. From the analysis of the article the surface temperature of green roofs depends on what kind of vegetation has used there. For the different kind of vegetation, it could be variable. Also, various places can make some differences. If its covered by thick dark green vegetation, then it will measure lower temperature and higher temperature which are covered by spars red vegetation or which are covered by only soil. But the differences of the temperature of the external surface mostly depends on the construction of the building. For those old building the result is always obvious. In basic scenario for moderate insulated building the total percentage of energy savings is varied from 4 and for alternative scenario its 7%. Finally, it can be assumed from the article that for energy savings of a well-insulated building the impact of green roof is almost less than 2% [4].

In the article "**The influence of dual-substrate layer extensive green roofs on rainwater runoff quantity and quality, page (465-476)"** by the journal **science of the total environment** They investigate about the dual substrate layer of green roof. It can be added few advantages for green roof. This dual substrate layer can retain water from rain and help to reduce pollutant leaching. In dual substrate layer green roof, the substrate consists of an upper organic nutrition layer to help the pant to grow and there another lower inorganic adsorption layer for water absorption and pollution reduction. In this article there is a comparison made in between dual layer green roof and single substrate layer green roof. The result is double substrate layer green has achieved good support for better natural vegetation growth. It covers more than 90%. On the other hand, in compare with double substrate layer green roof single substrate layer supports less number. It covers over 80%. They examined the retention properties of the dual substrate layer green roofs which has the mixture of activated charcoal with perlite and vermiculite as the adsorption materials showed more and good water retention properties. They did this with four different types of rainfall

and the result they got is that the dual substrate layer green roof has more water retention properties than single substrate layer green roof. Most of those dual substrate layer green roofs showed to be sinks for organics, heavy metals and all forms of nitrogen in every case but the act as source for phosphorus contaminants during heavy rain. By considering the factor of water retention, reduction of pollution and green roof service life, a mixture of activated charcoal or pumice with perlite and vermiculite can be recommended as the adsorption substrate. There is still some investigation going on to improve the water retention properties of dual substrate layer green roof and their quantity of long-term rainwater runoff and the cost analysis. Normally, dual substrate layer green roof is an application for retaining rainwater in urban areas [5].

By going through the article "**Water-retention additives increase plant available in green roof substrates, pages (112-118)"** from the book **Ecological Engineering, volume 52,** we know about the importance of water retention and the factors of it to green roof on growing plant in green roof substrates. In dry climates with a high temperature can make green roof to face drought in its growing substrates. Normally in urban areas green roof get water in their growing media from rainwater. The shallow substrate of green roof which is called by growing media has some materials which can provide water for plant but it's not enough sometimes if the climate is too dry. So, to increase the volume of the substrates and increasing the depth water holding capacity (WHC) and limiting its application can help green roof substrate to get more water for a longer period. To increase these characteristics in this article they have talked about some water retention additives. Here they have used two water retention additives and they are hydrophilic polymers or hydrogel and silicate-based granules. Hydrogels is a widely available additives which is also called as a super absorbent polymer which can absorb and save water 500 times more than its own weight. On the other hand, silicate-based granules which contain natural silicate-based stone powder, carbon compound and cellulose. These particles can increase the surface area, it's also effective for nutrient and water adsorption. It's also described in this article that though hydrogels can be effective of water retention to increase the plant growth and supply plant available water (PAW) bit sometimes it depends on the properties of additives. Hydrogels can increase water holding capacity which doesn't mean that they can increase the water available in plant. Recently it has evaluated that hydrogel can improve the growth rate of plant on green roofs, but it's not determined yet that they can increase plant available water. In this article they have worked and talked about

this. Here they are doing this test by making two green roof substrates which is made by roof tiles substrate and scoria with using two different additives we are talking about. For more particles and other standards here they have followed Australian standards and substrates were tested for air filled porosity, water-holding capacity and bulk density. Moisture release curve of two substrates without any additives was measured by filter paper method. This method is common to use for green roof. Also, here they have used glasshouse drought experiment using winter wheat to evaluate permanent wilting and biomass. This experiment was designed with two growing substrates and three additives' treatments. None, hydrogel, and silicates with two plant species. Pot was arranged in the glasshouse to make a random block design. After the experiment plant available water was calculated by the change in substrate water content from pot capacity to permanent wilting and it was divided by substrate volume and then multiplied by 100%. Later of this the effectiveness of water retention additives on water holding capacity, air filled porosity and bulk density of substrates were evaluate and examined by using two-way analysis of variance. It's also called ANOVA. It can also determine the effects of water retention additives and growing substrates on plant available water. As a result, they got a result about both water retention additives working capabilities. They also mentioned that additives behave different in different substrates. In their experiment silicate increase the water holding capacity on both substrates where hydrogel only did it in scoria substrates.

From the article **"Effect of green roof media depth on crassulacean plant succession over seven years, page (310-319)** & journal **Landscape and urban planning** we can see

From the research part we can conclude it that properties of aquadesk materials can be changed by combining the natural fibers with aquadesk materials. It can be achieved better results by this. In the experimental part this fields will be briefly discussed.

3.2 Geo-Textiles:

ASTM defines geotextiles "as a permeable geosynthetic comprised solely of textiles". Two largest groups of geosynthetics which are designed to be used as a constructional material and which are

also textile fabrics like woven, nonwoven, knitted or braided and work with other geo technical materials such as rock or soil in the applications of civil engineering sector. Geotextiles has several functions in geotechnical engineering applications. The important advantage what geotextile has that across their manufacturing plan they are porous to liquid flow. They also have advantage to thickness for the same reason [9]. Geotextiles has around 100 application areas. widely uses of geotextile fabrics are given below [10]:

- Separation: when it comes about separate the soil and coarse materials geotextiles works as a separator. By segregating the materials, it helps to block the mixing under a load. So, geotextile prevent the gravel not to penetrate and let them mix with the subgrade [11].
- Reinforcement: Geotextiles works as a reinforcement when the high tensile strength of the fabric helps to stable the weak subgrade or soil by providing them strength. The main principle to use geotextile in reinforcement to make a relation between soil structure and geotextiles which can be able to increase cohesion between the grains [10].
- Drainage: it works as a drain when it gets excessive liquid or gas and move it towards outlets. It helps to transfer the fluid without causing any soil particles loss [12].
- Filtration: when liquid comes with fine particles then geotextiles work as a filter. It separates the whole particles and let the liquid pass through. When soil particles are carried by water current it allows to be seeping of water containing most of the soil particles [10].
- Protection: Geotextile can be used in so many ways as a protector, but mainly sand-filled geotextiles bags are being used to protect the large rivers means the riverbank and scour protection. For protections of agricultural areas, in recent areas geobags have been developed. Geobags are being used to protect river erosions and have been used for emergency protections at various locations in the world [13].

There are also more important and essential applications of geotextiles. Some of them are mentioned below [9]:

- Carpet backing and composites
- Packaging where it needs to maintain the porosity
- Face masks (consumer and medical)
- House wrap to make it weather resistance
- Disposable clothing

3.2.1 Classification of geotextiles

According to manufacturing techniques geotextiles can be classified by three types [9]:

1. Woven: It made on conventional textile weaving. Where high strength and high modulus in the direction are more important that prefers woven geotextiles. Multifilament, monofilament, slit film and fibrillated are four woven geotextiles.
2. Non-woven: Nonwoven geotextiles are formed by continuous filaments.
3. Knitted: Classical knits and insertion knits are two knitted geotextiles. Classical one is formed by interlockings and insertion one is formed by insertion yarns into a knit.

In our research we will work with nonwoven geotextiles, so the description of nonwoven geotextile is given below.

Non-woven geotextiles:

Nonwoven geotextiles are created from continuous filament or short fibers, or which can be called also by staple fibers. It's necessary to arrange it in all direction. There is no necessity to do it randomly and its bonded together in structure of planar. The flexibility is more, and it has a [9]lower modulus. It has a higher elongation so doesn't break easily. Under any unrestrained condition it shows an appropriate and favorable deformation which helps to keep on right track. Which helps to spread the fabric over even if the surface is uneven. Even under restrained condition, it has a resistance from deformation also it helps the fabric to hold the position over geotextiles beneath it [9].

3.3 Water Absorbency

In every process or techniques and the characteristic of end uses or applications there is one key factors for textile materials. That one is water retention or absorbency properties. During the

dyeing and finishing processes of textiles materials this key factor affects most. Its affect the process parameter and the final finishing characteristics of the product. Moreover, in textile industry retention or absorbency means “The ability of a textile material to absorb and retain liquids within its structure”. It has two components and those are capture and hold.

1. Capture is one kind of ability to attract the moisture quickly like the speed it delivered and there won’t be any runoff.
2. Hold is the total amount the moisture is collected by those materials when its wetted out and it doesn’t need any different condition. It can be used under any normal condition.

Distribution of wetness is another factor of water retention. Fibers that have a good holding factor for moisture on the contrary they have poor distribution capability. Few fibers or fabric has better capability and, they are better at spreading the wetness. Among those few fibers’ polyester is one of them. So, mixing polyester and a non-absorbing fiber which can distributes well into cotton or bamboo, or hemp would be effective in the case of spreading moisture in a larger area and using all efficient fibers in the fabric to absorb it.

