



MARMARA UNIVERSITY
FACULTY OF ENGINEERING



**DESIGN AND PRODUCTION OF PALLETS
MADE FROM WOOD SCRAP WASTE**

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GRADUATION PROJECT REPORT
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**MARMARA UNIVERSITY
FACULTY OF ENGINEERING**



Design and Production of Pallets Made from Wood Scrap Waste

By

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June 2022

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ABSTRACT

Design and Production of Pallets Made from Wood Scrap Waste

Wooden pallets are frequently used in almost most factories and warehouses. However, wooden pallets take up a lot of space in terms of shape. In addition, wooden pallets are not very durable under heavy loads. New design studies have been carried out to find solutions to these problems. As a result of these studies, compressed wooden composite pallets have emerged.

Compressed wood composite pallets have many advantages. They have features such as taking up less space and being more durable than wooden pallets. In this thesis, we conducted research on their advantages and how they deform under load. We also supported these studies with a tensile test.

SYMBOLS

F=Force

σ =Stress

E=Elasticity Modulus (Young Modulus)

A_0 =Cross Sectional Area

ε =Strain

L_0 =Initial gage length

ΔL =Change in gage length

σ_u =Ultimate tensile strength

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1 INTRODUCTION

Wooden, plastic, or cardboard products that are produced especially for use in the logistics sector, facilitate transportation and can be stored regularly are called pallets. Recently, businesses and manufacturers are constantly looking for better quality pallets to help them increase efficiency through lower shipping times and costs. Our pallet type used in this thesis is compressed wood composite pallet.

Compressed composite wooden pallets are a very preferred pallet type in factories and warehouses due to their structure and shape, stackable and interlocking. It really relaxes the factory ergonomically. In addition, these pallets attract attention with their ability to be recycled and recyclable. The pallet, which is quite light compared to other wooden pallets, has many advantages.

Compressed wood composite pallets are very durable due to the materials used and their structure. In this thesis, we will do the tensile and shear tests of this pallet with the samples taken from the pallets.



Figure 1-1:Pallets

2 LITERATURE SURVEY

2.1 What is a presswood pallet?

Press wood pallets, also known as pressed wood pallets, are made from wood by-products such as waste pallets, raw wood chips, wood waste, sawdust and other materials containing wood fiber.[1]



Figure 2-1:Front view of the pallet

Their unique design means they can carry significant load capacities and are also relatively light. They can also be both stacked and nested, helping to reduce storage space and freight costs during shipping.[1]

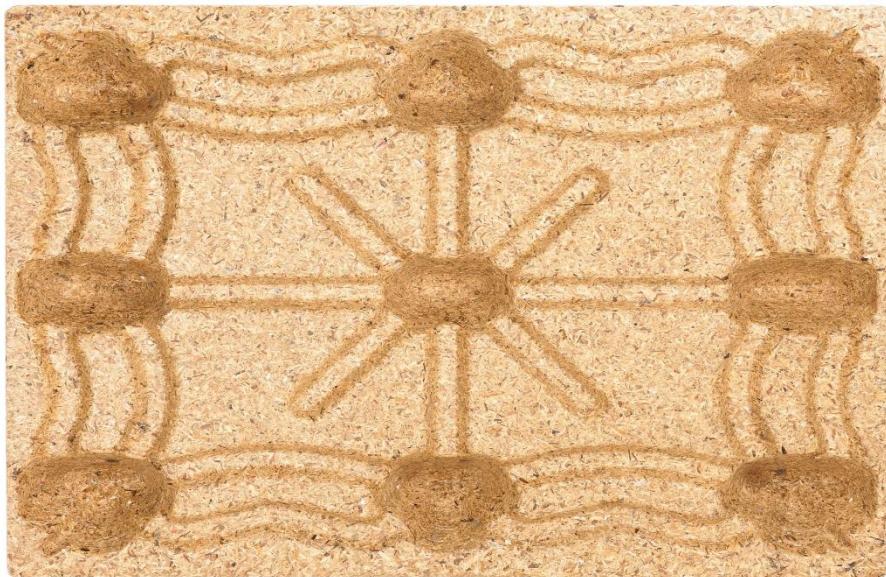


Figure 2-2:Top view of the pallet

They are usually made from "resinous" woods (pine, fir, etc.), the chips come directly from lumber and sawmills or the wood recycling industry. This makes this particular type of pallet extremely environmentally friendly.[1]

2.2 How are presswood pallets made?

2.2.1 Get Raw Materials

Waste wood, scrap of the wood, sawdust wood chips, wood shaving, wood chips, big chips, raw wood, burned forest, logs, wood board, branches, timber, wood flakes, waste furniture, and waste pallets, etc.[1]



Figure 2-3:Waste wood chips

2.2.2 Chipping Raw Materials

Wood chipper is chipping the raw materials into wood chips, about 30-50 mm in length, 50 mm in width, 3-5 mm in thickness, if the raw materials are large size.[2]



2.2.3 Crushing Raw Materials

The bigger size wood chips will be crushed again in order to get better raw materials to make the pallet. The size of the wood chips after crushing is about 30-50 mm in length, 1-2 mm in width, 1 -2 mm in thickness.[2]



Figure 2-4:Wood chips

2.2.4 Drying Crushed Raw Materials

The chips are dried at high temperatures such as 65°C. In order to get better pallet, the moisture content of the raw materials should be 5%.[2]



Figure 2-5:Drying process

2.2.5 Mixing Dried Materials with Glue

Glue mixer is to mix the dried materials with glue. The ratio of raw materials to the glue is 85:15.[2]



Figure 2-6: Mixing process with glue

2.2.6 Pressing Mixed Materials

The resulting raw materials are put into the press wood machine and then pressed manually or automatically. The respective pressures and temperatures can be up to 85 kg/cm² and 150°C, respectively. This process takes between 7 and 8 minutes. This hot compression molding

process is used to kill all live plant pests. The high density of this type of pallet of 1.3 g/cm^3 means it is resistant to all wood boring insects and infestations.[2]



Figure 2-7: The process of placing particles into the machine



Figure 2-8: Start of pressing



Figure 2-9:Press process



Figure 2-10: End of pressing



Figure 2-11: Ready-to-use pallets

2.3 The Advantages of Using Presswood Pallets

Space Saving

One of the main advantages of molded presswood is its versatility. As mentioned earlier, pressed wood pallets can be both nested and stacked.

