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MULTILAYER PAPER BOARD BY USING POLYURETHANE

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DECLARATION

I, Rifah Tasnia, Student ID: 140548 declare that this thesis is the result of my own research work except for quotations and citations, which have been duly acknowledged. I also declare that it has not yet been submitted or accepted for any other degree at any other institutions.

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DEDICATED
TO
MY BELOVED PARENTS

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ABSTRACT

This work was performed to assess alternatives and opportunities for the development of innovative laminated paper board made from newspaper, offset, white writing paper and polyurethane. The identification of such laminated board will create a stable market for recovered waste polyurethane and paper while providing a new material for application. The goals were to identify methods and processes to produce laminated paper with suitable properties. Three types of paper (newspaper, offset, white writing paper) to polyurethane mixing ratios (1:2, 2:3, 3:4, 4:5, 5:6) were designed to identify possible laminated paper board that would the interfacial strength between paper and polyurethane, Furthermore, five types of layered paper (Single Layer, Double Layer, 3 Layer, 4 Layer and 5 Layer) with different parameters like, temperature (160, 170, 180, 190, 200°C) and different thickness of paperboard were also designed to identify possible laminated paper board that would provide better tensile strength. Average Tensile Strength value for 3-layered Offset paper board was 40.78 $N/mm^2$the highest value among all the treatments.

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1. INTRODUCTION

1.1 Background of the study

Lamination is a process when multiple layers of a material cover another material or an object in order to improve its appearance, strength and resistance. Lamination paper is a type of paper which is used as a laminate (Sawyer et al., 1998). Lamination paper is often used on common copy paper in order to prevent the content of the paper being ruined by getting ripped or getting wet (Liebel, 1993). Lamination paper is also used on furniture, decoration panels and flooring. Apparently, the first proper use of laminating paper may have dated back to the mid-1800s where damaged documents where repaired with translucent paper (Bettendorf, 1946). Lamination paper was first widely used in the 1930s in order to strength copy paper. Lamination did actually exist before that as an insulator for industrial products. As more uses of plastic lamination was discovered, the product became more popular in the 30's (Smith, 1971). Especially after discovering that it could be used as decoration since looks are all that matters. Lamination paper also proved to be cost-effective for protecting large quantities of important documents(Mark, 1983).

Adhesives based on urea–formaldehyde and phenol-formaldehyde are commonly used, but are very sensitive to hydrolysis and stress scission(Desai et al., 2003). These adhesives also produce health hazards because of the formaldehyde they release(Ashida, 2006). To overcome such problems, scientists are trying to develop new polymeric adhesives. Polyurethane (PU) is a class of polymer that is used in coatings, elastomeric items, foams and adhesive (David et al., 2010). PU adhesive has developed a reputation for reliability and high performance. Its applications include footwear, packaging, automotive components, and furniture assembly. Properties of PU adhesives can be tailor-made to fit the application due to the great variety in raw materials that can be used to formulate PUs (Ulrich, 2002).Although for many years researchers have been trying to develop PU coatings and interpenetrating networks from oils, many different types of Pus have been made from synthetic chemicals (Schmelzer, 1988).

Paper and paper board are widely used in packaging applications and is biodegradable and therefore perfectly safe for the environment. Paper consists of a porous cellulose structure made up of micro fibrils, which are composed of long-chain cellulose molecules in a crystalline state with amorphous regions regularly disrupting the crystalline structure. The hydrophilic nature of cellulose, due to the OH sites in the basic unit of cellulose

($C_6H_{10}O_5$)and fiber network porosity, limits the water-vapor-barrier properties of paper. Paper packaging also easily absorbs water from the environment or from the food and loses its physical and mechanical strengths. Moisture migration can occur in paper by diffusion of water vapor through the void spaces as well as in condensed form through the fiber cell walls (Khwaldia et al., 2010).

Polyurethane (PUR and PU) is a polymer composed of organic units joined by carbamate (urethane) links. Polyurethane polymers are traditionally and most commonly formed by reacting a di- or tri poly-isocyanate with a polyol. Both the isocyanates and polyols used to make polyurethanes contain, on average, two or more functional groups per molecule. Polyurethanes are used in the manufacture of high-resilience foam seating, rigid foam insulation panels, microcellular foam seals and gaskets, durable elastomeric wheels and tires (such as roller coaster, escalator, shopping cart, elevator, and skateboard wheels), automotive suspension bushings, electrical potting compounds, high performance adhesives, surface coatings and surface sealants, synthetic fibers (e.g., Spandex), carpet underlay, hard-plastic parts (e.g., for electronic instruments)(Seymour and Kauffman, 1992).

Over the past several decades, industrial grade paperboard and hardboard have been recognized throughout the paper industry as ideal substrates for laminated paperboard constructions, utilizing various types of overlay surfacing materials (Paperboard, 1993). Laminated paperboard has been used widely in the secondary manufacturing processes in the paperboard and packaging industries. Paperboard has been favored by laminators because of its uniform density, thickness tolerance and surface smoothness (Fiske and Fogg, 1990). Other board properties such as dimensional stability, strength, stiffness, flatness and workability contribute significantly to the ease of fabrication and ultimate performance of the laminated end product. Laminated paperboard is a widely used packaging material (Hamad et al., 2013). Its use is increasing every year, mostly because it is almost 100% recyclable and inexpensive (Henshaw et al., 1996). Paperboard can be converted into packages by relatively straightforward operations such as cutting, folding and gluing (Morris, 2016). The main purpose of lamination of the paperboard is to protect the product from the undesirable effects of such factors as light, oxygen, humidity, and microbes. Depending on the application, coating functions also include improved grease proofness, heat resistance or peel ability, or enhanced printing and finishing properties (Khwaldia et al., 2010, Seboa, 2002).

The lamination process mostly depends on the types of materials to be laminated. The materials, which are used in the lamination process, can be the same or different, depending on the lamination processes and the object to be laminated. In the same way, the paperboard may be conventionally laminated with a various types of materials, such as polyethylene (PE), ethylene-vinyl acetate (EVA), polyvinyl chloride (PVC), polyvinylidene dichloride (PVDC), etc to increase the properties and durability. However, a difficulty in paperboard converting is the cracking of boards of high grammage during folding. Cracked folds render packages less appealing to consumers and also compromise their strength (Beex and Peerlings, 2009). Warping of paperboards is another long-standing problem associated with use of laminated paperboard industries. Warping is defined as the out-plane deformation of a panel from an initially flat condition (Cai, 2004). Some other types of problem also associated with the lamination of paperboards, such as irregular surface, delamination, etc(Panshin and Zeeuw, 1964);(Kirwan, 2005).

Nowadays, different experimental approaches and methods are carrying out by the scientists and researchers to overcome their respective issues in a good and satisfactory way. In the paperboard and packaging production sector, several types of experiments are going on to overcome the shortcomings and increase the lifespan of the products. In the history of paperboard, laminating process was carried out with various types of materials to protect the board properties (Mark, 1983). However, polyurethane is used to laminate the paperboard as a laminating material(Lee and Kim, 1996). And it could be a promising approach to produce multilayer paperboard laminating with polyurethane to enhance the properties of the multilayer board and its durability (Seboa, 2002). Thus, this study is intended to produce laminated multilayer paperboard with polyurethane and the technical feasibility of polyurethane as a laminating material. Newspaper, offset, white writing paper and polyurethane are the raw materials which are used to produce a laminated paperboard. Paperboard is made of renewable raw material. Wood is part of the ecological cycle of nature, a renewable and sustainable resource which we must manage with care. Forest management methods are developing rapidly, not only to meet wood quality and quantity demands, but also to secure biodiversity, meet wildlife needs and to provide opportunities for recreation.

1.2 Objective of the study

Many different polymers are used to coat paper surfaces in order to obtain a wide variety of properties, including decorative, barrier or functional properties. However, polyurethane can be tailor-made to enhance certain desired properties for a specific application. The other desired PU properties include minimum blockage of the coated paperboard to each other, thermal and chemical stability. Thus, the specific objectives of this study are:

- To assess the board from similar market board.
- To study the feasibility of laminated multilayer paperboard manufacturing with polyurethane.

2. LITERATURE REVIEW

2.1 General Introduction of Paper

2.1.1 Paper

Paper is a thin material produced by pressing together moist fibres of cellulose pulp derived from wood, rags or grasses, and drying them into flexible sheets. It is a versatile material with many uses, including writing, printing, packaging, cleaning, and a number of industrial and construction process (Holik, 2006).