Types of fibers: Cellulose fiber is mostly used in the case of absorbency. Cellulose fibers are made from cotton, bamboo, and hemp. Cellulose is a hydrophilic fiber according to its nature. Hydrophilic fibers have a good holding capability and that’s the reason why it swells. Hydrophilic fibers don’t distribute moisture properly because of their holding characteristics also they have an intension to flatten out when they become wet.

There are some fibers who doesn’t like water that much and those are called hydrophobic fibers. Synthetic fibers like polyester are one of the hydrophobic fibers who doesn’t swell. But those hydrophobic fibers can distribute moisture and can be a better one as an absorbent when it’s blended with cotton, bamboo, or hemp.

Types of fabrics: Fabric which has a web which is prepared by hydrophilic fibers like natural fibers (cotton, bamboo, or hemp) works well as a water absorbent fabric. The retention level of those fabrics is always good because they can trap moisture in between the fibers until fibers try to swell and saturate themselves. But those natural fibers like cotton, bamboo and hemp they can’t stay with this characteristic for a long time. Most of those natural fibers they lost their web/pile and chance of trapping moisture because getting wetted for long time makes them flat.

Microfiber fabric has a good characteristic to hold and trap moisture but still it doesn't last for a long so mixing microfiber with others makes it a better performed one.

3.4. Aquadesk

Aquadesk is a board which is to be installed on the roof to use it for various causes. Aquadesk is a nonwoven geotextile fabric which is used for vegetation. This geotextile fabric works for green roof what provides super water absorbency, retention, mechanical properties also so many others good and essential needs. Aquadesk is normally made from recycled polyester fiber. To keep these fibers together the fibers are connected by using fusible fibers and the bonding's are applied by thermal bonding. Mostly aquadesk is to be installed on to the roof having good water absorbency, high mechanical properties, retention properties, good heat insulation system and so on. Aquadesk materials are totally recyclable. Aquadesk can be produced without using any chemical, so it refers one of the key advantages of this material. To grow plant on roof aquadesk is one of the best options to use which can be called as a green textile. Retention properties of aquadesk is one of the major tasks of aquadesk material which has so many good impacts on environment [2]. In fig 3.4 aquadesk board is showed.

Figure 3.4 Aquadesk materials [2]

3.5. Other Materials

Few types of materials can be used to make aquadesk board. Here we will talk these we are going to use in our experiments. There are few materials available to make this board but according to our need and supply we will mostly use four types of materials to create this aquadesk board. Some of them are bicomponent fiber, flax fiber, and super absorbent fiber.

3.5.1. Bicomponent fiber

‘A bicomponent fiber is made from two or more polymers of different chemical (e.g., composition, additives) or physical (e.g., average molecular weight, crystallinity) nature, extruded from one spinneret to form a single fiber [14]. Up to the spin pack the flows of polymer will be kept separated from the place through the spinneret they will meet and exit together. During the time when the filament moves from spinneret that time it consists of non-mixed components which get touch at the interface. The dynamics at the interface is undoubtedly play a significant role to affect the behavior and the performance of the system. Bicomponent fiber cross through common melt drawing processes which is like conventional synthetic fibers [15]. In the fig 3.5.1 the cross section of bicomponent fiber is mentioned.

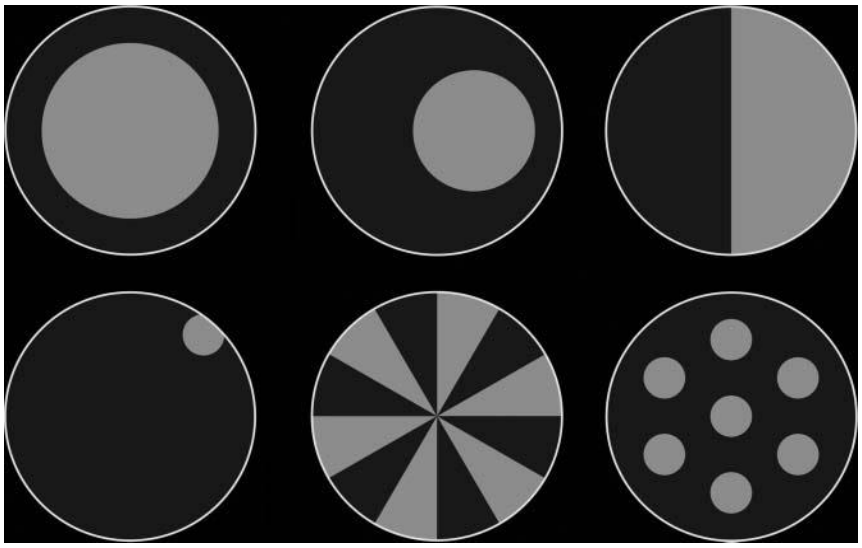

Figure 3.5.1 Typical Cross section of Bicomponent fiber [16]

Applications of Bicomponent Fibers:

Bicomponent fibers works as a bonding element in nonwovens. In the production of nonwoven fabrics bicomponent fibers are used by through-air thermal bonding [17]. A web of fiber will be mixed with thermo-bondable core-sheath bicomponent fibers which will be treated by blowing hot air through the web. To complete this process the temperature of the air needs to be higher than the melting temperature of the sheath component but in compare with core component it must be lower. If it follows this term, then the shape of the fiber will be maintained. By following this technique, it is possible to produce the excellent, flexible, high bulkiness and good absorbent nonwoven. By developing of a PP/PE bicomponent fiber further advancement of the bicomponent fiber can be accomplished. The utilized fibers to produce nonwoven fabric comes with a soft touch, which are usable to produce diapers and hygiene products [18]. Bicomponent fiber also useful as a microfiber, fibers with special cross sections, fibers with high performance core, fiber with functional service, biodegradable fibers, polymer optical fibers, electrically conductive fibers, liquid core fibers, fibers for fully thermoplastic fiber-reinforced composites, shape memory fibers etc. [16]. Among all of them shape memory characteristics would have a significant act for our topic.

With a shape memory character two polymers with different phase transition temperature can be combined in terms of forming a composite material [19]. Materials which are prepared by shape memory materials they can recover their previous original shape upon reheating [16].

3.5.2 Flax

Flax fiber is an interesting and important reinforcement for polymer composites materials because of its high mechanical performances and it also comes from its plant-based origin. It has environment friendly nature. It has been using as a textile raw material, weaving yarn, composing cords or in fashion industry. It also has a vast of importance in high quality fabric upholstery [20]. It can work as a substitute of glass fiber because of its plant fiber-based origin. Because of its renewable properties, origin, low density and human health friendly nature it gets advantage to replace glass fibers and that's how it's getting popularity day by day. Because of sustainable behavior it has a huge impact in our topic. It will be largely used to produce our sample.

3.5.3 Super absorbent polymer

Super absorbent polymer is a hydrogel which absorbs water as high as 500-1500 g/g where the other common absorption materials have the rate of not more than 1000 g/g [21]. It has a three-dimensional network polymer such as water-swellable, water insoluble organic or inorganic material which absorbs thousands time than its original weight. It has a wide range of applications. Those various fields are agriculture, biomedical, daily physiological products, separation technology and wastewater management [22]. Based on the mechanism of water absorption super absorption polymer can be divided by two categories. Those are chemical and physical absorption. In terms of different raw materials, it's also divided by six categories. Such as starch, cellulose, protein, copolymers of acrylic acid and acrylamide, chitosan and the last one is the blend and composites. It can also be divided by two categories according to cross linking. Such as poly cross lined and starch cross linked [22].

Methods of Preparation:

There are few methods to synthesis the super absorbent polymers. In a way they can be divided by two parts. Such as, chemical synthesis methods and physical synthesis methods. There are few chemical synthesis methods, and they are bulk polymerization, solution or cross-linking

polymerization and radiation polymerization. On the contrary physical methods refers to freeze cycle technology and cross-linked by hydrogen bond [22] [23]

3.6. Nonwoven

"A non-woven is an engineered fibrous assembly, primarily planar, which has been given a designed level of structural integrity by physical or chemical means, excluding weaving knitting or paper making. It can be defined as a manufactured web or sheet or batt of fibers who are directionally or randomly orientated and the bond between them can be happened by friction or cohesion or adhesion." By EDANA (European disposables and non-woven associations) [24]. Nonwovens are produced by interlocking or bonding or by orienting the fibers in a randomly or directionally in form of web and bonding will occur by various techniques. It can be used as a disposable nappy, tags, levels, filters, insulation, house wraps, products for roofing or geo textiles or for many other useful things. But among all those categories' hygiene is by far the largest one [25].

3.6.1. Classification of Nonwoven

According to the production method nonwovens has three types. Those are given below:

1. Wet Bonded: In wet bonded system, a fiber slurry is collected on a wire mash and then it needs to be condensed so that it can form a web and then it needs to be dried to get the exact required results [25].
2. Dry Bonded: When nonwovens are producing from staple fibers a carding process is always required to separate the fibers and web formation. That system by which those webs are produced is called dry bonded web which are three type according to fiber orientation. Those are parallel laid, cross laid and random laid [25].
3. Spun bonded: It's a process of forming fabric by continuous filaments which will be layering on a forming screen and there will be bonding also. It also includes extrusion of the filaments from the polymer raw materials [26]

Apart from that nonwoven have more variation in types and some of them are staple fibers nonwoven, durable, semi durable, water absorbent, flame retardant, disposable, water repellent etc.