This versatility means they can be stored in smaller stacks, freeing up valuable warehouse space for businesses and manufacturers.

This also allows businesses to store more pallets in the field and expand their products, equipment, machinery, etc. It allows you to maximize the space available for storage.[2]

Easy to Export

The high temperatures used to make molded wood pallets mean it is considered a engineered wood. This means they are exempt from IPPC's ISPM15 export packaging regulations.

It is a low-cost, hassle-free way to export goods worldwide. Due to the high heat treatment, they are also free from unwanted pests and pollutants.

This can help businesses save both time and money.[2]

Affordable Cost

With pallets pre-made for export, customers don't have all the hassle or worries about additional certification requirements.

Presswood pallets can also help businesses reduce freight and warehousing costs in the medium to long term. Businesses can further reduce storage and shipping costs by maximizing storage space.[2]

Environmentally Friendly

Presswood pallets are a very environmentally friendly way of producing pallets.

Old pallets that can no longer be used can be easily shredded and re-glued to make new pressed wood pallets. Plus, they're all made using recycled wood, which can significantly reduce a company's carbon footprint and save money.[2]

2.4 What Industries Are This Type of Pallet Best Suited

Compressed wood pallets offer customers a number of additional benefits over traditional wood pallets, including lower transportation and storage costs and ergonomic benefits.

However, as we discussed earlier, pressed wood pallets offer many of the same benefits of plastic pallets in terms of resistance to parasites and bacteria. They are often much cheaper and lighter, providing businesses with huge savings in shipping costs.

Therefore, pressed wood pallets can be an excellent choice for companies in the pharmaceutical and food and beverage industries.

Because they are lightweight, they are the perfect choice for any business that consistently uses airfreight as their shipping method.[2]

3 THEORY

3.1 Tensile Test

The tensile test is a basic materials science test in which a sample is subjected to uniaxial tensile forces until it breaks. The results from the test are used to select materials for any application, quality control, and predict how the material will behave under other forces. The most widely used test to reveal the mechanical properties of the material is the Tensile Test. The results from this experiment can be used directly in engineering calculations.[3]

Force (F) and Elongation (Δl) curves are obtained as a result of this experiment. But the more accepted is the Stress-Elongation curve. For this reason, the applied force is divided by the initial cross-sectional area of the sample ($\sigma=F/A_0$), the force values are converted to stress values and the Stress-Elongation graph is obtained. [3]

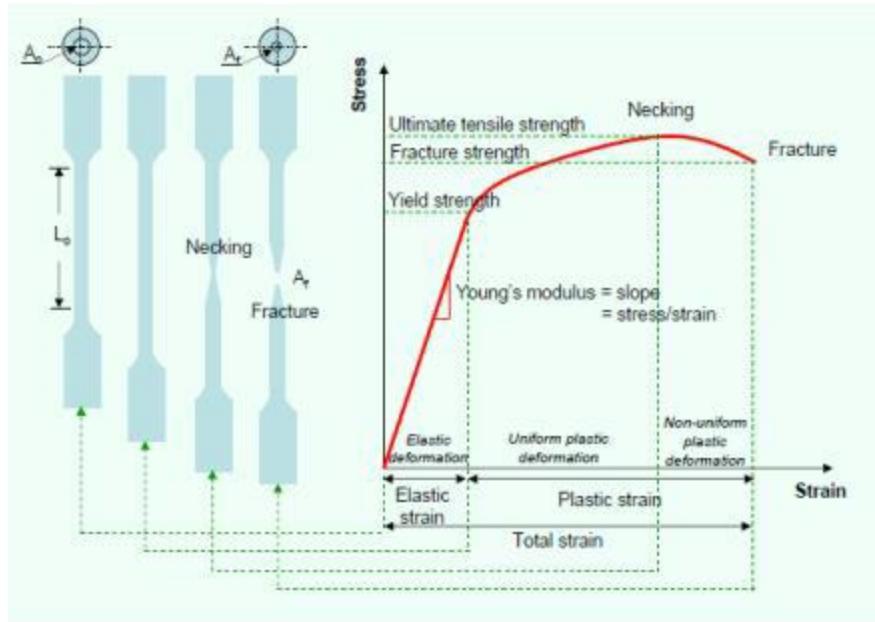


Figure 3-1:Strain-Stress Graph

As a result of the tensile test, strength values such as Elastic modulus, Yield value, Tensile strength, and ductility values such as elongation at break, shrinkage at break and toughness are determined. These properties depend on the type, chemical composition, and metallographic structure of the material. [3]

3.1.1 Yield Strength

As the force increases as the material is pulled, the elongation will increase. However, it comes to a point where the elongation of the material continues even if the force does not increase in a certain place. This point is called the pour point. Up to this point, the material has changed shape elastically. In other words, when the force on the material is removed, the material will be able to return to its original state. However, after this point, the material has undergone plastic deformation and will not be able to recover even if the force on it is removed. For this reason, the strength limit of materials is expressed by the yield stress. [3]

3.1.2 Young Modulus or Elasticity Modulus

The modulus of elasticity is a measure of the strength of the material. The greater the modulus of elasticity of a material, the more durable the material is. And that means it's so resistant to shapeshifting. Indicates the amount of stress generated per unit elongation. The relationship

between strain and normal stress gives the modulus of elasticity. Normal stress is compression or tensile stress. [3]

The modulus of elasticity is defined by the formula:

$$\text{Elasticity Modulus}(E) = \frac{\text{Normal Stress}(\sigma)}{\text{Unit Elongation}(\varepsilon)}$$

This relationship is also called Hooke's Law, since the elongation is proportional to the force, and therefore also proportional to the stress. That is, the slope of the Hook line or the proportionality coefficient becomes the modulus of elasticity. [3]

3.1.3 Tensile Strength

The highest tensile stress that a material can withstand until it breaks or breaks is called Tensile Strength. This stress is the highest stress value in the tensile diagram and is found with the highest applied force. In all strengths, the first cross-sectional area (A_0) is taken as the area. [3]

$$\sigma = \frac{F}{A_0}$$

Strain (ε): It is the ratio of the length change that occurs when the force is applied to the material, to the initial paint before the force is applied.

$$\varepsilon = \frac{\Delta L}{L_0}$$

3.2 Specimen of Tensile Test

A tensile specimen is a standardized sample cross-section. The cross section of the specimen is usually round, square or rectangular. It has two shoulders and a gauge (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.