2.1.2 Classification of paper

Paper is classified two broad categories; paper and paper board on the basis of weight per unit area of the sheet. The dividing line is usually a weight of 250 grams per square metre. A number of varieties of paper and paper board are distinguished. The better known ones are described below separately under paper and paper board (Khwaldia et al., 2010, Holik, 2006).

2.1.3 Categories of paper

There are different types of paper according to (Fiske and Fogg, 1990, Xia et al., 2002, Smook and Kocurek, 1982, Holik, 2006, Koubaa and Koran, 1995, Aurela et al., 1999, Gao et al., 2005). Among them the most important and familiar types are given below:

1) Animal paper: This is used for letters and circular mailed by air. Light weight is the most significant property. Opacity is also important.

2) Art paper: This is used for half-one reproductions of the highest quality. It consists of a base paper made of chemical pulp in which a surface coating of mineral matter mixed with adhesive is applied in such a way that the fibres of the body paper do not at all show on the surface.

3) Bible paper: This is a light-weight, opaque, printing paper used in books, bible and encyclopedias, where small bulk is an essential feature. It is generally made from rag pulp, using titanium dioxide as filler.

4) Bond paper: This is a grade of writing or printing paper originally used where strength, durability, and permanence are essential requirements, e.g., government bonds, legal documents etc. Its use has extended into other fields such as business letter heads and forms

where strength and permanence are really not so essential. Its special qualities are obtained by the use of a mixture of rag and chemical pulp.

5) Book paper: Book papers vary considerably according to the class of book involved. The better grades are usually made from chemical pulp, but for cheaper productions the papers are made largely of mechanical pulp.

6) Cigarette paper: The requirements of cigarette papers are rather exacting. The paper must have no characteristic smell or taste on burning and it must be thin but yet opaque. Opacity is secured by the addition of a filler such as calcium carbonate which also gives a good white appearance. The raw material used in India for cigarette paper is sun hemp (crotalaria juncea)

7) Cover paper: This is use for the outside covers of catalogues, pamphlets, booklets, magazines, and other printed matter requiring protection from handling. It is made from chemical pulp in a range of weights and colors.

8) Drawing paper: A good quality drawing paper must be strong permanent, white and opaque and should take on Indian and writing inks well, accept color wash without mottle and withstand the action of India-rubber or an erasing knife. It is made from rag pulp or chemical pulp and is well sized. Opacity is obtained by increasing the thickness as the weight of the sheet is of minor importance.

9)Grease-proof paper: The satisfactory permanence of grease-proof papers depends on the extent to which the pores have been closed. This is done by beating the fibres to a much greater extent than is necessary for most other papers, so that the pulp approaches the jelly stage. Paper made from such a pulp has comparatively few inter-connecting pores between the fibres with the result that the passage of liquida is difficult.

10) Imitation art paper: This is paper cheaper than art paper but with a surface similar to that of art paper. It is made by adding a large quantity of mineral loading to the pulp in the beater; it is decidedly inferior to art paper from the point of view of appearance and finish, but is sufficiently smooth to give reasonably good results with fine screen half-tone blocks.

11) Kraft paper: This is a comparatively coarse paper, particularly noted for its strength and is used as wrapper or packaging material. It is made entirely from unbleached pulp produced by the sulphate process. It is used as a wrapping paper. It is also covered into such products as grocer's bags , envelopes, multiwall sacks etc.

12)Ledger paper: This is used for writing purposes, especially for pen and ink-records. It is usually made from of a mixture of rag pulp and chemical pulp and is well sized. As it is subjected to appreciable wear, it requires a relatively high degree of durability and permanence. Significant properties include strength, erasibility, water and ink resistance, uniformity of surface and color and smoothness. A good surface for ruling is also important.

13) Newsprint: This is the paper used for newspaper printing. Cheapness is of paramount importance. Permanence is unnecessary but the printed matter must be clearly legible and half-tone illustrations recognizable. It is made from mechanical pulp containing sufficient (usually about 30 per cent) chemical pulp to give the sheet necessary strength.

14) Vegetable parchment: This is a paper resembling animal parchment. It is made by passing a sheet prepared from rag or pure chemical through a bath off sulphuric acid and then thoroughly washing and drying it. It is odorless, tasteless and grease resistant and has a high wet strength. It is used principally as a wrapper for butter, meat, fish and almost all moist food products and as an especially for letter -heads etc.

15) Blotting paper: this is the simplest paper from the structural point of view. In its manufacture the main object is to produce an open, absorbent sheet and therefore the blocking of the channels should be avoided. The fibres should be clean and of good quality (preferably cotton) and the beating process is restricted to a cutting action. No loading is added in the beater.

2.2 Laminated Paper

Lamination paper is a paper used for laminates. Normally on particle or fiber board giving a good-looking and resistant surface for use as furniture, decorating planner and flooring (Paulapuro, 2000).

2.2.1 Laminated Particle Board

Laminated particle board is manufactured by attaching a thin layer of laminates on the surface of plain particle board. The lamination enhances beauty and increases durability of particle board. Laminated particle board is widely used to make modular kitchen, as well as wardrobes and shelves, particularly shutters, as it avoids subsequent polishing and painting (Mandic et al., 2015).

Laminates are most commonly used surface finish for furniture elements, as they provide decorative look in comparatively less price. They also enhance the durability of the furniture as they are scratch resistant and easy to clean. Due to availability of various types of laminates, commercial and corporate offices, industries, restaurants, hotels, showrooms, etc. are also now decorated by using laminates(Shibata et al., 2006).

There are different types of laminates available in the market according to their application. Here I have tried to provide the brief information on different types of laminates according to (Vlot and Gunnink, 2011, Gao et al., 2005, Holik, 2006, Khwaldia et al., 2010, Shibata et al., 2006). The various types of laminates are as follows:

2.2.1.1 Types of Laminates Based on Pressure Applied

a) High Pressure Laminate (HPL):

High pressure laminates are produced by attaching the décor paper at high pressure to the kraft paper. They are commonly fixed by carpenters over plywood and MDF while making the furniture. High pressure laminates are extremely durable and can take heavy loads.

b) Low Pressure Laminate (LPL)

In low pressure laminates, the decorative paper is soaked in melamine resin, and the laminated paper is then directly bonded to particle board or fiber board (MDF and HDF) at low pressure.

2.2.1.2 Types of Laminates Based on Thickness

(a) Regular Laminate Sheets

The regular laminate sheets have a thickness that ranges from 8 mm to 1.5 mm. These sheets are glued by carpenters to substrate materials such as plywood using common adhesives like Fevicol.

(b) Compact Laminate Sheets

Compact laminate sheets have a thickness ranging from 3 mm to 30 mm. These laminates are self-supporting and hence do not need to be glued to woods or any other material. The top and bottom sides of compact laminate sheets have decorative surfaces.

2.2.1.3 Types of Laminates Based on Usage

a) Decorative Laminates

Decorative laminates are hard sheets of around 1 mm and are widely used to give finished look to the furniture elements. They are commonly used to decorate and protect wooden furniture. Decorative laminates are manufactured in a wide variety of colors, designs and textures. They are generally used in residential areas to create a decorative look of the house.

(a) Industrial Laminates

The industrial laminates have higher strength, higher resistance to scratches and wear and tear and durable. They are also fire-resistant, antibacterial and chemical resistant. They have wide application in industries and hospitals. Circuit boards are made using industrial laminates.

2.2.1.4 Types of Laminates Based on Surface Finish

(a) Solid Colored Laminates

These are the most common laminate sheets. The whole laminate sheet is of one solid color. It is generally used in bathroom vanity and kitchen countertop.

(b) Gloss Finished Laminates

There is a glossy finish to the décor paper, and can often make the furniture look more eye catching and stand out with this type of finish. It is most commonly used in restaurants, hotels, and in event industry.

(c) Matt Finished Laminates

This is a flat finish that gives "matt" effect on the surface of the laminate. It is more commonly used in corporate areas like large professional business offices where a subtle but stylish look of office is desired.

(d) Textured Laminates

Textured laminates are designed such that you can feel the pattern or texture, which is printed on the décor paper. Generally natural materials such as wood, natural stones, leather, metals, etc. They give realistic effect to the furniture. They are most commonly used for wall cladding and flooring.

(e) Wood Grain Laminates

Wood grain laminates are designed in such a way that they give aesthetics like real wood. They are extensively used for laminate wood flooring. Wood grain laminates are available in various designs of hardwoods as well as softwoods.