3.6.2 Non-woven Production

Non-woven production has four stages [25].

- Supply of raw materials: All types of fibers are usable for nonwoven production though the choice of the fiber depends on the profile of the fabric required and cost effectiveness. To produce nonwoven fabric cellulosic and synthetic origin chemical fibers, natural fibers and inorganic fibers are used [27].
- Web formation: In every no woven processes, fibers or filament form as a web or they are condensed in a web and fed to a conveyor belt. Web formation normally converts staple fibers or filament fibers into a two dimensional which is web or in three dimensional which is batt. But the structure depends on the dimension, structure and properties of the final fabric [25].
- Web bonding: To determine the fabric mechanical properties the degree of bonding is the primary factor. It can be carried out a separate operation but normally it carried out in line of web formation. Some fabric construction demands more than one bonding's at a time [25].
- Finishing: To change the aesthetic chemical finish are used and to change the physical properties mechanical finish are used. So, finishing can be divided by two parts such as chemical finish and mechanical finish. Some finishes can be done by both combinations. To develop the certain properties of fabrics with mechanical device its mechanical finishing and which rely on the application of certain chemicals to the fabric by applying the different methods of application is called chemical finishing [28].

3.7. Supply of raw materials

Almost every type of fibers can be used for non-woven fabric but mostly the selection of fibers depends on the application of fabrics and the cost measurement. Among all those raw materials few of them who are mostly used for the commercial purpose to produce a non-woven fabric. In fig 3.7 those raw materials are mentioned accordingly [27].

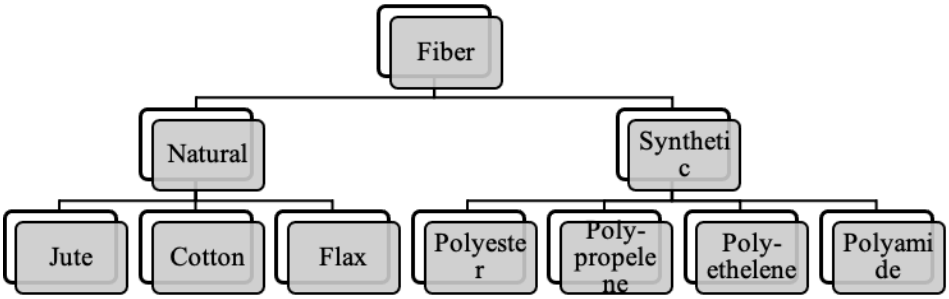

Figure 3.7 Raw materials of non-woven

In our thesis we will mostly work on polyester. In a word recycled polyester. To make aquadesk board polyester is one of the important raw materials [2].

3.7.1. Polyester

Polyester fiber is produced by petroleum. Polyester fiber is prepared by the extraction of petroleum from crude oil. It seems like it can be dangerous for environment, but it proven to be wrong compared to other man-made fiber. Polyester fiber is much more safe than other man-made fiber. Even by observing the entire life cycle of polyester fiber, it is proven that polyester fiber is more eco-friendly than the other natural fiber. So far polyester became one of the leading and most used fiber in the whole world textile industry [6]. Chemical reaction for polyester formation is given below in figure 3.7.1 [29].

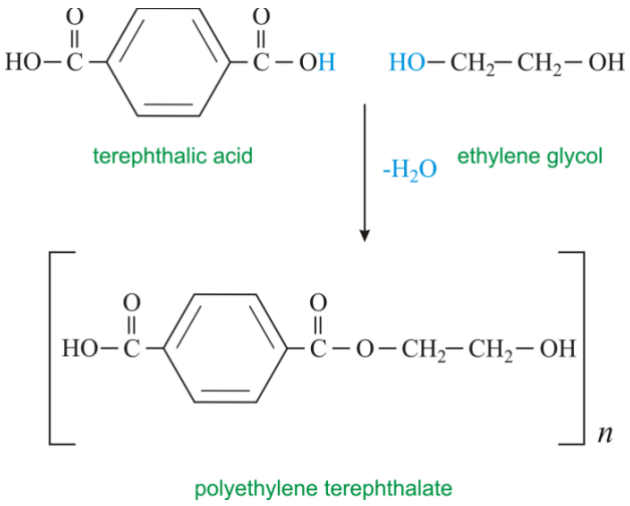

Figure 3.7.1 Chemical reaction of polyester

One of the remarkable polyesters is polyethylene terephthalate which is used in various textiles. It is also using in commercial or domestic purposes. It acts as a major raw material in many sectors such as beverages, food packaging, water bottles, kitchen containers, wrapping materials etc. but it has more impact in textiles than in other sections [6].

Physical properties of polyester are discussed below [30].

1. Mechanical properties: Polyester fiber properties can be variable. It depends on the processing method. When the degree of stretch is increased the crystallinity and molecular orientation become greater also the characteristics like tensile strength and young's initial module increased. If molecular wight increase tensile strength, modulus and extensibility also increase.
2. Specific gravity of polyester is around 1.38
3. Moisture regain of polyester is generally lower in compare with others. It varies from .2-.8 percent.

4. Polyesters and polyamide both has almost similar melting points. The range of melting points of polyester is from 250-300°C. when polyester fibres melt it shrinks from the flame and it leaves a hard black residue. During melting a pungent odour comes from polyester fibres.

Chemical properties of polyester fibers are discussed below [30].

1. In a certain room temperature polyester fiber have a good tolerance level against acid.
2. In a cold conditions polyester fiber shows good resistance ability against alkalis but it doesn't have any resistance at boiling temperature, and it dissolves in NaOH.
3. Polyester fibers have good resistance against sunlight also against abrasion it shows good resistance. Soaps or synthetic detergents can't damage polyester fibers. Polyester fibers show oleophilic character and that's one of the disadvantages of polyester fiber. Polyester fibers absorb oily materials so easily and it's hard to separate oil from polyester fiber [30].

In our research we will work with nonwoven geotextiles mostly with polymers. Nowadays polymeric geotextile materials are so common to use in geotechnical and environmental applications. It shows great performances in various purposes like filtrations, drainage and reinforcements. There are numerous numbers of polymeric geo textiles available and every one of them has their own specific functions. Most of these polymeric geotextiles are nonwoven and it made by needle punching or melt bonding processes [31].

3.7.2. Polyolefin Fibers

"Polyolefin fibers" this term and the terms "olefin fibers" both of the generic name is approved by united states federal trade commissions to explain it as a manufactured fiber in which the substance that form the fiber is a long chain synthetic polymer which is composed at least 85% by mass of ethylene, propylene or other olefin units [32]. Polyolefin fibers are aliphatic polymeric hydrocarbons. Carbon and hydrogen are the chemical elements by which they are normally composed. Polyolefin fibers has lower density. It's usually lower than water. The density of two types of polyolefin fibers are .95-.96 gcm^{-3} (polyethylene) and .90-.91 gcm^{-3} (polypropylene). The most important polyolefin fiber is polypropylene (PP). It has more commercial use in textile

sectors than any other polyolefin fibers exist. After that there is another one who has good uses in textiles but in less amount than polypropylene. That is polyethylene (PE) [33].

Improvement of the use of polyolefin in nonwoven: In last few years the uses of polyolefin increased so much. Especially polypropylene (PP) is dominating the production of melt blown and spunbonded nonwovens. Polyolefin as a raw material is comparatively inexpensive and available through the worldwide. Polyolefin fibers has a huge demand in nonwoven sectors because of its unique characteristics. In recent years some development happened in polyolefin catalyst technology and in their unique molecular tailoring capabilities which can have a good effect on nonwoven sector [34]. Polyolefin offers attractive cost with a good value rate and a good use when it comes to the comparison against polyester or polyamides. That's one of the reasons of polyolefin resins to become most uses fibers in nonwovens sector. The advances made for polyolefin resins in recent years which is strengthening the olefin properties ration which is one of the important characteristics to make them suitable for nonwovens application. Because all of this necessity PP is one of the major single raw materials for nonwovens than any other polyolefin resins [35]. PP is used widely in the production of disposable diapers, sanitary product markets and medical textiles. PP has also a large use in the sector of geotextile's, nonwoven furniture construction sheeting and carpet components etc. it has a huge demand in wet filtration application. On the other hand, PE is widely used in united states for garments use for industrial work, house wrap, envelops and other paper product [36]. The future of polyolefins is counted as a promising factor in nonwovens. Due to their low cost and easy processing systems polyolefin has good future in nonwovens sectors also. It will have a specialty in nonwoven markets because of metallocene and new generation of ZN catalyst. Elastic fasteners for diaper and medical gowns is a good features from polyolefin in nonwovens market [37].

3.7.3. Recycled Polyester

As the textile industry is one of the largest sectors in the world because of its huge number of requirements to maintain the lifestyle of human beings, therefore it has a conflict with environment as well. Polyester command the textile industries with cotton. They both have almost same amount of uses in worldwide textile industries. It didn't take a long time for

polyester to overwhelm the cotton fiber as the single most demandable material. But the production causes an extensive damage among mankind and environment. It caused due to plastic which is also toxic and non-degradable. These characteristics can damage our environment as well as harm our normal lifestyle [6]. The conversion of polyester to fiber is mentioned in Fig 3.7.3 [6].