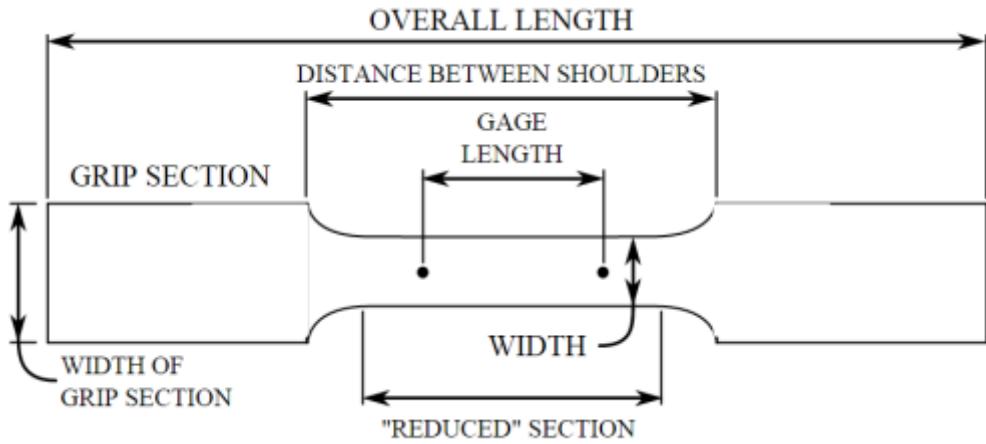


Figure 3-2: Description of the sample



Figure 3-3: First specimen of experiment of tensile test



Figure 3-4: Second specimen of experiment of tensile test



Figure 3-5: Third specimen of experiment of tensile test

The distances between the ends of the gage section and the shoulders should be great enough so that the larger ends do not constrain deformation within the gage section, and the gage length should be great relative to its diameter. Otherwise, the stress state will be more complex than simple tension.



Figure 3-6: Placing the specimen in the machine

3.3 Video Extensometer

An extensometer is a device used to measure small/large changes in the length of an object. This device is used in stress strain and tensile tests. For most materials, strain can be measured using mechanical extensometers attached to the sample or strain gauges attached to the sample. However, these devices are generally not suitable for testing sensitive materials such as fibers, foams or soft plastics. This is because the parameters of these devices, such as weight and attachment method, both affect the results and breaking point for the material. In order to solve these problems, systems such as laser and video extensometer that measure without contacting the sample are used today.



Figure 3-7:Tensile Test Machine

The video extensometer device enables to measure the stress/strain of the materials by taking continuous images on the sample through digital video cameras connected to the computer during the test. Samples of the material under test are usually cut in a specific way and marked with special markers (usually special labels or pens that distinguish the marking from the sample color and texture in recorded images). The pixel distance between these marks in the images recorded while the tested sample is in the pulling/pressing state is constantly followed by the video camera. An accurate strain measurement value is obtained by measuring pixel distances. With proper calibration and a good image algorithm, resolutions far lower than a micrometer (μm) can be achieved.

4 RESULTS AND DISCUSSION

We subjected the samples I prepared to tensile force in the tensile test machine. The details are in the relevant section. Then, I performed the static analysis of the pallet I had drawn in Solidworks program under a load of approximately 2500 kg in Ansys program.

4.1 Tensile Test Output



Table 1: Specimens Data

Name	Thickness	Width	Gauge Length
Unit	mm	mm	Mm
1	11	10	57.60
2	11	10	73
3	10	9	80

Table 2: Maximum Stress and Strain Values of Specimens

Name	Maximum Stress	Strain
Unit	N/mm ²	%
1	16.8688	0.18944
2	11.4789	0.24953
3	16.6030	0.49713

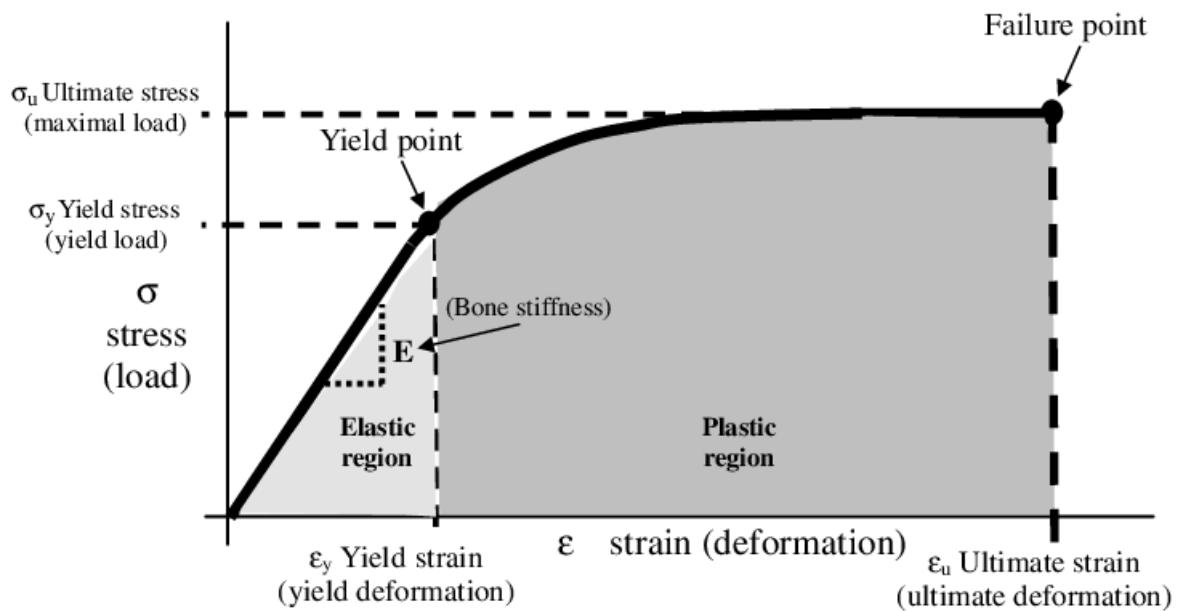


Figure 4-1: Tensile test guide chart

Table 3: Results of Tensile Test

Parameters	SPECIMENS		
	FIRST	SECOND	THIRD
Cross Sectional Area (mm^2)	110	110	90
Modulus of Elasticity (MPa)	10702.89071	20768.35574	4573.485433
Yield Stress (MPa)	6.95691	7.6012182	8.3511844
Yield Strain	0.0006500029	0.000366	0.001826
Ultimate Tensile Strength (MPa)	16.8688	11.4789	16.6030
Ultimate Tensile Strain (MPa)	0.18944	0.24953	0.49713