(f) Metal Laminates

Metal laminates give metallic look to the surface of furniture. Metallic laminate is ideal for commercial as well as residential purpose. It is used in offices, corporate buildings, showrooms, etc.

(g) Leather Laminate Sheets

Leather laminate sheets give look of leather material. Leather laminate sheets are used in cabinets and other furniture elements.

05. Types of Laminates Based on Advanced Properties

(a) Fire Rated Laminate

Special fire resistant resin is used to make these laminates. Fire rated laminate is commonly used for interior decoration in fire prone applications like, industry, airports, hospitals, institutions & banks, kitchens, etc.

(b) Anti-Bacterial Laminate

In hospitals and restaurants where hygiene is most important, these laminates are widely used. Antibacterial laminate resist growth of bacteria and pathogens.

(c) Outdoor UV Laminates

Outdoor UV laminates are used to make billboards.

(d) Electrostatic Dissipative Laminate

Electro static dissipative laminates are commonly used in electronic assembly, dust-free environments for manufacturing of circuit boards and other work areas like hospitals, medical offices and laboratories.

2.3 Application of Laminated Paper Board

Lamination paper is a paper used for laminates. Normally on particle or fiberboards giving a good-looking and resistant surface for use as furniture, decoration panels and flooring. Through laminating different papers, a wide variety of characteristics are possible making this a very versatile application of laminated paper board. The laminated paper board is often used as:

- The back cover of photo frame
- Packaging material
- File holder
- Toys
- Food and drink packaging
- Consumer goods packaging
- Industrial packaging
- Retail ready packaging

2.4 Advantages of Laminated Paper Board

The advantages of using laminated paper board over normal paper board

- The laminated paper board is considered environmental friendly
- Complete utilization of paper is achieved
- More aesthetic value than normal paper board
- Require less time
- Lower cost as long lasting
- Minimize the adverse effects knots, defects and so on
- Most durable thus, save our woods and forest

(Vlot and Gunnink, 2011, Gao et al., 2005, Holik, 2006, Han et al., 2010, Paulapuro, 2000, Kirwan, 2008)

3. MATERIALS AND METHOD

3.1 Materials and Equipment

3.1.1 Paper

Three different types of well available paper materials are used which are Newspaper, Hand sheet paper and Offset paper.

3.1.2 Polyurethane

Polyurethane is used as a binder and laminating agent for producing multilayer paper board.

3.1.3 Hot press

Particleboard a digital hydraulic hot press was used to press the mat into particleboard. It has multi-layer plate. The both platen were movable up and down. Maximum temperature range within 400 c and pressure up to 4MPa commonly occur.

3.1.4 Hydraulic Universal testing Machine (UTM)

An analogue hydraulic Universal Testing Machine (UTM), model: WE-100, made by time group Inc. was used to determine the mechanical properties of the particleboard. There were two units of this machine, one was control unit and another was working unit. A meter was attached with the control unit for measuring the load (KN). And a scale (mm) was attached with the working unit to measure the deflection. The length of the span, on which the samples were laid, was 248 mm. Another part of the working unit was used to determine the tensile strength, which works vertical.

3.1.5 Scissors

Scissors are hand-operated shearing tools and mostly used for cutting purpose. We used it to cut the paper and polyurethane as well as different regular laboratory purposes.

3.2 Method and Procedure

3.2.1 Collection of raw material

Newspaper, Hand sheet, Offset, Polyurethane were purchased from the local market of Khulna under Khulna District, Bangladesh. These were used for the manufacturing of paper

plastic board or laminated board. The weight of the poly-urethane was 0.369gm and the thickness of the poly-urethane was 0.13mm. The characteristics of using paper are:

- Rectangular
- Not less than 3½ inches high, 5 inches long, and 0.007 inch thick
- Not more than 4¼ inches high or more than 6 inches long, or greater than 0.016 inch thick.

3.2.2 Preparation of raw material

The papers and polyurethane were cut in conventional size

3.2.3 Manufacturing Place

The paper plastic board or laminated board was manufactured at wood lab that is controlled under by Forestry and Wood technology discipline, Khulna University, Khulna. All tests for it quality were also done here.

3.2.4 Manufacturing procedure

3.2.4.1 Mat Formation

After collecting the raw material, the each type of paper were formed into mat. the mats of each type were formed manually. At first I made single layer of each type paper like newspaper, white writing paper, offset. In this layer one polyurethane was coated both side with paper. Then I made double layer of each type paper. In this layer, two polyurethane was coated with three papers. In this process I made third, fourth and fifth layer.

3.2.4.2 Hot Pressing

After mat formation, a steel sheet was placed onto the mat. At the same time, the electric coil was switched on to raise temperature before inserting the mat into it. When the temperature was raised up to 160c then the single layer mat was inserted manually into hot press for pressing. After inserting the Mat into the hot press, the pressure was raised manually by digital hydraulic hot press up to 10 MP. There the total press time was 15 minutes.

Later the double layer mat was inserted manually into the hot press; the pressure was raised manually by digital hydraulic hot press up to 10MPa. There the total press time was 15 minutes, temperature was 170°C.

Then the third layer mat was inserted manually into the hot press, the pressure was raised manually by digital hydraulic hot press up to 10MPa. There the total press time was 15 minutes, temperature was 180°C.

After the fourth layer mat was inserted manually into the hot press, the pressure was raised manually by digital hydraulic hot press up to 10MPa. There the total press time was 15 minutes, temperature 190°C.

Lastly the fifth mat was inserted manually into the hot press, the pressure was raised manually y digital hydraulic hot press up to 10MPa. There the total press time was 15 minutes, temperature was 200°C.

3.2.3 Finishing of manufactured laminated board

3.2.3.1 Conditioning

After stopping temperature the board was remained fixed for cooling and conditioning. The boards are removed from the hot press machine and further conditioned to equilibrate board moisture content and to stabilize and fully cure the adhesives (AWPA, 2001)

3.2.3.2 Trimming

Laminated boards have been cut into conventional size.

3.3 Laboratory test

3.3.1 Tensile Strength

Tensile strength, the maximum tensile force developed in a test specimen before rupture on a tensile test carried to rupture under prescribed conditions. Tensile strength (as used here) is the force per unit width of test specimen (Rhim, 2010).

The tensile strength was tested by UTM in the laboratory of forestry and wood technology Discipline, Khulna University, Khulna.

3.3.2 Data Analysis

All the data, obtained during the laboratory tests for characterization of tensile strength of each type of particleboards were analyzed by using Microsoft Office Excel 2010 (USA) and IBM SPSS 20 (USA). ANOVA (Analysis of Variance) were done to analyze the data ($\alpha \leq 0.05$).

4. RESULTS AND DISCUSSION

4.1 Tensile Strength of Different Types of Paper Board with Variation of Layers

A variation of the mean values of tensile strength over different layered of Offset paper board is shown in Figure 1.