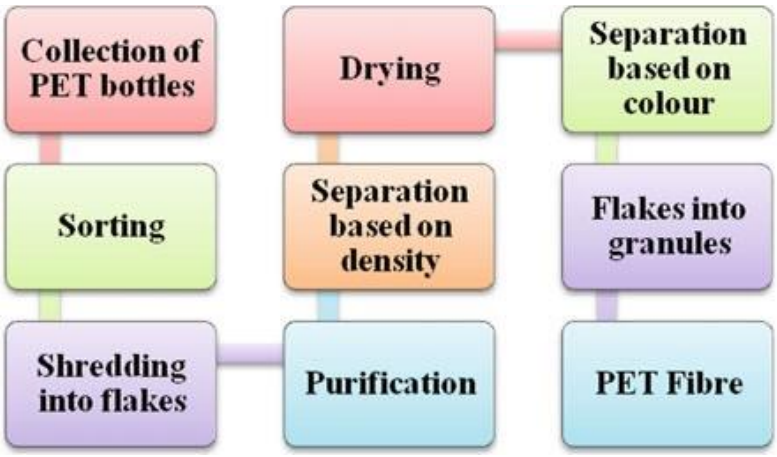

Figure 3.7.3 Process of recycling polyester

The non-degradable character of polyester has a harmful impact on ecosystem. So, for the reason so many research and the excess utilization of polyesters helped to think about the recycle process of polyester what can be effective both for environment and world textiles sectors. Polyester materials don't harm the eco system directly but indirectly their properties of non-biodegradability became the biggest threat for environment. From this part there are two processes to protect environment from this wastage of harmful polyester materials and recycling is one of the useful one so far. The approach of recycling process doesn't have any negative impact on environment. It's an effective method to manage polyester waste. The process of polyester recycling is expressed in Fig. 2. By the help of this recycle polyester fiber aquadesk materials can be made. It's one of the uses raw materials to make aquadesk board [6].

Recycled polyesters have so many beneficial features. Those are given bellow.

- Recycle the same materials again and again helps to reduce the amount of petroleum use for polyester production.
- Helps to balance the solid waste accruements.
- Less production of polyester and recycle the waste helps to decrease the number of non-degradable polyester which can be thrown to landfills.
- Diminish the harmful effect of plastic and save the environment and eco-system.
- In compare with the raw polyester recycled polyester are always less harmful for environment.
- Balance the greenhouse gases and ozone.
- Recycling the polyester helps to reduce non-degradable chemicals which can be used to produce raw polyester [6].

3.7.4. Regenerated fiber

Population of world rises is rising exponentially. On the other hand, resources what can fulfil our basic needs is not increasing like the way our demand on those are increasing. Basic needs like food, energy, water, resources, and chemical are going down while population of this world are increasing [3]. Global warming became one of the biggest threats and industrialization is one of the main reasons behind it. In textile industry fiber is the basic raw materials which has a huge field of uses. To produce fiber for this vast necessity could be a big threat for environment. So, now is the time to initiate utilization of sustainable materials by which we can produce sustainable textiles [3]. By producing sustainable textiles, we can reduce a huge burden from environment. Cotton could be an example because among all-natural fibers use for textile cotton is of the most uses raw materials which is 80% of total raw materials use for textile. So, to cultivate that large amount of cotton according to it needs is one of the threats for worlds environment. So, to get rid from this problem system should be like where we can recycle and use the same materials again and again which can take off the burden from environment causes by huge cultivation of cotton. That can be done by those regenerated fiber. “Regenerated fiber is created by dissolving the cellulose area of plant fiber in chemicals and making it into fiber again (by viscos method). Since it consists of cellulose like cotton and hemp, so it’s called regenerated cellulose fiber” (AWA) [3].

3.7.5. Production of Regenerated fiber

Viscos rayon was the first man-made fiber which was developed just as a replacement of silk. Later then lyocell was developed which is more eco-friendly. It has a combined property of softness, drape, and antibacterial quality. Due to manufacturing process all the natural cellulose fiber is also called as regenerated cellulosic fiber. All-natural fibers are suitable renewable materials. Among them cotton is one of the most used raw materials in textiles. It can be found everywhere like in woven, knit or yarn form. At the end of one-character cotton can be recycled to make it for another character. It's easy to recycle cotton for further use. Even for aquadesk material we can use recycled cotton to mix it with other materials [3].

3.8. Web formation

The purpose of web formation is to convert the fibers into a web. This is the first step and the beginning of the manufacturing of non-woven geo textile. Normally in web formation to form a layer of web the fibers or filament are laid on each other. There are few processes of web formation. Those are given below in Figure 3.8 [25] [38]:

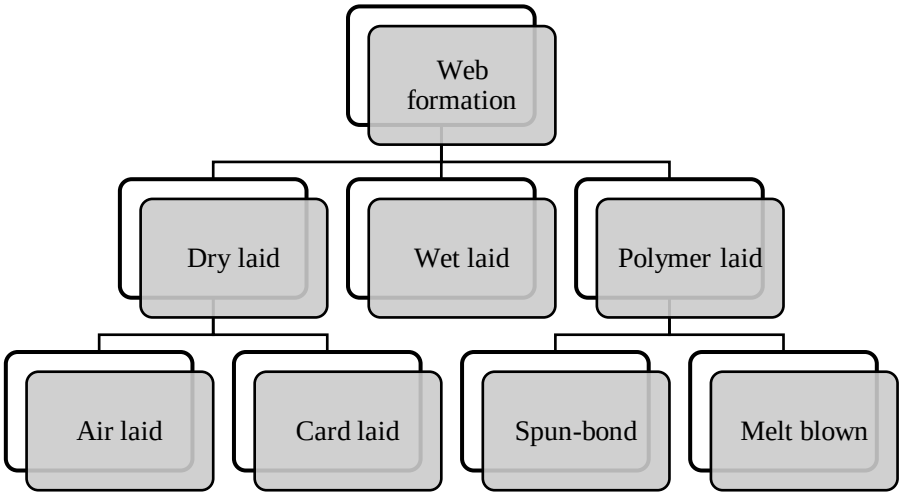

Figure 3.8 Process of web formation of nonwoven

3.8.1. Air laid

Here for our thesis air laid technique will be used to make our nonwoven product. In figure 3.8.1 the process of making nonwoven by air laid is given below [39].

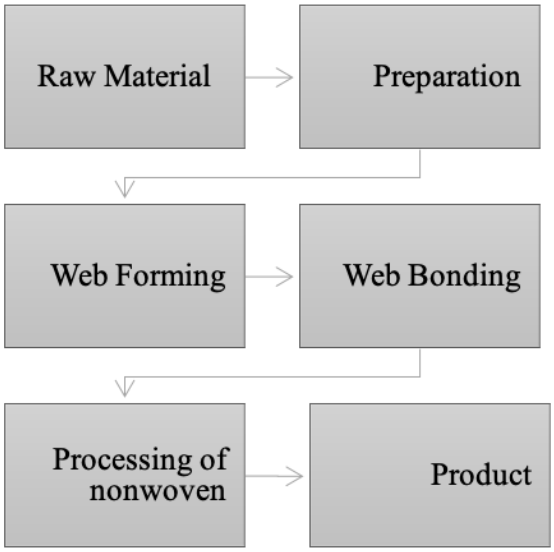

Figure 3.8.1 Process of Air laid [39]

The raw materials for making nonwoven by air-laid technique can be natural fibers, synthetic fibers or other fibers. Then it comes about preparing the raw materials which is opening the raw materials from bale and send it to the next process which is web forming. It will have aerodynamic process that refers to random laid of raw materials. Then it comes to web bonding. There are few web bonding techniques. Such as, mechanical, thermal or chemical web bonding. For our research thermal bonding is used. After that when that product is prepared then it comes to the processing of nonwoven which refers to finishing, printing and coating. After all this required process we will get the final and finished product nonwoven fabric [39].

Air laying Technology:

In air laying technology there is an airstream where uniform dispersion of individualized fibers occurs then it leads that mixture of air-fiber to a permeable screen or conveyer. In this permeable

screen or conveyer, the separation of air and fiber is to be done then that fiber are randomly deposited as a form of a web. Therefore, separation of fiber is one of the important and essential part of the air laying process and influences the local and global uniformity of the final web. For the formation of lightweight webs, it is necessary to make sure about that opened, it's also necessary to remove the clumps from individualized fibers and it needs to introduce the entanglements into the airstream. Orientation of the fiber in the final web is impacted by the dynamics of the airflow close to landing area and happens in the fiber transport chamber. Rotation of the opening or fiber dispersing unit above the transport chamber can have a strong impact on it. To transport fibers from the opening unit to the section of web forming some methods are used. Those are given below:

- Free fall
- Compressed air
- Air suction
- Closed air circuit
- A combination of compressed air
- Air suction system

Principles of ai laid technology are given below in figure 5.3.1 [27].

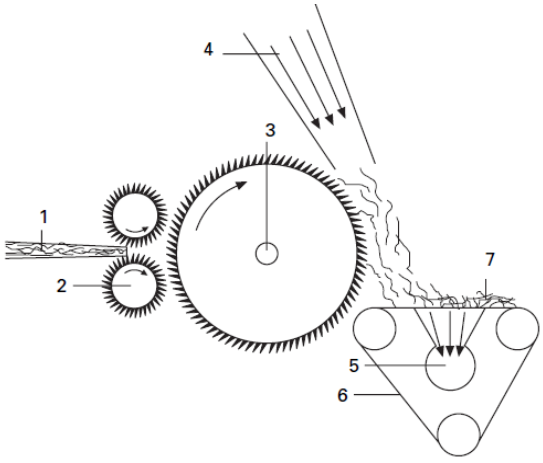

Figure 5.3.1 Air laid technology [27].