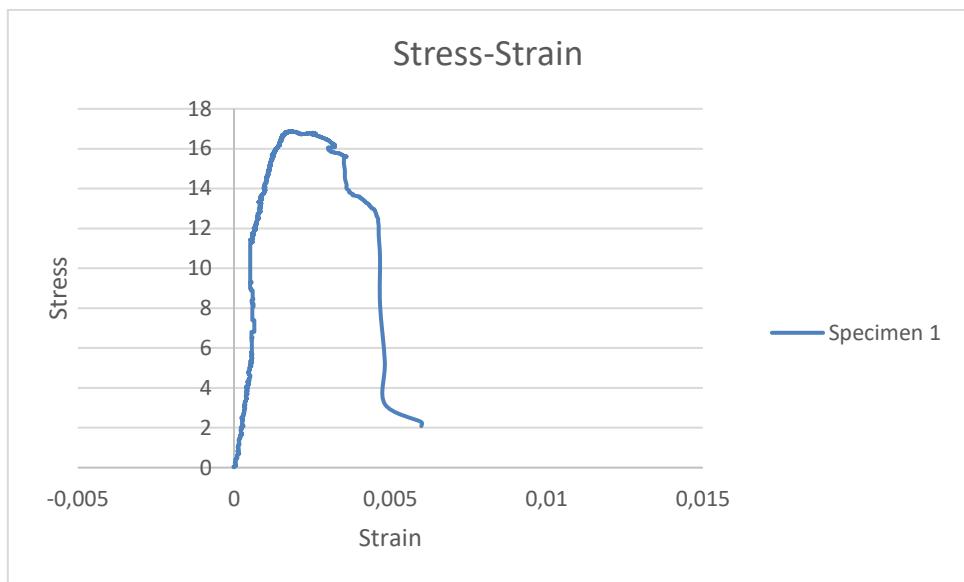


Figure 4-2: Stress-Strain Graph of First Specimen of Tensile Test

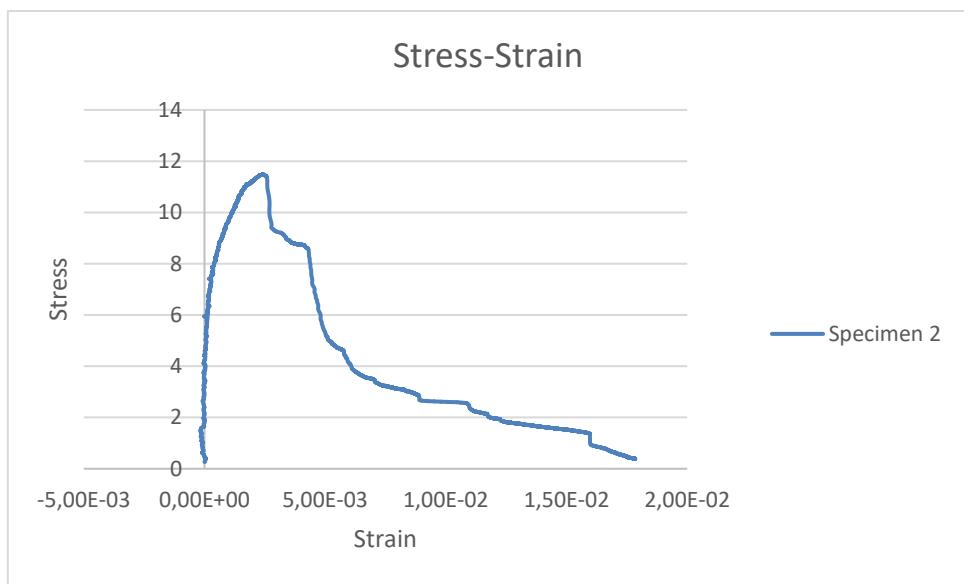


Figure 4-3: Stress-Strain Graph of Second Specimen of Tensile Test

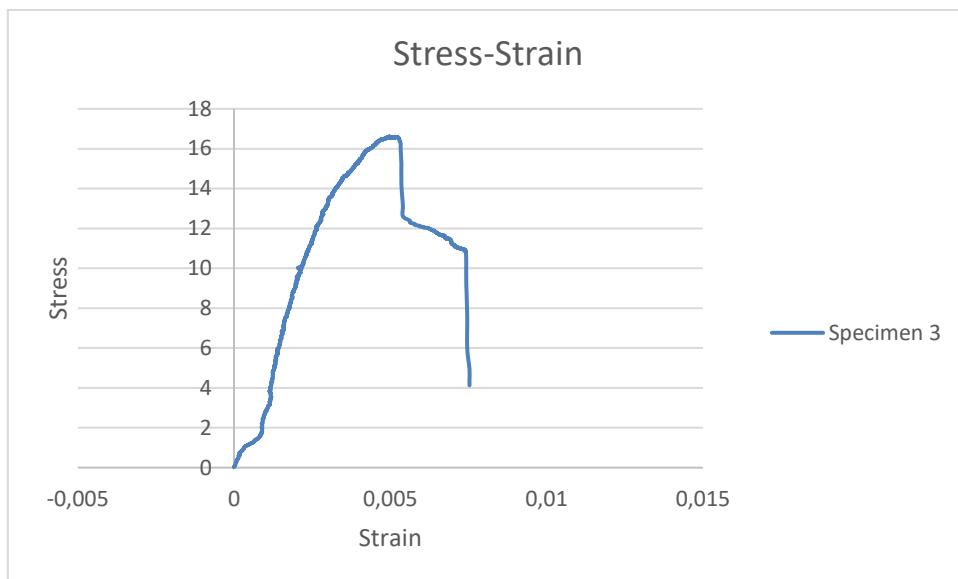


Figure 4-4: Stress-Strain Graph of Third Specimen of Tensile Test

4.2 Solidworks Drawings

I drew the drawings I made in this study in the Solidworks program.