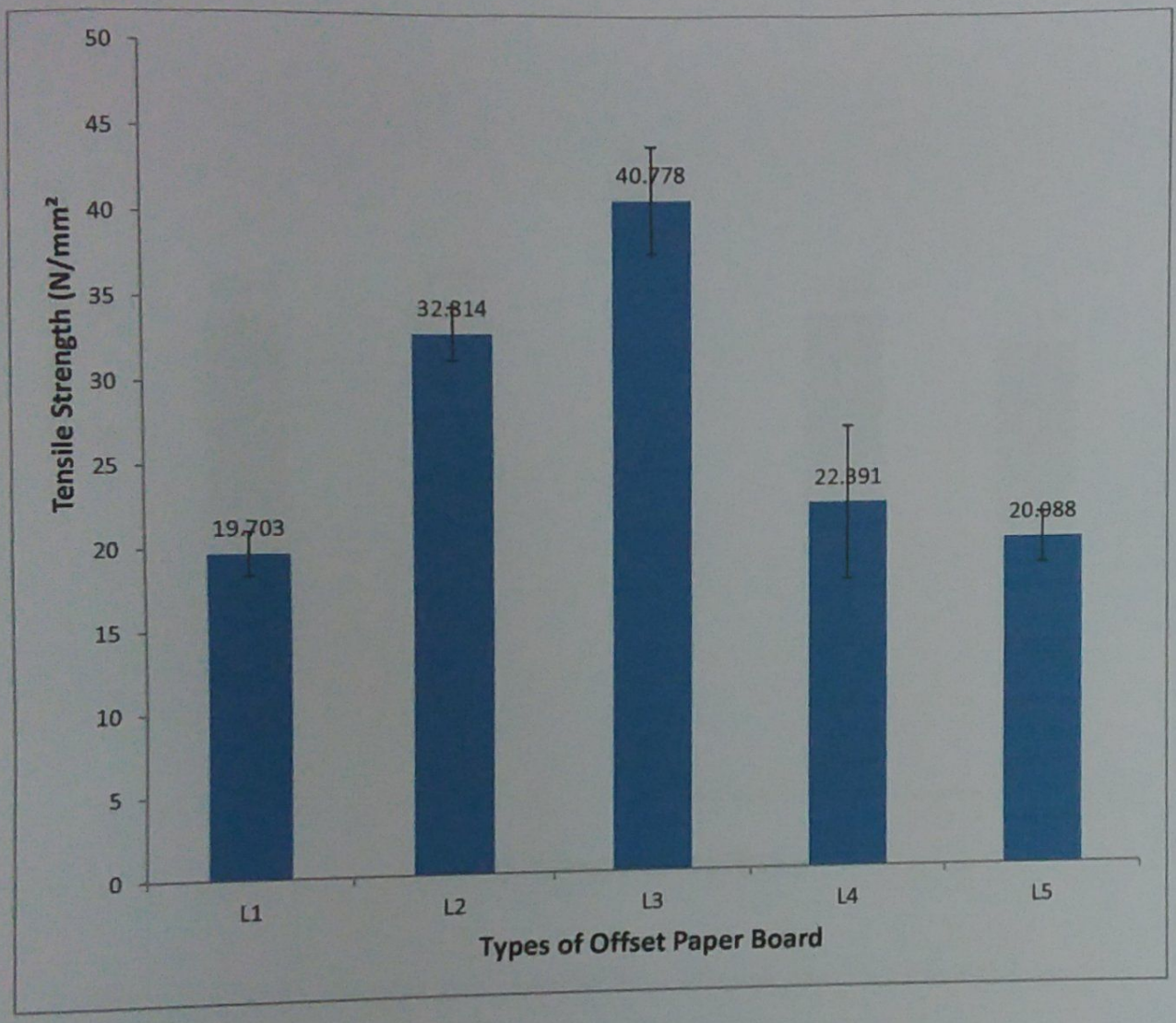

Figure 1. Tensile Strength of Offset Paper Board with Variation of Layers

In case of Offset paper board, among five treatments (L1, L2,L3, L4 and L5), 3-Layered paper board (L3) resulted in highest tensile strength value (40.778 N/mm^2) followed by L2, L4, L5 and Single Layer paper board (L1) resulted in the lowest tensile strength value (19.703 N/mm^2).

A variation of the mean values of tensile strength over different layered of Offset paper board is shown in Figure 2.

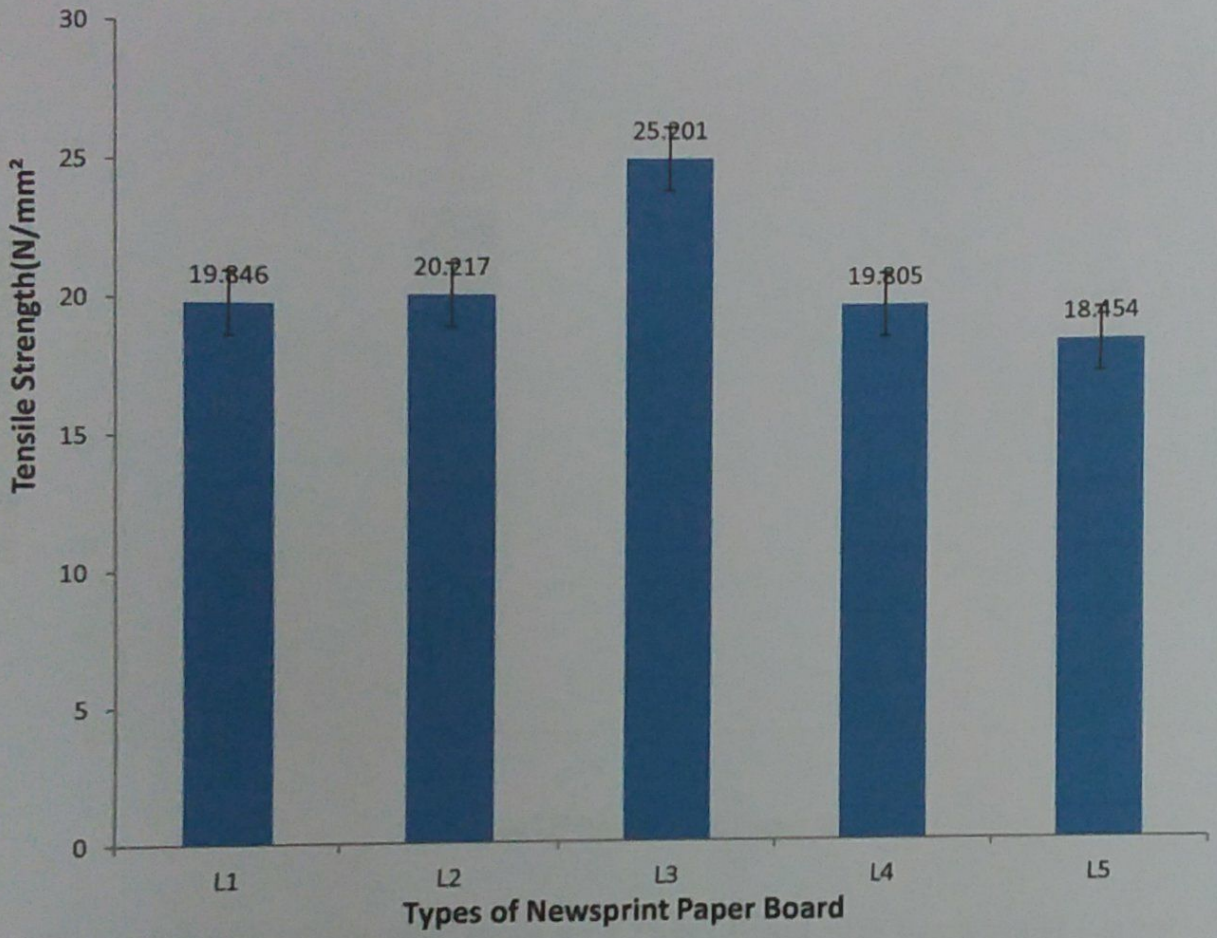

Figure 2. Tensile Strength of Newsprint Paper Board with Variation of Layers

In case of Newsprint paper board, among five treatments (L1, L2,L3, L4 and L5), Likewise Offset paper board 3-Layered paper board (L3) resulted in highest tensilestrength value (25.201 N/mm^2) for newsprint paper board as well and 5-Layer paper board (L5) resulted in the lowest tensile strength value (18.454 N/mm^2).

A variation of the mean values of tensile strength over different layered of Offset paper board is shown in Figure 3.

In case of Hand sheet paper board, among five treatments (L1, L2,L3, L4 and L5), 2-Layered paper board (L2) resulted in highest tensile strength value (27.215 N/mm^2) and 4-Layer paper board (L4) resulted in the lowest tensile strength value (11.124 N/mm^2).