In the feeding system there will be two feed rollers, feed plates, nose bar and overhead feed plate. In the fig it shows the principle of web formation in a simple air laying process [27].

1. Pre-made batt

2. Feed rolls
3. Main cylinder
4. Air blower
5. Suction
6. Conveyor belt
7. Air laid web

From the fig we can see the suction assisted landing area and using it is the principle of airlaid web formation. According to this machine design, the preparation of reopened fibers is prepared using the feeding and the mixing and opening occurs here which are fed by to a pair of feeding rollers, and it happens in the same way as carding. Which is constructed and designed to handle the fiber and try to reduce the numbers of large clump which is drawn into the system. To make sure the regulation of feeding automatic feed control systems of used by the carding industry is applied here. Fibers that are transported by feed roller are removed from the fringe by the rotation drum or cylinder. Cylinder is like a drum which is covered by wire teeth and fibers are transported by hooking with those wire teeth and later they are continuously removed by a high velocity airstream from the wire teeth surface over the cylinder [25]. So, during this process the fibers are getting mixed with air and fibers goes directly to an air permeable conveyor where this conveyor separated this the fiber from air and collects all those fibers to a form of web or batt structure. There are few machines with different designs and working procedures are in the market for ai laid process. Properties of the final web materials depends accordingly to the method we are using. The parameters of the web properties are the number of materials is feeding there and the air flow in the transport chamber and it depends on the density of the web as well as the properties of fibers used [39].

3.8.2. Needle Punching Technology

Needle punching counts as one of the oldest techniques to produce medium to heavy weight nonwoven fabric or product. Production of numerous products are done by needle punching. This fabric is made from webs or batts of fibers. Here barbed needles drive the fibers upward or downwards. By friction force all these interlock fibers hold their structure together same as binding point which is also bonded by friction forces [40].

Intertwining of the fiber and the inter fiber friction creates by compression of the web occurs the fiber web bonding in needle punching technology. In figure 3.8.2 Phases of needle punching mechanism is mentioned [40]:

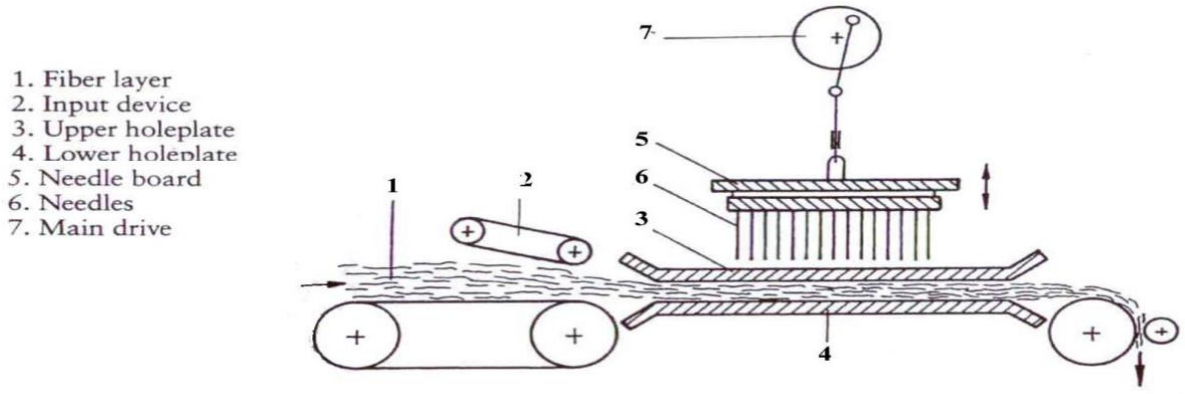

Figure 3.8.2 Phases of needle punching mechanism

There is a drawing in roller which helps to pass the web over the feed table. After that feed rollers helps to feed the web to needling zone. In this needling area needles make the web perforated and reoriented. This process continues for several times. After the above part or stripping plate of the web is done then the lower part of the web is pressed to throat plate. To support the needle board there is a needle beam here which is situated above the needle plate, and this is all powered by the drive over cam shaft. Needle board has holes to take the needle and shanks of the needle has barbs. To hold the fibers as the perforated web barbs is essential. As the barbs is only face in one direction and the needle come back so fiber always stay in the new spot virtually unchanged. After the final needle web forms, the delivery roller transports it from the needle zone. The feeding of the materials can be intermittent or continuous. By the needle punching technology we can get the nonwoven textile for the high-performance application [40].

Needle punched nonwovens: Needle punched nonwoven is flexible and it has a fibrous network with distinctive pores what makes it exactly suitable to use for the applications of filtration and also for drainage. Because of its bulky nature needle punched nonwovens are entangled to form a 3D structure which is comparatively complex in nature also for good drainage. The properties that

can vary the performance characteristics and application of nonwoven needle punched geo textiles are types of the fiber, fiber quality, fiber lubrication, needle shape, depth of the penetration of the needle, batt areal density etc. These types of nonwovens are normally used in civil engineering purposes including road constructions, railway constructions, sea defense, as a reinforcement etc. [41]

3.9. Web bonding

For this application its more important that the performance parameter must meet what the application requires by keeping the strength which imparted inside the web. On the geometry of fiber parameters, position, mass of web and the strength of fiber parameters mostly the level of bonding depends. The bonding of web is performed by either chemical or physical treatment. Physical bonding is achieved by friction or cohesion which achieve it by imparting strength of fibers. Binding agents are using for chemical bonding. In Fig 3.9 we can find the usual figure of web bonding [25]:

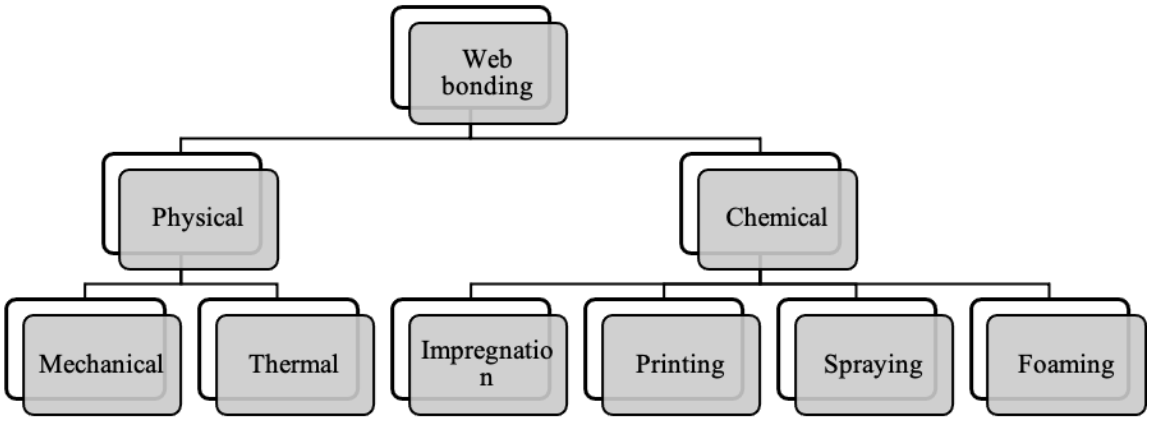

Figure 3.9 Process of Web bonding

Degree of bonding technique is one of the important issues for the mechanical and filtration property of fabric. There are few kinds of bonding system but among all of them for the manufacturing of geo textile mechanical and thermal bonding's are commercially used [25].

Interlocking of fibers are done by the mechanical entanglement of the fibers which is consist by mechanical bonding. Needle punching, Stich bonding and hydro entanglement are the techniques to gain interlocking. For Needle punching the commercial technique is mostly used. Needle punching is one of the mostly used technique to produce mechanical bonded geo-textile [38] [25].

3.9.1. Thermal Bonding

For thermal bonding a thermoplastic component is used. Normally, it is used in a firm of powder or film or a biocomponent fiber. To melt the thermoplastic components or to make it viscous the main process is to apply heat until it turns into the required one. Due to surface tension and capillary action which helps to flow the polymer fiber to fiber bonding reason are formed and cooling fix it further. Amount and type of binder materials is liable for the fabric properties [25] [38].

There are few classifications of thermal bonding's. In fig 3.9.1 these are mentioned [25] [38].

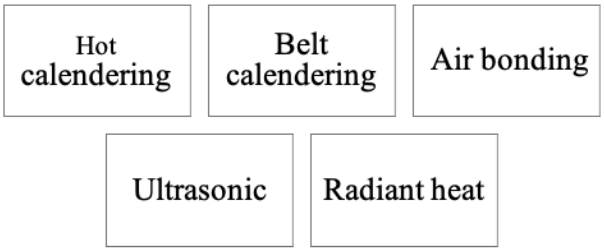

Figure 3.9.1 Classification of thermal bonding. [27]

3.9.2. Uses of Bicomponent in Thermal Bonding

According to the required properties of the fabric during the web formation a fix portion of thermoplastic component is added. During the process that thermoplastic materials turn into a viscous or melts which is fixed by cooling system. When bi-component fiber or powder as a binder material melt move to flow into the web also, they tend to around the fibers. It drives the formation of bonding points over the web for both on the surface and to the thickness. After the cooling process these bonding points form a mechanical bond, and it occurs between the thermoplastic component (bicomponent) and the fibers in the web.