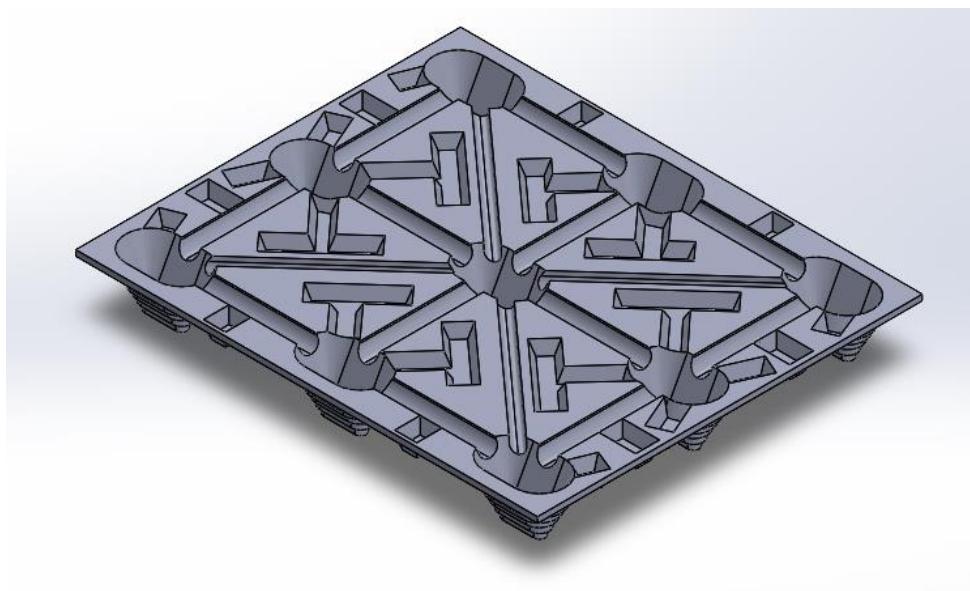


Figure 4-5: Pallet Drawing

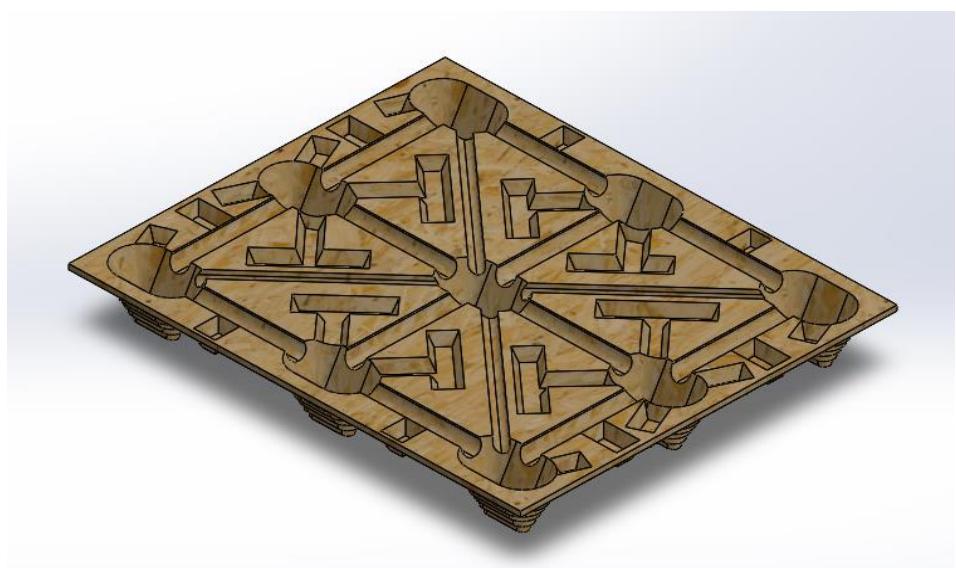


Figure 4-6: Wooden Pallet Drawing

4.3 Ansys Structural Analysis

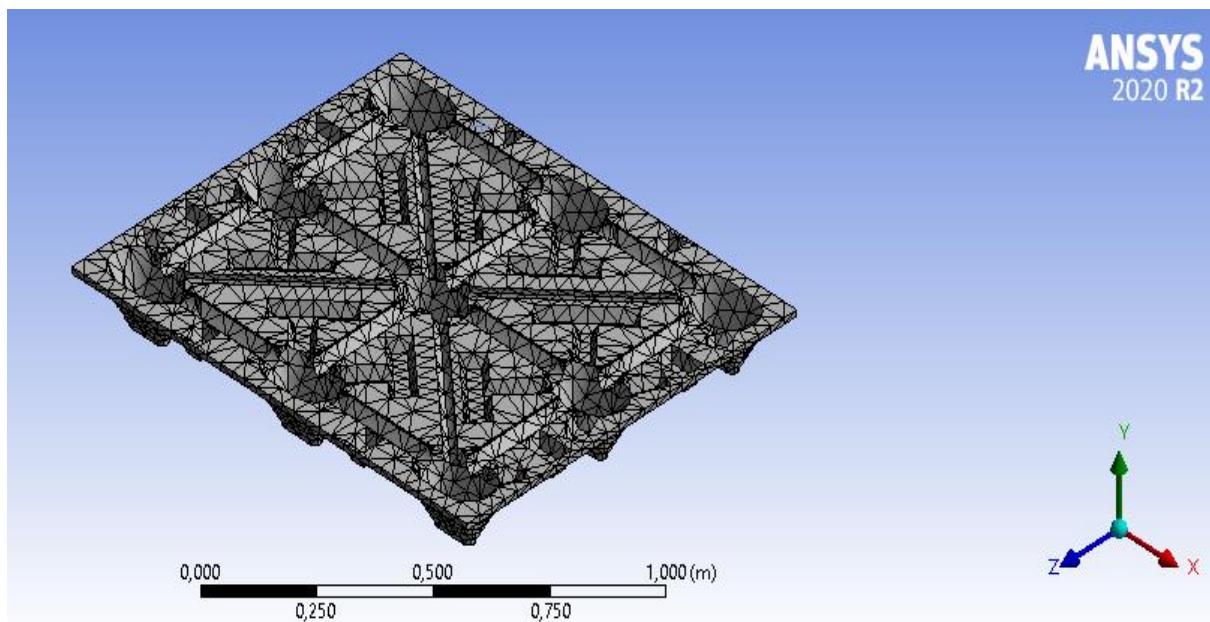


Figure 4-7:Meshing Process

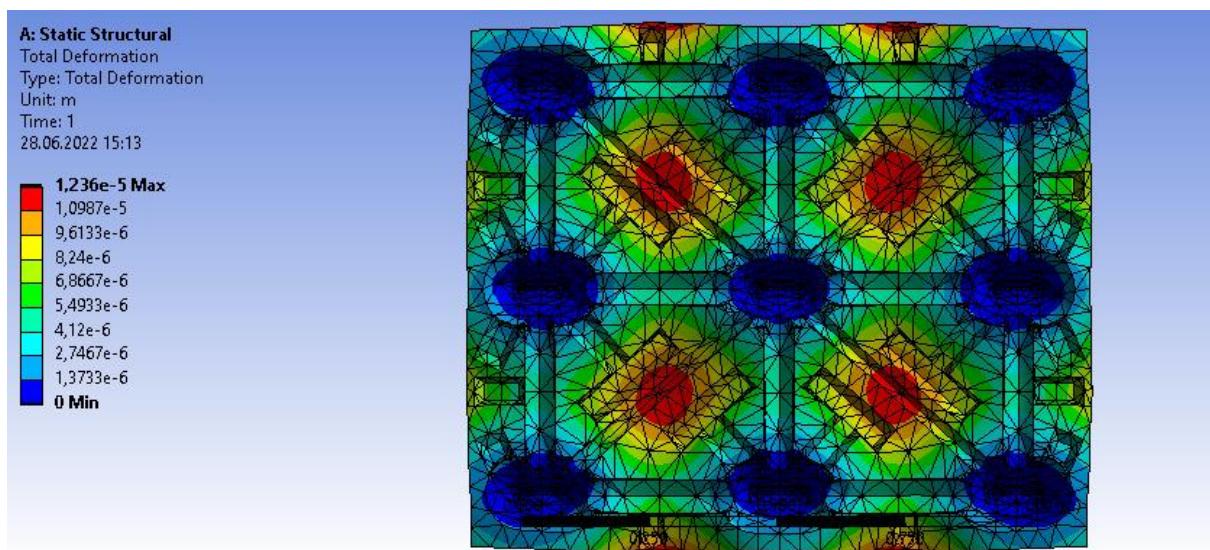


Figure 4-8:Top view of Total Deformation Result

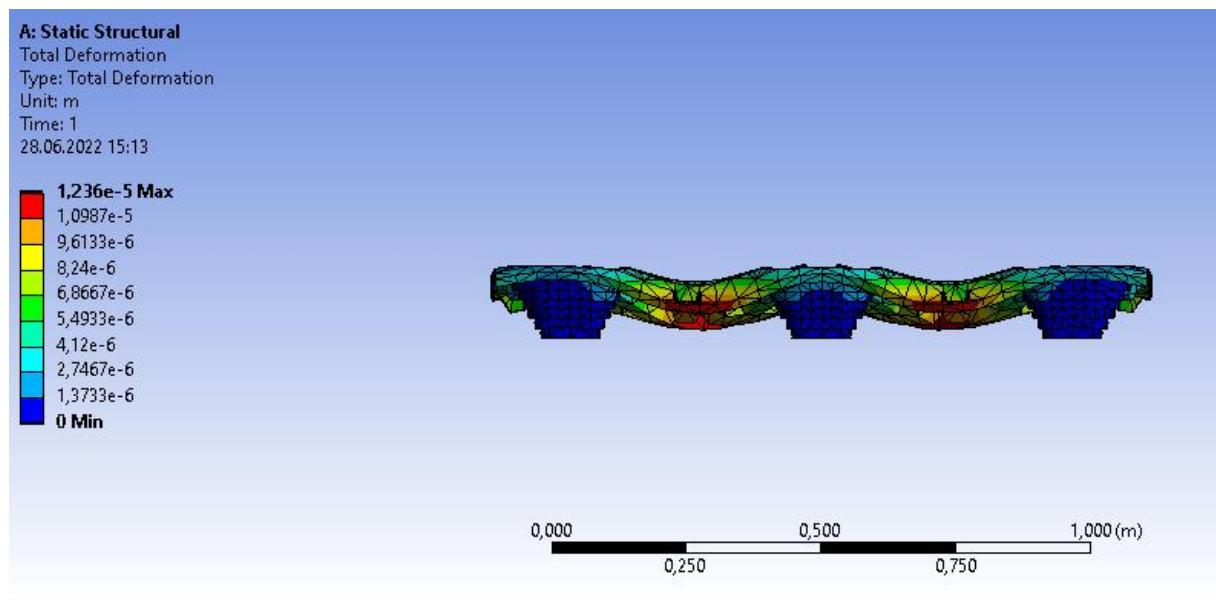


Figure 4-9: Side view of Total Deformation Result

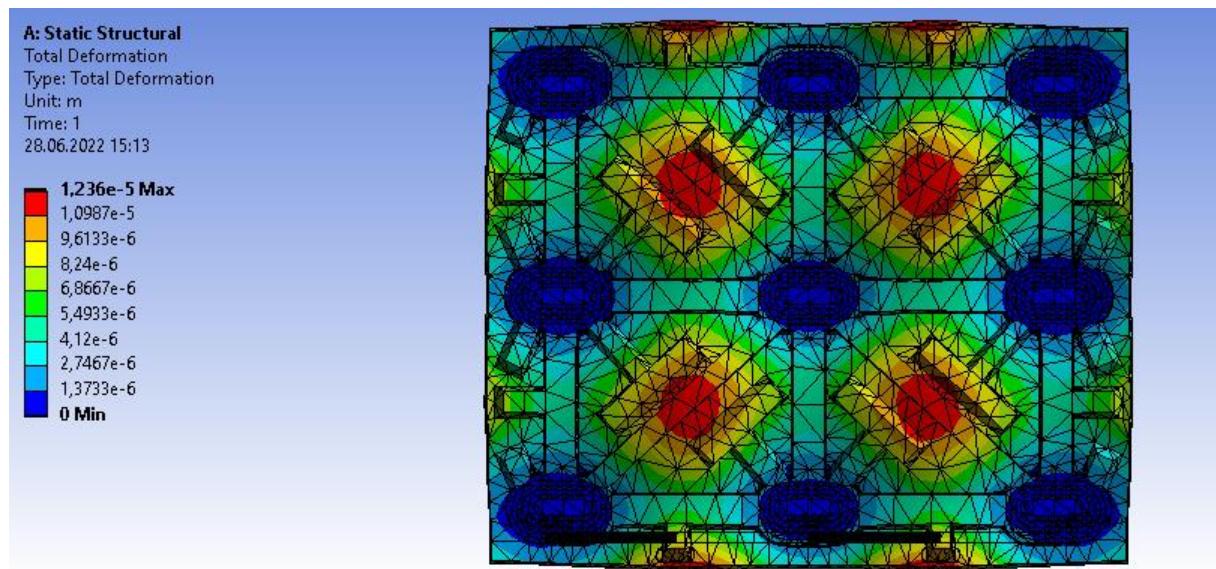


Figure 4-10: Bottom view of Total Deformation Result

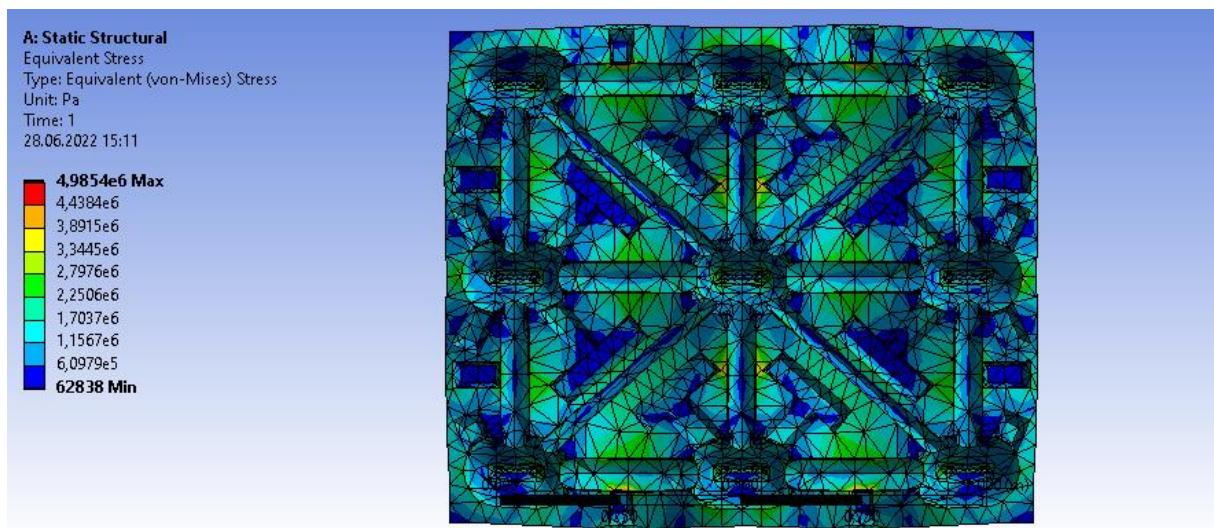


Figure 4-11: Top view of Equivalent (Von-Mises) Stress Result

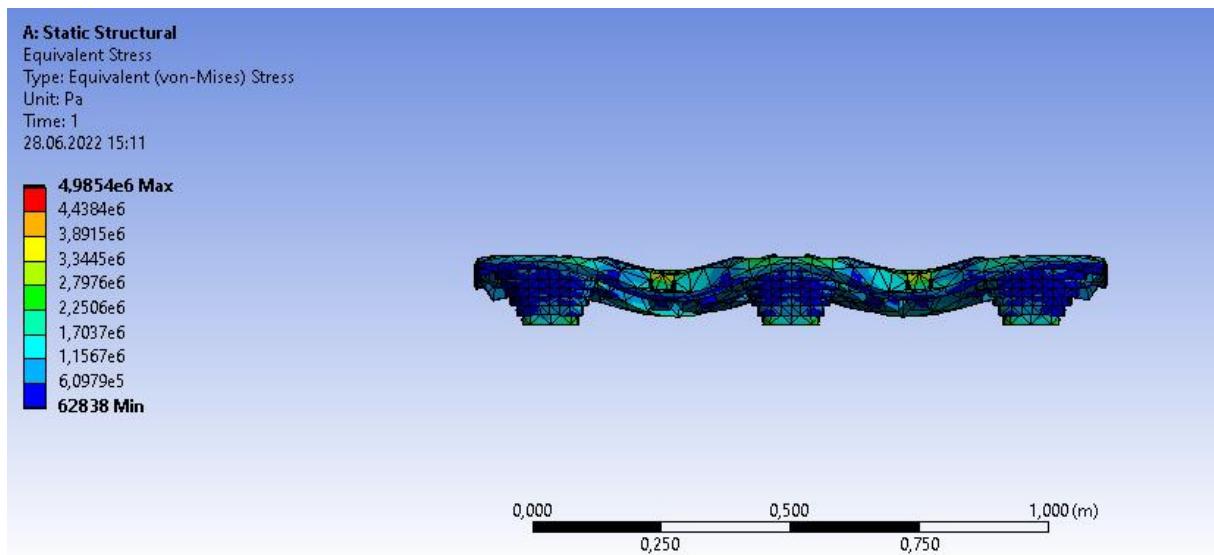


Figure 4-12: Side view of Equivalent (Von-Mises) Stress Result

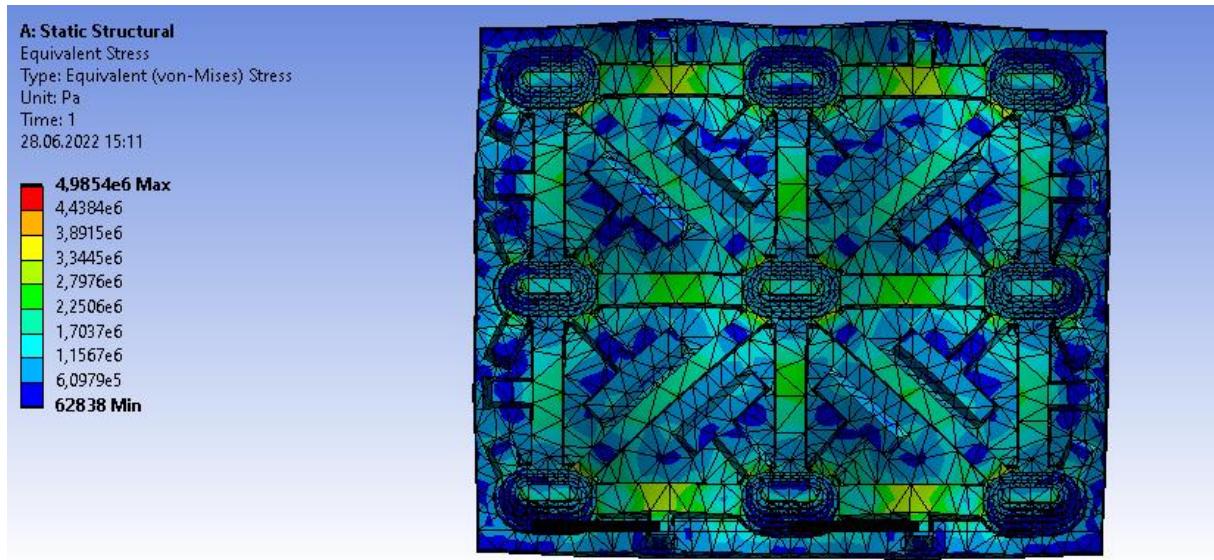


Figure 4-13: Bottom view of Equivalent (Von-Mises) Stress Result

For Brittle Materials

$$\text{Safety factor} = \frac{\text{Ultimate Strength}}{\text{Working or Design Stress}}$$

$$n = \frac{16,8688}{4,985}$$

$$n = 3,384$$

We subjected the 3 samples we obtained to the tensile test. The results of the tensile test are given in the tables above. The maximum tensile stress was found to be approximately 16 Mpa. We applied a force of 4 tons (39240N) on the surfaces of the pallet in the Ansys program (in the -y direction). As a result, we obtained our Von-Mises Stress value as a maximum of 4,985 