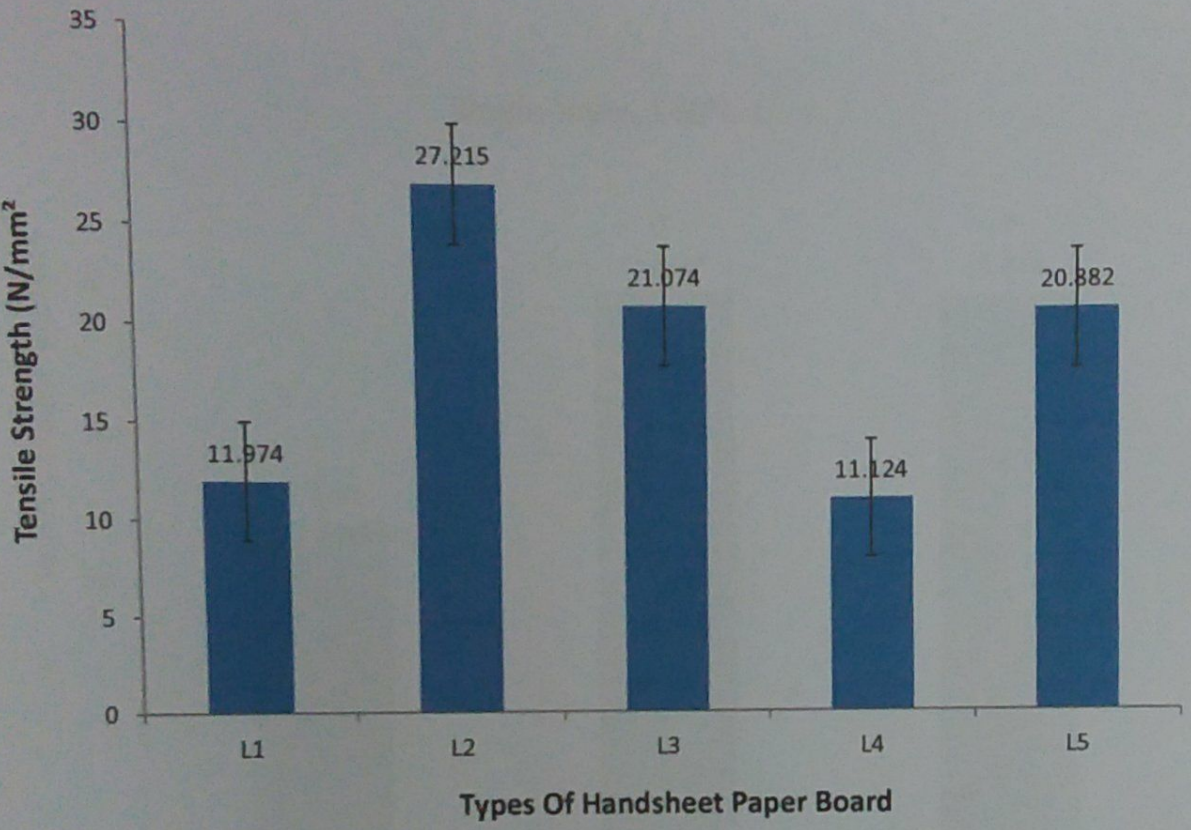

Figure 3. Tensile Strength of Hand sheet Paper Board with Variation of Layers

After all of this data interpretation for tensile strength over different types of layer board, we observed that in offset paper board, 3-layer board showed highest tensile value likewise in newsprint paper board. But in case of Hand sheet paper board 2-layer showed highest and best tensile strength.

(Rhim, 2010) produced solid-bleached-sulfate (SBS) paperboard and he got 17-30 N/mm^{2}tensile strength. (Aremu et al., 2015) also summarized the offset paper and newsprint paper board tensile strength and he got 32-55 N/mm^{2}tensile strength for offset paper and 9-17 N/mm^{2}tensile strength for newsprint paper. (Fadiji et al., 2017) investigated different tensile strength of paper board used for different packaging material and observed 21.9-35.9 N/mm^{2}tensile strength.

4.2 Tensile Strength with Different Types of Paper Used for Paper Board

A variation of the mean values of tensile strength over different types of boards for single layer paper board is shown in Figure 4.

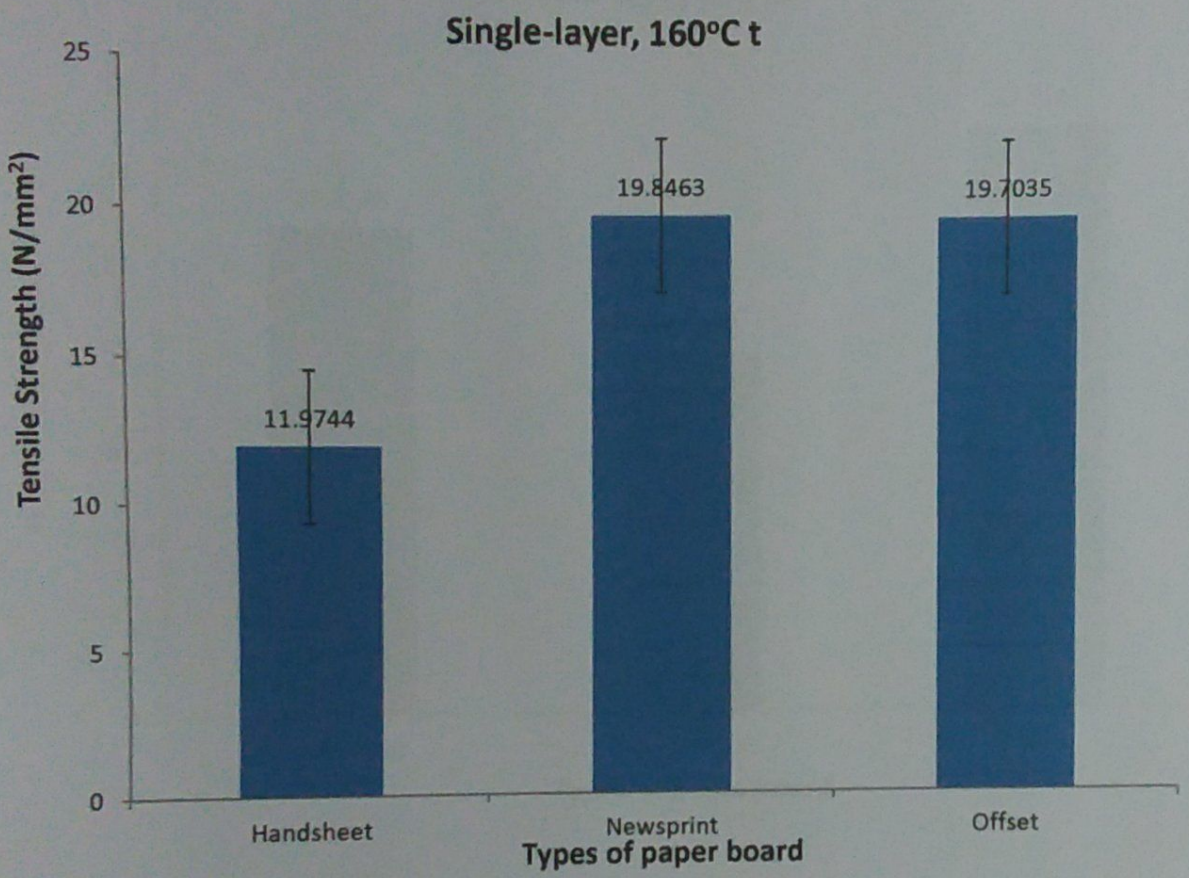

Figure 4. Tensile Strength of Paper Board using Different Types of papers for Single Layer Paper Board

In case of Single Layer, among three treatments (Hand sheet, Newspaper and Offset Papers), Paper board using Newsprint paper resulted in highest tensile strength value (19.8463 N/mm^2) and Hand sheet paper board resulted in lowest tensile strength value (11.9744 N/mm^2). Offset paperboard resulted very close value (19.7035 N/mm^2) to Newsprint. This may be occurred because of their fiber strength.

A variation of the mean values of tensile strength over different types of boards for single layer paper board is shown in Figure 5.