For thermal bonding binding materials is one of the most essential factors. In that case binding materials can be in various form. Binding materials finds in form of a bicomponent fibers or powder, film, low melt webs etc. Throughout the whole web physical form and distribution of the binding material presides over the formation of binding points which has a significant influence on the web properties.

In our thesis to make an aquadesk board we are going to use thermal bonding technique and as a binding agent we will use bicomponent fibers. Biocomponent fibers is produced from two or more polymers of different chemicals such as composition, additives or physical such as average molecular weight or crystallinity. It's extruded from one spinneret so that it can form a single fiber [42]. Microscopic view of bicomponent fiber is given below in figure 3.9.2 [42].

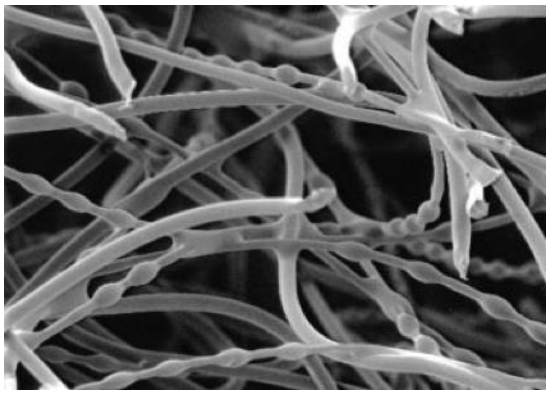

Figure 3.9.2 Microscopic view of biocomponent fiber.

3.9.3. Advantages of Thermal Bonding

Thermal bonding is one of the useful and important method to produce nonwovens. The advantages they possess are given below [9]:

1. Environmentally clean and friendly to environment because no chemicals are used for this bond.
2. It occupies less space but provides high production rate.
3. Like chemical bonding here there is no chemical extrusions so doesn't pollute water.

4. Products like diapers, sanitary, napkins and medical application this bonding is used because those products are made from cellulosic fibers, so it doesn't have any allergic reaction with body.
5. The products made by thermal bonding are soft to feel and it has good water absorbency also its water permeable.
6. Products made by chemical bonding face a loss of weight where thermal bonding doesn't have this problem.
7. For wadding and padding this bonding is perfect one.

3.10. Finishing

Finishing is also important like other steps for nonwoven. To get extra value of product producers always add value by increasing the technical functionality, appearances or aesthetics which helps to develop the fitness of product. There are still some finishing steps for nonwoven which are done prior to the conversation and packaging stages of nonwoven production. Dyeing, padding, or calendaring are some of the old and traditional processes of nonwoven finishing whereas there are few more. Technically two finishing method of nonwoven are bringing a great opportunity to develop the nonwoven fabric and increase the product function. In fig 3.10 flowchart of finishing is given below [25].

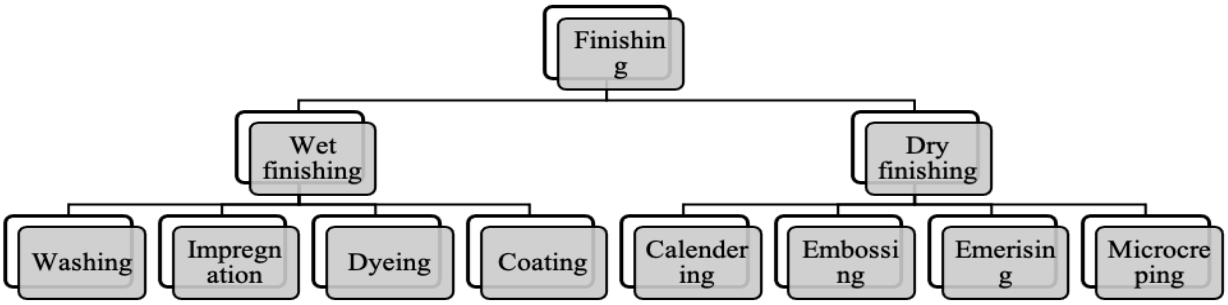

Figure 3.10 Processes of finishing of nonwoven [38].

Apart from these nonwovens also have some other finishing steps. Such as, nonwovens are also can be printed, flocked or combined with other fabrics. Also, it can be a as a film or foil to form laminate which make all the properties together of all layers who contributes [25].

4. MATERIALS AND METHODS

In this chapter the discussion will be included all raw materials and methods for the development of aquadesk materials. Also, we will focus on the discussion of manufacturing of aquadesk materials and test the absorbing water properties. Our main objectives are here to produce an aquadesk board with various raw materials mixing. Then make a discussion about the percentage of the raw materials in each sample. Find out the important properties and work on it to bring some changes and get a suitable result which can provide some advantages than previously used materials. Here we mostly used recycled polyester's (pet), bicomponent fibers (Bic), flex and super absorbent fibers. All those materials are provided by the company RETEX. To prepare this board we simply used normal fiber mixing procedure, carding and air laid.
Here is some detail about the raw materials we have used during the process.

4.1. Recycled Polyester

In 3.7.3 paragraph we already talked about recycled polyester. Here we are going to talk about some basic parameters regarding why we specially use recycle pes here instead of any other materials. We could also do this experiment by using some other cheap materials what could give us the nearest results we were expecting. As potential stuffs and properties about recycle pes are already discussed in mentioned paragraph, we will just briefly talk about the necessity behind we use PET in our experiment to make aquadesk board. One of them is it could add shape retention properties to our required aquadesk board. Recycled polyester has good resistance to shrinkage. It happens because of the chemical compositions of polyester. So, if we use recycled polyester as a main material here to make aquadesk board then it would add these useful properties to our product and make it durable for long use. Also using recycled polyester will take us one step forward to

sustainability. Using recycled polyester means the less use of petroleum as the raw materials. What is helpful in both environment and financial sides.

Also recycled polyesters can add shape memory properties here. After deforming it to another shape according to our need it can be reshaped again like the previous one before deformation. It's also a cost saving fact, and this can be called as a biodegradable and biocompatible one. In fig 4.1 the picture has shown which is taken during the experiment.

Figure 4.1 Recycled polyester

In Table 4.1 it was discussed about the properties of recycled polyester [6].

Table 4.1 Properties of Recycled Polyester

Molecular weight & viscosity	Both are less
Compressive strength	73.7 MPa
Tensile strength	7.85 MPa
Elasticity	27.9 MPa
Flexural strength	22.4 MPa
Sound absorption capacity	50-5700 Hz
Resisting capacity	Great resisting capacity

4.2. Bicomponent fiber

We have used bicomponent fiber here. The main reason behind it to get a bonding material. To make an aquadesk board we are mixing few different types of materials who has differences in properties and end applications. In that case bicomponent is working to bond all materials together by melting themselves with projected temperatures. Here we got this bicomponent fiber from the company called RETEX who offered this topic to us. So, the actual properties are secret because of company policies. This bicomponent fiber provides good thermal bonding, good bulking properties, very fine fiber properties, unique cross sections and better functionality. In the fig 4.2 it is showing the bicomponent fiber which has Been used throughout the process.

Figure 4.2 Bicomponent Fiber

4.3. Flax

It's a natural fiber which is extracted from the bast or skin of the stem of flax plant. We have already talked about this above in the 4.2.2 Paragraph. It had also provided us by the company retex. There are few properties of flax fiber which has a good role in our experiment. One important reason to use flax fiber to make this board is to gain strength. That helps to keep using it for a longer period. Also, it has a property to gain strength when wet and that is the most important task here as this aquadesk board must have a good water retention property. This board will continuously absorb water, but this flax fiber has a hydrophilic property which will keep it dry

after absorbing water. It has properties to keep the board cool in warm weather as most of time it will be configured on roof top. It doesn't have any static or pilling problems and its washable. So far, all these important properties it's going to be used here as an important one. that fiber which has been used throughout the whole process in mentioned in fig 4.3.

Figure 4.3 Flax

4.4. Super Absorbent Material

As this topic was about increase the water retention properties of aquadesk materials so super absorbent materials is the main difference maker here. Moisture regain percentage also depends on it. To increase the water retention properties, we need to change the percentage of super absorbent polymers we are using to make this aquadesk board. In fig 4.4 the super absorbent was used is attached.

Figure 4.1 Super Absorbent

4.5. Study on the given sample

There was a sample given by the company RETEX and the main term was study on it by checking the water retention properties of this sample. So, few samples were prepared from this big board

by cutting into the size (10*10) cm^2 most of them and measuring their gsm. Then find out the percentage of water retention properties of these cut samples by following the standard ASTM D-570-81.

Figure 4.5 Aquadesk Board

4.6. Process Flow Chart

Based on the methods and proposals found in the literature, a set of experiments were planned according to initial observation and the subsequent results need to obtain. With every iteration, a more accurate method was being proposed. Culminating in a satisfying method set up which can be used as the foundation of follow up studies.

4.6.1. Temperature study

Based on the methods and proposals found by the company and literature sample will be made by four raw materials which is already mentioned above whereas bicomponent will help to bond all materials together. So, to do this experiment we used an oven to heat up bicomponent fiber to find out a minimum melting point and actual time to melt. Here we found out the suitable temperature 120-125°C and the time could be 3-5 minutes to get it melt. The picture of that oven we used is attached in fig 4.6.1.