Mpa. These two values are sufficient to find the safety factor. Since our material is a brittle material, the safety factor was calculated using the formula suitable for brittle materials. As a result of the calculations, the safety factor of the wooden pallet was approximately 3.5. Generally, the safety factor of wooden pallets should be 2 according to the standards. Since the safety factor of the pallet in this experiment was 3.5, we can say that our pallet is resistant to 4 tons (39240N).

5 COMPARISON OF WOODEN PALLETS AND PRESSWOOD PALLETS



Compressed wooden pallets, which are durable up to 4000 kg, are more affordable cost than wooden pallets. Compressed wooden pallets cost between 15-20€. Wooden pallet cost vary between 20-30 €. These pallets, which are ahead in terms of price performance, also come to the fore with their other features.

6 CONCLUSION AND RECOMMENDATIONS

In this thesis, we examined the durability and deformation of the compressed wood composite pallet under a certain load. As a result of the tensile test, we calculated the tensile stresses of the samples obtained from the pallet. Then, we applied a load of approximately 25000N (in the -y direction) to the pallet that I had drawn in the Solidworks drawing program.

As a result of the experiments, it has been observed that compressed wood composite pallets are more durable and take up less space than other wooden pallets. Another remarkable feature is that the pallets produced are interlocked with each other. This feature provides a very good ergonomic space saving in warehouses or factories. One of the most important features of this pallets is that it is a recycled product.

Finally, compressed wood composite pallets find buyers at more affordable prices than other pallets in the market. I can easily say that it is a completely environmentally friendly product.

7 REFERENCES

- [1] Ap Plastic Pallet/Associated Pallets.'A Guide To Presswood Pallets''.12June2019.
<https://associated-pallets.co.uk/blog/guide-presswood-pallets/>
- [2]Thoyu.'How to Make Presswood Pallet''.12Sep2018.
<https://www.palletblockmachine.com/how-to-make-presswood-pallet.html>
- [3] Shigley'Mechanicals Engineering Textbook
- [4] Cherif,Chokri.,Seidel,Andre.,Younes,Ayham.,Hausding ,Jan.(2010).Evaluation of a Tensile Test for The Determination of The Material Behaviour of Filament Yarns Under High Strain Rates
- [5]Deviatkin,Ivan.,Khan,Musharof.,Ernst Elizabeth.,Horttanainen,Mika.(2019).Wooden and Plastic Pallets:A Review of Life Cycle Assessment Studies
- [6] LITCO International, Inc.'31Jan2017.Export and Domestic Pallets Load Securement Solutions Molded Core Plugs. <https://www.litco.com/wp-content/uploads/ansi-2016-pallet-standard-part-14.pdf>