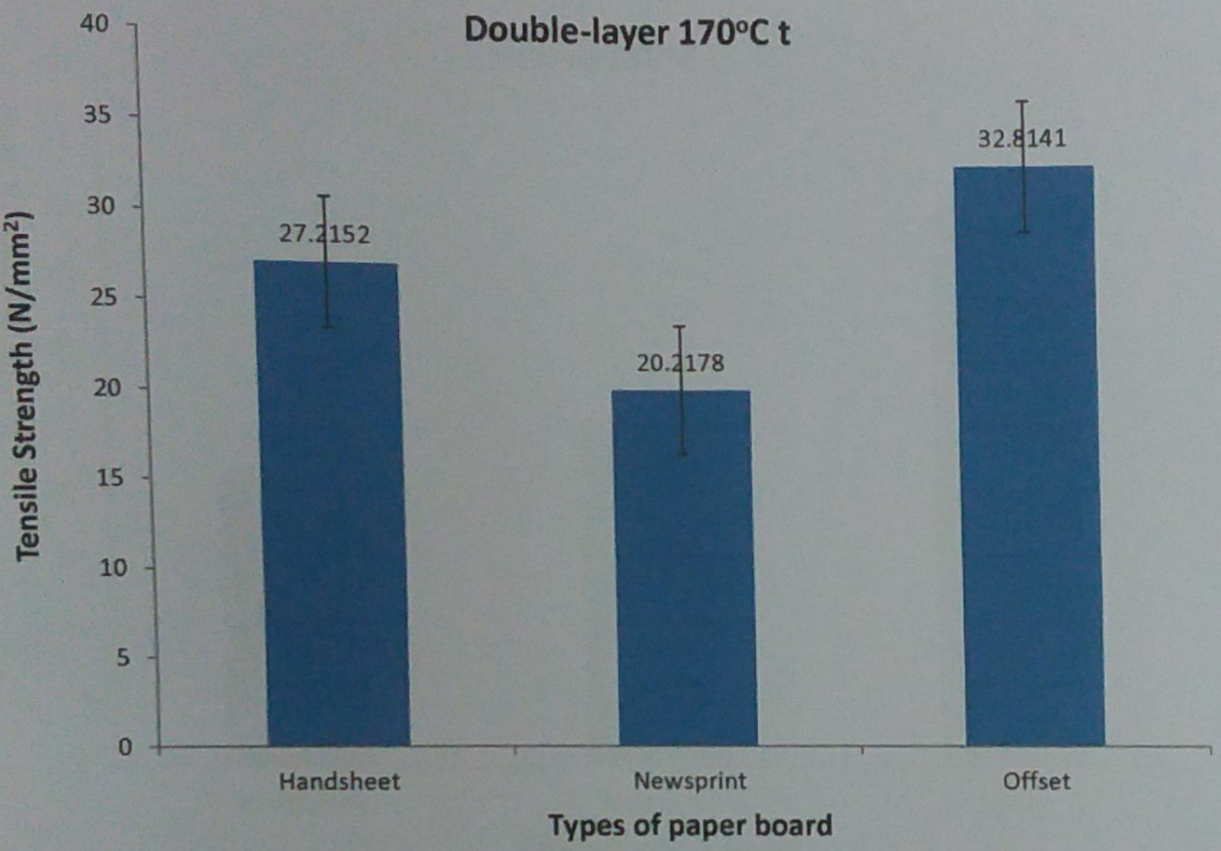

Figure 5. Tensile Strength of Paper Board using Different Types of papers for Double Layer Paper Board

In case of Double Layer, among three treatments (Hand sheet, Newspaper and Offset Papers), Paper board using Offset paper resulted in highest tensile strength value (32.8141 N/mm^2) followed by Hand sheet and Newsprint where Newsprint paper board resulted in lowest tensile strength value (20.2178 N/mm^2).

A variation of the mean values of tensile strength over different types of boards for single layer paper board is shown in Figure 6.

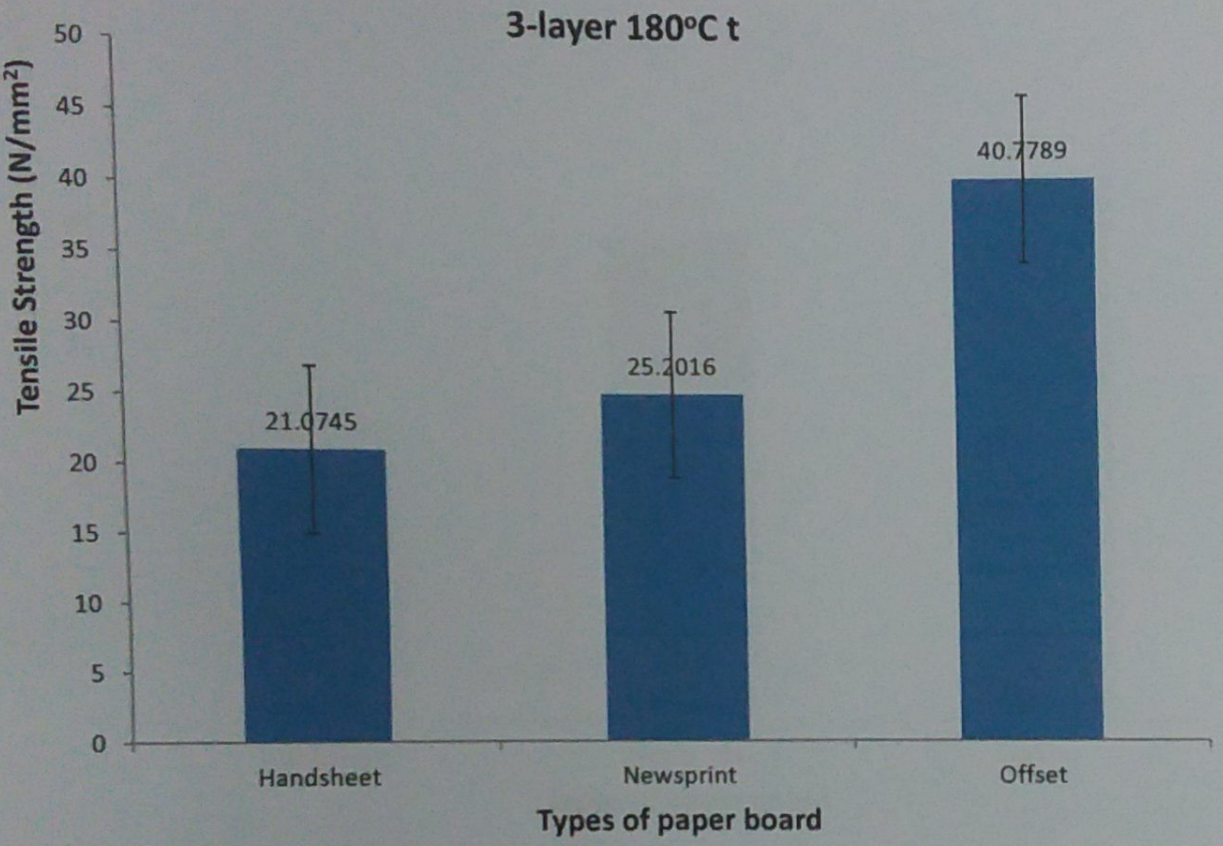

Figure 6. Tensile Strength of Paper Board using Different Types of papers for 3 Layer Paper Board

In case of 3-Layered, among three treatments (Hand sheet, Newspaper and Offset Papers), Paper board using Offset paper resulted in highest tensile strength value (40.7789 N/mm^2) which is the highest value for all the other treatments. Hand sheet paper board resulted in lowest tensile strength value (21.0745 N/mm^2) in 3-layered paper board. It may be happened due to low fiber strength of Hand sheet paper. In addition, it may assume that increasing of layer increasing the tensile strength, but testing result showed that 3-layer board showed highest tensile strength.

A variation of the mean values of tensile strength over different types of boards for single layer paper board is shown in Figure7.