Figure 4.6.1 Oven

4.6.2. Opening, mixing, pressing & final product

The first step was to open and then mixing all the materials we had. The chart is mentioned below in fig 4.6.2. There were four different raw materials to make this sample but first, we had to open those materials by opener. It was an air laid process to open all the materials and mix it all together which follows the standards **ISO 9001:2008**. It was done by air to just get a uniform mixing air fiber. To do this first it needs to feed those materials which was supposed to be mixed. So, all the materials had gone through by a feeding belt. To get a uniform opening and mixing of raw materials it's good to keep the speed of feed plate slow. Here we used only 50% of the feed belt speed so that it can open those materials properly and into small particles and mix it uniformly and the feeding speed will one meter per minute.

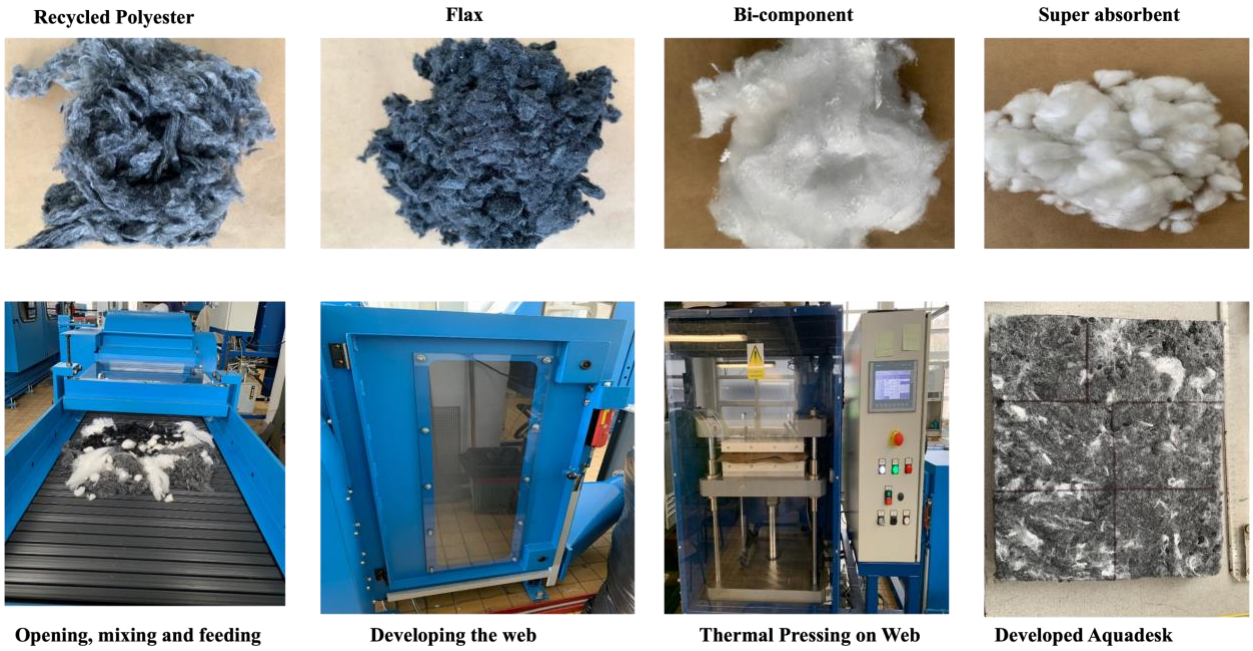

Figure 4.6.2 Design of Experiment

After the feeding done inside it there is a fan who works to mix all the opened materials together. The working rate of that fan was set up at 65%. There is a wire frame which catches all the fibers and hold it. It was enough to keep this process on until it opens all the feeding materials and mix it. Then it was collected from that wire frame. This whole opening and mixing process by airflow was performed by the standards **ISO 9001:2008.**

The next step of this part was thermal pressing. In previous step fiber web was prepared. So here with the help of thermal pressing the required product can be made. The machine was used who has properties mentioned below in the table 4.6.2 and the standard of this machine is **CSN EN ISO 12100.** It was used to put thermal press on the fiber web.

Table 4.6.2 Configuration of Pressing m/c

Type	HVL 15.2
Current	12 A
Pressing Force	150 kN
Heating plates	2*3.6 kW

According to the material properties and the temperature study it was known that bicomponent fiber was used here which has a melting temperature around 120-125°C and the melting time was 4 minutes precisely so after considering the fact the configuration of the pressing machine was similar. In fig 4.6.3 we can see two plates or boards which will press the feeding materials. It will generate the heat from both sides and the distance between the two heating boards can be controlled on the accurate thickness.

From the fig 4.6.2 its visible that siliconized papers are used to feed the fiber web in between two thermal pressing boards. It holds the mixed fiber web and protect it from not to stick with the heat pressing board. Moreover, its protecting and preventing from excess adhesive sticking to the surface or the press plate. After perfectly pressing done the result will be a developed aquadesk board (Fig 4.6.2). Before performing the next test gsm of each sample has to be measured.

4.6.3. Characterization

Temperature effect: During the thermal pressing process temperature can be flexible for pressing plates to melt the fusible materials. Here before starting the process the convenient melting temperature and time was fixed but few times increase the temperature doesn't justify the suitable results. Due to the increase of temperature more than 125°C the fusible bicomponent materials got melted fast and sample got more stiffness but apart from that there weren't many changes here.

Water Retention percentage: By following the formula 4.6.3 [43] we will get the measurement. Here 1st we must take the measurement of dry sample then we must put the sample into water retention test. After a certain minute when we get the wet or equilibrated sample then we need to take the measurement of the changing weight percentage by using this formula. For this water retention test to calculate the result the standard **ASTM D-570-81** was followed.

$$WR\% = \frac{Weight\ of\ equilibrated\ sample - Weight\ of\ dry\ sample}{Weight\ of\ dry\ sample} \times 100\% \text{.....(4.6.3) [43]}$$

After getting that final sample (4.6.2) now it's time to run some tests to get the water retention properties of the new sample. Here we are following a simple process to get the results. Considering some facts this test would be done in few angles. As the main task of aquadesk

materials using as a vegetation board of green roof [2] so the test will be conducted by considering two angles. Such as 0° and 30°. The sample will be set up with an angle of 0° and the next one will be with an angle of 30°. To do so the sample must need to be cut off into similar size of pieces. By considering the fact that the result should be the comparison between given sample (4.5) and self-preparing samples water retention properties so the same method will be applied on both samples. According to the fig 4.6.3 first step should be done by preparing all samples in same size. So here all those testing samples was (10cm×10cm). The motive behind keeping it all sample in same size so that the changes of weight will be visible whereas the cutting sample was taken from the same sample board. It will also bring the uniformities to check the comparison after it absorbs water.

First, the gsm will be measured for each sample then sample weight should be measured and noted. Then, samples will be placed on the board and after fixing the angle, water will be dropped on it. The amount of water was kept constant for every sample with different angles. It was done under room temperature and the observing time of the sample after pouring water considered 5 minutes. After this the weight of the sample was measured to check how much weight it gained by absorbing water. By following the equation (4.6.3) the percentage of water retention properties of each sample was measured.

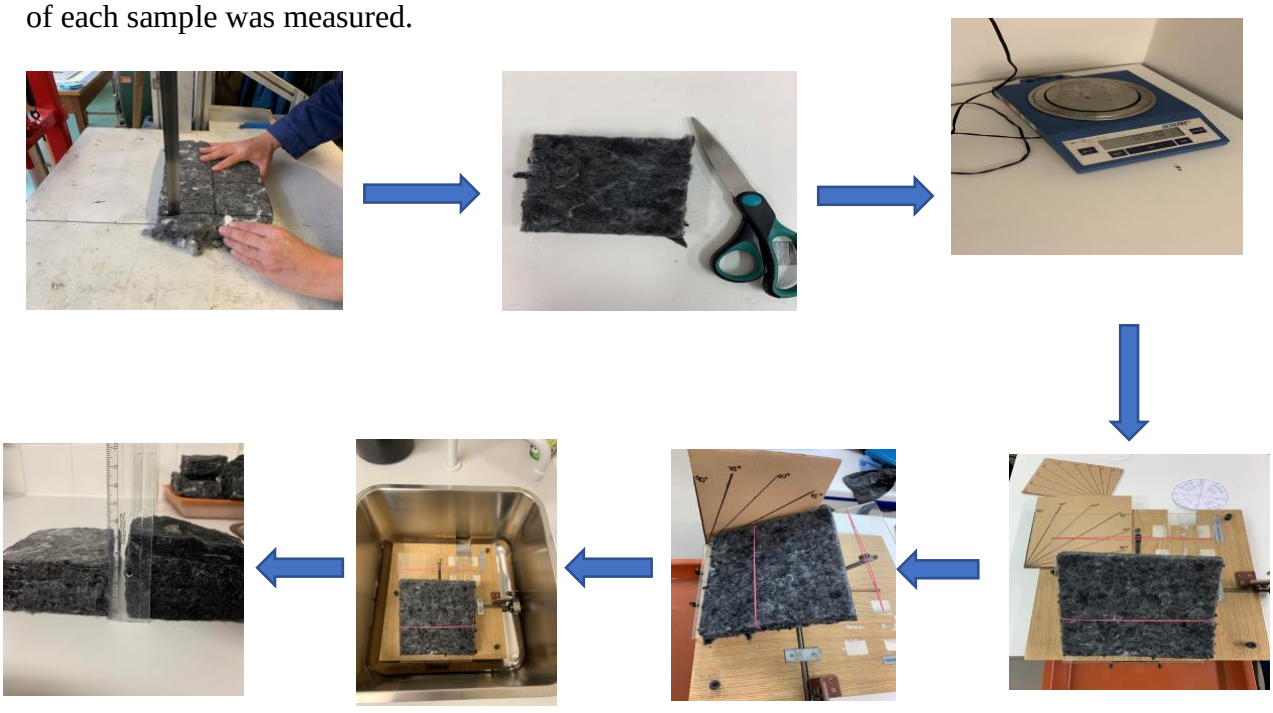

Figure 4.6.3 Steps of water retention test

5. RESULTS AND DISCUSSION

This chapter contains the results by following the experiments which is described in the previous chapter, also the discussion and analysis based on the data which is obtained and the studied method and principles.