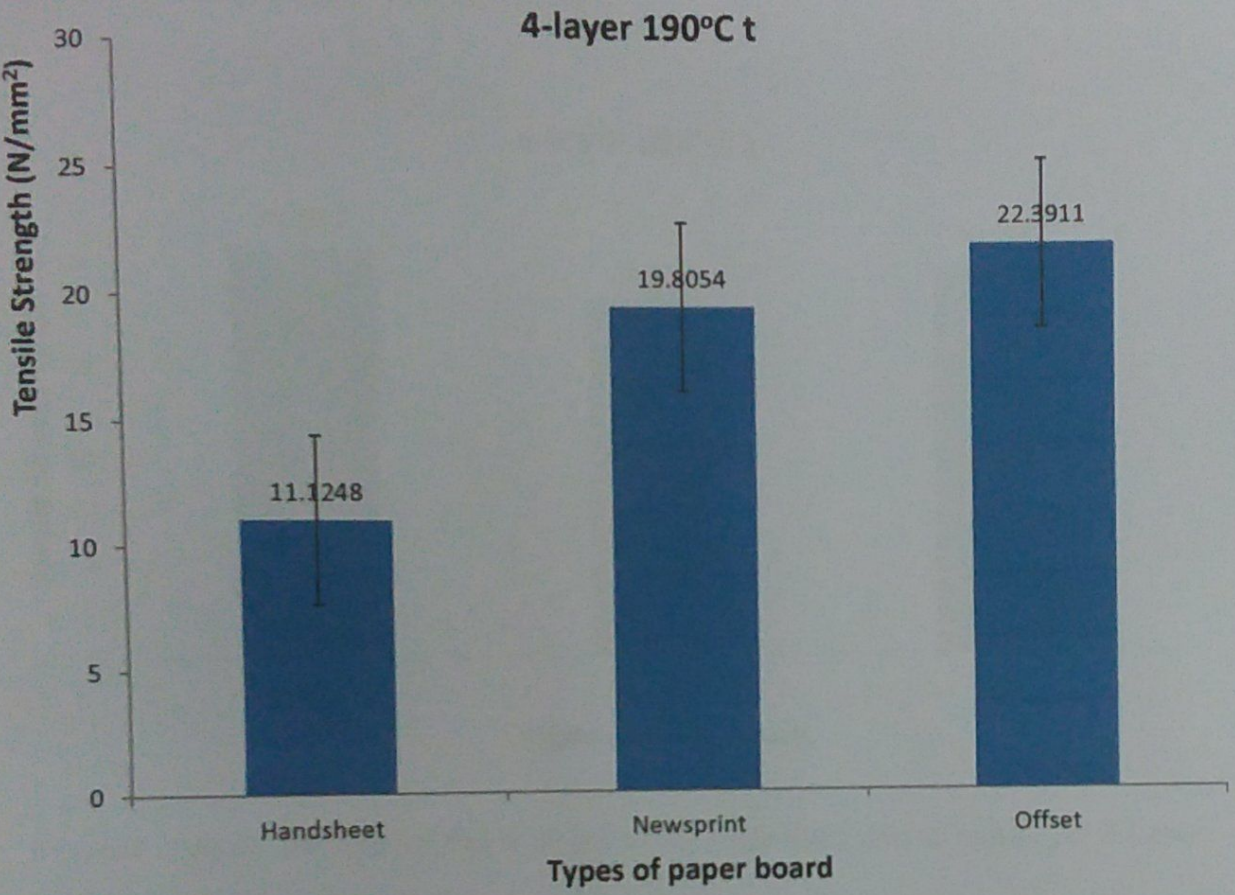

Figure 7. Types of papers for 4 Layer Paper Board Tensile Strength of Paper Board using Different

In case of 4-Layered, among three treatments (Hand sheet, Newspaper and Offset Papers), Paper board using Offset paper resulted in highest tensile strength value (22.3911 N/mm^2) followed by newsprint and Hand sheet where Hand sheet paper board resulted in lowest tensile strength value (11.1248 N/mm^2).

A variation of the mean values of tensile strength over different types of boards for single layer paper board is shown in Figure 8.

In case of 5-Layer, among three treatments (Hand sheet, Newspaper and Offset Papers), Paper board using hand sheet paper resulted in highest tensile strength value (20.8827 N/mm^2) with very close to Offset paper (20.0884), and Newsprint paper board resulted in lowest tensile strength value (18.4549 N/mm^2).

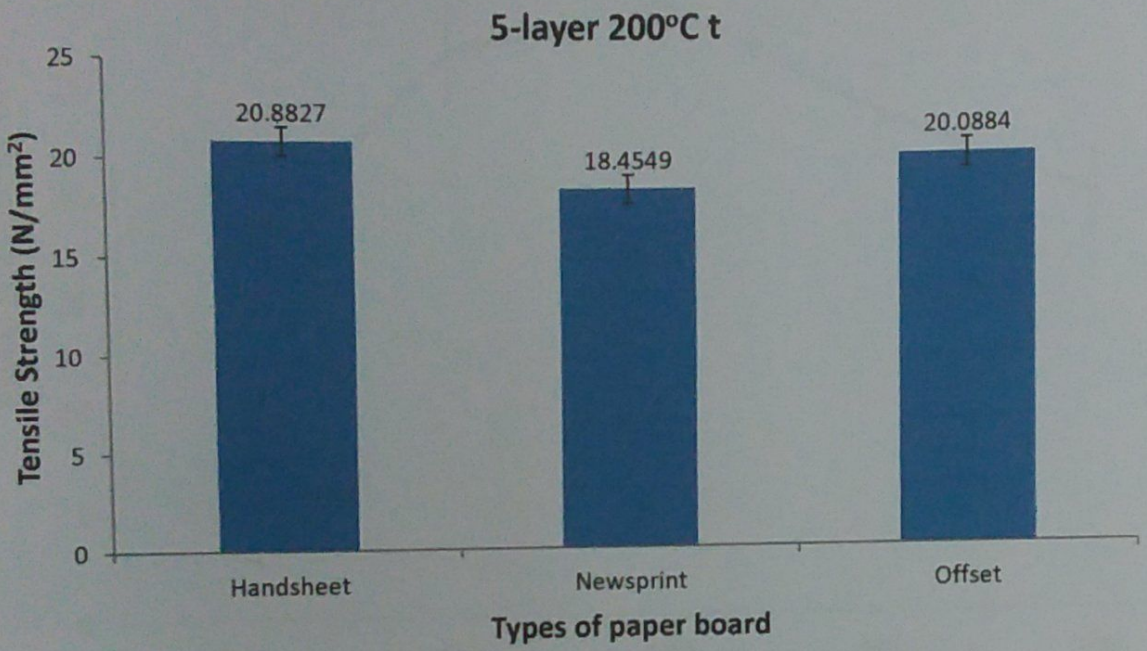

Figure8. Tensile ***Strength of Paper Board using Different Types of papers for 5 Layer*** **Paper Board**

After all of this data interpretation, we observed that Offset paper board is best and it showed highest result in most of the time. Among five layer treatments 3-layer Offset paper board showed highest tensile value (40.7789 N/mm^2) among all others. Furthermore, for single layer, newsprint is best but very close to offset paper board, for double, 3 and 4-layer paper board offset is best and very interestingly in 5-layer board Hand sheet showed highest tensile value though very close to offset.

According to Fadiji et al. (2017), investigation of mechanical properties of paperboard materials showed 21.9-35.9 N/mm^2tensile strength with different thickness of the board. (Rhim, 2010), (Aremu et al., 2015) also resulted similar result in tensile strength of paper board.

4.4 Tensile Strength with Different Types of Paper and Different Thickness

A variation of the mean values of tensile strength with respect to different temperatures used in paper board is shown in Figure 9.

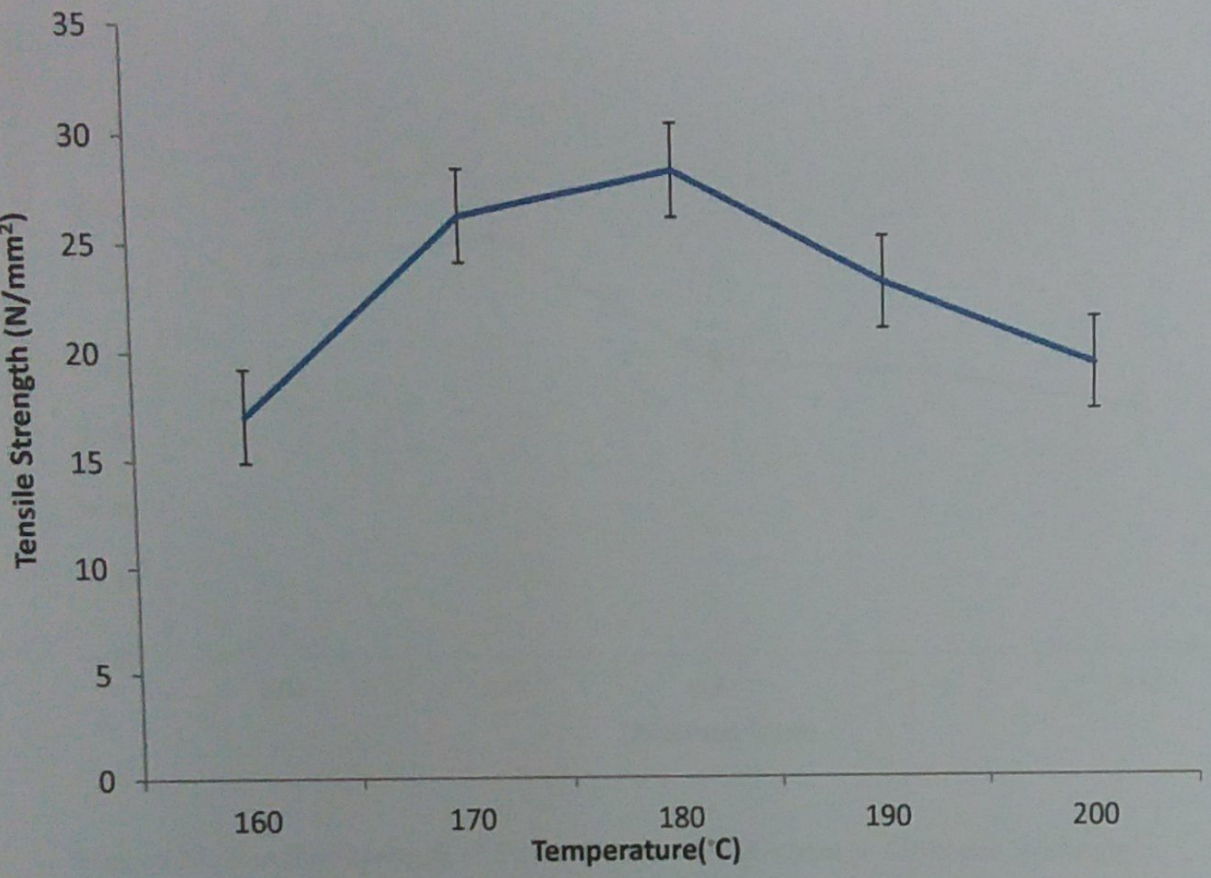

Figure 9. Tensile Strength of Paper Board using Different Types of papers for 5 Layer Paper Board.