5.1. Ratio of Materials

Here in table 5.1, it has shown that we have prepare some samples by changing the ratio of materials in those samples but the gsm of every newly prepared sample was close to the company made sample. There were few samples prepared with different ratio of raw materials to check which one can be proved with a better water retention property. By following the table 5.1 it can be noticed that time is constant for each sample preparing which is described in above paragraph 4.6.2.

Table 5.1 Ratio of Materials

Sample	PES %	Bicomponent%	Flax %	Superabsorbent%	Angle (°)	Time (min)	WR%	WR% (company)
Sample 1	50	20	20	10	0	4	0.151917098	0.04828105
Sample 2	50	20	20	10	30	4	0.121376438	0.04647619
Sample 3	50	20	25	5	0	4	0.119294067	0.037040498
Sample 4	50	20	25	5	30	4	0.104507432	0.035580737
Sample 5	45	20	30	5	0	4	0.09340443	0.038450561
Sample 6	45	20	30	5	30	4	0.076649382	0.033271028
Sample 7	60	15	15	10	0	4	0.140610902	0.038921215
Sample 8	60	15	15	10	30	4	0.102583587	0.039442295

As the main testing concern was changing the water retention properties so, to get a precise result here super absorbent materials had a good role. While making new samples the percentage of super absorbent materials was a main concern but after few tests it was fixed that the amount should be somewhere in between 5-10%. But later when the water retention test has done it showed 10% was the suitable one to get a good water absorbing properties. In the following table 5.1 there are four different types of samples which has different ratio of each raw materials but same types of raw materials. During the lab work there were plenty of samples prepared by using different ratio but among all of them these four has the best output. Then in the table its shown that every sample

was tested considering two different angles to check the water retention properties by placing the samples in two different angle positions because as it uses as a base or vegetation board of green roof so no matter that it always has a flat surface. it was done by following the standard **ASTM D-570-81.**

5.2. Comparison of water retention percentage

In table 5.2 the calculation is mentioned and where the following equation is use which has already shown in above equation (4.6.3) by following the standard ASTM D-570-81.

$$WR\% = \frac{Weight\ of\ equilibrated\ sample - Weight\ of\ dry\ sample}{Weight\ of\ dry\ sample} \times 100\%$$

Table 5.2 Water Retention%

SAMPLE	Weight Of Equilibrated Sample (g)	Weight Of Dry Sample (g)	Water Retention Result	Water Retention %
Sample 1	375	23,16	15,19171	0,151917
Sample 2	331,2	25,21	12,13764	0,121376
Sample 3	298,54	23,09	11,92941	0,119294
Sample 4	331,27	28,93	10,45074	0,104507
Sample 5	252,1	24,38	9,340443	0,093404
Sample 6	217,23	25,07	7,664938	0,076649
Sample 7	480,75	31,92	14,06109	0,140611
Simple 8	370,4	32,9	10,25836	0,102584

As there were a task to compare the newly prepared sample results with the company samples so in the following figure 5.2 it has shown that the four lab prepared samples showed good WR% than the company one but there are few parts to consider for newly prepared sample which can be worked in future because water retention properties is not only one to consider about the quality of a product. Considering this figure 5.2 its cleared that those new samples who has a good percentage of super absorbent materials are showing better WR% then the premade one from

company but not only the super absorbent materials also the ration of recycled polyester, flax and bicomponent fiber has a role to play here. As all their properties, advantages are already discussed in previous chapters. Furthermore, research should be done on this product to complete the samples and get the better performances from all aspects. Some of the future research on it will be mentioned in Future work section. According to the figure 5.2 the sample 1 from which was created in lab has percentages of raw materials (pes 50%, bicomponent 20%, flax 20% and superabsorbent 10% showed the better result in 0° angle test and in 30° angle test sample 2 shown the better result which has the same ratio of raw materials like sample 1 (table 5.1).

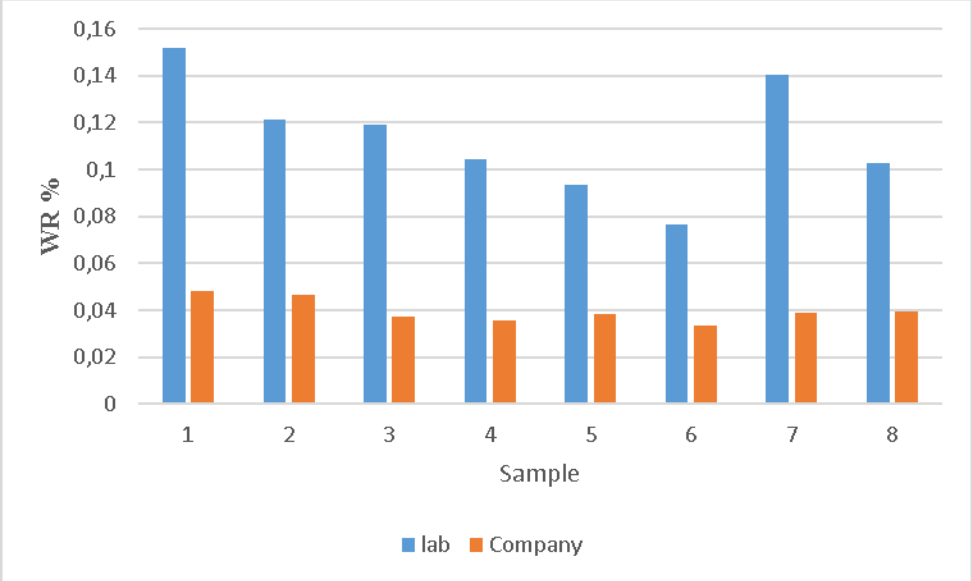

Figure 5.2 Comparison of water retention %

By following the standard ASTM D-570-81 and this test was done under room temperature. The result was carried out by following the WR% equation.

6. CONCLUSION

In this diploma work, there is an extensive literature review which was carried out about the present and the future impact of sustainable nonwoven textile such as green roof towards the environment, as well as the importance of sustainable textile in the field of textile was discussed here. Aquadesk board is one of the important parts of green textile project which can have huge impacts to develop the working capacity of green roof.

In this thesis the main goal was to increase the water retention properties of aquadesk board which is more important to green room water holding and transferring system. There was a sample already given by a company and few samples are prepared in lab by changing the percentage of materials and adding new properties materials. There were few samples which was made by changing the ratio of each raw materials every time. While changing the ratio of input raw materials the percentage of super absorbent materials was the focus along with others. The properties ratio of given sample was unknown because of company business policy but during the sample testing experiments few of the newly prepared samples showed better result than the company pre prepared one. Four raw materials such as recycled polyester (50%), Flax (20%), Bicomponent fiber (20%) and superabsorbent (10%) given the best water retention properties. There are few of them but among all, this one showed more differences in compare with the given sample. There were two different angles (0° and 30°) to conduct the water absorbency percentage test. Where the sample with mentioned properties showed water retention percentage (.152) and (.121) for the angle 0° and 30°. Which was better than the company one (.05) and (.04).

Water retention properties of aquadesk is directly connected to green roof water retention. This aquadesk board works as a vegetation board of green roof and the water drops on green roof it goes to aquadesk board due to its porous surface. so, the more water retention this board get it helps to absorb and store more water and help green roof when its dry due to lack of rain or water supplying source. It doesn't end here only. It helps to drain the excessive amount of water also that

can prevent some natural disasters like flood. Because to prevent the excessive level of water it just doesn't leave it away because under the hot sun the excess amount of water leaves the green roof as a vapor. So, during the rainy season the vast number of green roofs in a big city help to prevent small floods or excess water problems from rain.

There are significant chances to continue this research on various fields of aquadesk board. This sustainable textile has lots of opportunities to carry on some research on it to develop it more and increase the workability. Some of them will be mentioned in future work sections.

7. FUTURE WORK

By considering the diploma work water retention properties is not the only field to research about this topic. There are plenty more research can be done on this topic. In future if I get chances then I will conduct some more research on this topic such as acoustic properties of this board which is connected to soundproof property of aquadesk materials. There can be more research on this board about the changing of thermal conductivity or thermal insulation. this material has a good future to change the environment and by saving it from the pollution and provide comfort to mankind.

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