The greatest mean value of tensile strength (29.0183 N/mm^2) was obtained at 180°C temperature among all five temperatures treatments (160, 170, 180, 190, 200°C). At first the mean value of tensile strength was increased with increasing of temperature (160-180°C) and after highest tensile value point at 180°C temperature, it started to decrease with increasing of further temperature. It may be happened because of the inner bonding capacity of chemical components of polyurethane decreases after a certain temperature. Time (15 minutes) and pressure (10 MPa) was fixed.

4.5 Tensile Strength with Different Types of Paper and Different Thickness

A variation of the mean values of tensile strength with respect to different thickness of boards are shown in Figure 10.

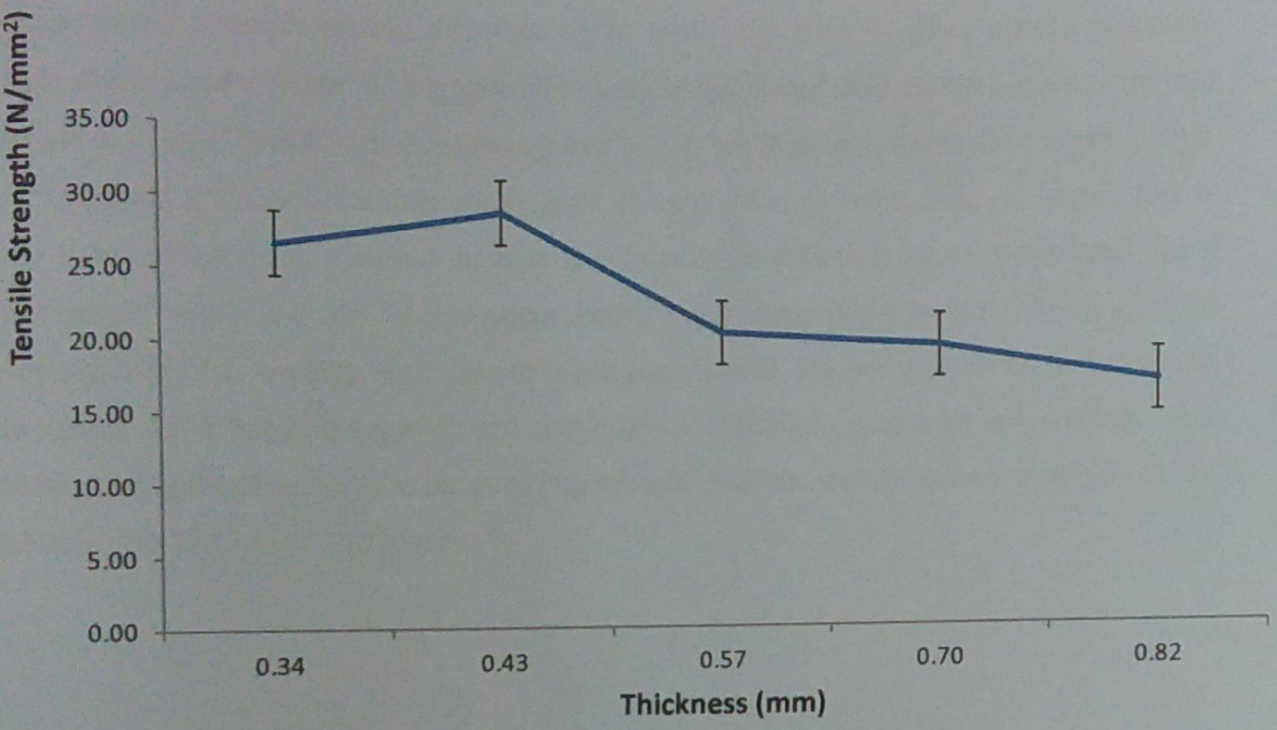

Figure 10. Tensile Strength of Paper Board with Respect to different thickness

Graph showed that initially increasing of thickness of the board increase the tensile strength of paper board, but after getting the greatest strength it decreased down with increasing of thickness of the board. 0.43 mm thickness of board showed highest tensile value (29.02 N/mm^2), and 0.82 mm thickness which is highest thickness among the treatments showed lowest tensile value (17.17 N/mm^2). It may be happened due to using polyurethane to make multilayer paper board, more thickness of the board means more number of layers used, so after a certain thickness it decreased with increasing of more layer, and polyurethane may fail to bond them perfectly when used multilayer board. Earlier we observed that 3-layer offset paper board showed the highest tensile value among five treatments (single to 5-layer board). If we used commercial adhesive like formaldehyde then the graph would increase with the increasing of thickness.

5. CONCLUSION

This study investigated tensile strength of three different types of paper board (Hand sheet, Newsprint and Offset) with five layer variation (single layer -5 layer) that were produced by using polyurethane as a binder and laminating agents, this study also observed the influence of temperature over tensile strength of paper board. 3-layer offset paper board resulted highest tensile strength among all other types where we used 4 offset papers and three polyurethane papers inside it. Though Newsprint paper board also resulted greatest tensile strength in 3-layer board similar to offset paper board, but in case of Hand sheet paper 2-layer board resulted greatest value than other types. In case of single layer, 2-layer, 3-layer and 4-layer board offset paper resulted greatest tensile strength followed by newsprint and Hand sheet paper board. But for 5-layer paper board Hand sheet paper board showed greatest tensile strength followed by very close to offset paper board. Further study is needed to assess the internal fiber bonding capacity and feasibility of different paper with polyurethane as a binding and laminating agent to produce paper board and thus we can answer precisely to the different question of our current result.

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Appendix: Data Obtained from Laboratory Test

Table 1. Data Set for Offset paper board, L1, L2, L3, L4 and L5 are the five type of layered board, Time 15 min and pressure 10 MPa is fixed.

Offset	L1	L2	L3	L4	L5
	21.7067	30.0157	41.1394	16.2944	21.7207
	17.1979	35.4934	46.1367	19.334	17.0478
	20.206	32.9332	35.0607	31.545	21.4967
Average	19.70353333	32.8141	40.77893	22.39113	20.0884
STD	2.296012614	2.740791	5.546792	8.071849	2.635618
ERROR	1.325603501	1.582397	3.202442	4.660284	1.521675

Table 2. Data Set for Newsprint paper board, L1, L2, L3, L4, and L5 are the five type of layered board, Time 15 min and pressure 10 MPa is fixed

Newsprint	L1	L2	L3	L4	L5
	22.3522	17.3574	25.396	15.8946	22.8622
	19.2969	23.0585	24.1086	19.5738	12.7447
	17.8898	20.2375	26.1001	23.9477	19.7579
Average	19.8463	20.2178	25.20157	19.80537	18.45493
STD	2.281366632	2.850601	1.009887	4.031541	5.183073
ERROR	1.317147639	1.645795	0.583058	2.327611	2.992448

Table 3. Data Set for Newsprint paper board, L1, L2, L3, L4, and L5 are the five type of layered board, Time 15 min and pressure 10 MPa is fixed

Handsheet	L1	L2	L3	L4	L5
	8.82387	13.918	18.5783	8.74459	14.041
	11.6205	34.0374	18.6541	8.73869	21.4359
	15.4789	33.6903	25.9911	15.891	27.1711
Average	11.97442333	27.21523	21.0745	11.12476	20.88267
STD	3.341601767	11.51705	4.258069	4.127686	6.58251
ERROR	1.92927468	6.649372	2.458397	2.383121	3.800414