- [7] Cision Pr Newswire.'Molded Wood''Pallet Standard Created by ANSI''.03Mar2017.
<https://www.prnewswire.com/news-releases/molded-wood-pallet-standard-created-by-ansi-300417473.html>
- [8] Modern Materials Handling.'Packaging Corner''.2December2016.
https://www.mmh.com/article/looking_at_the_1_of_pallets
- [9] Supply Chain Management Review.'Alternative Pallets 101''.1Sep2010.
https://www.scmr.com/article/alternative_pallets_101

8 APPENDIX

Key Word		Product Name		
Test File Name		RECEP.xtas		PVC Büyük Çekme.xmas
Report Date		09/06/22		03/06/22
Test Mode		Single		Tensile
Speed		1mm/min		Plate
No of Batches:		1		Qty/Batch: 50

Name	Thickness	Width	Gauge_Length
Unit	mm	mm	mm
1_1	2.6000	9.8000	1000000.0000
1_2	2.6000	9.8000	1000000.0000
1_3	11.0000	10.0000	57.6000
1_4	11.0000	10.0000	73.0000
1_5	10.0000	9.0000	80.0000

Name	Break_Ext.1 (Strain) Sensitivity: 10 %	Max_Stress Calc. at Entire Areas N/mm ²	Max_Ext.1 (Strain) Calc. at Entire Areas %	Break_Stress Sensitivity: 10 N/mm ²	Slope_Standard Stress 5 – 15 N/mm ² N/mm
Parameters	Unit				
1_1	13.0848	34.9793	8.43525	32.8281	382.850
1_2	—	0.33031	0.03728	—	—
1_3	0.46164	16.8688	0.18944	12.5005	13035.9
1_4	—	11.4789	0.24953	—	—
1_5	0.53060	16.6030	0.49713	16.3302	4569.90
Average	4.69235	16.0521	1.88173	20.5529	5996.22
Standard Deviation	7.26816	12.5230	3.66728	10.8017	6445.98
Range	12.6232	34.6490	8.39797	20.3276	12653.1

Name	YS1_Stress 0.2 % N/mm ²	YS1_Ext.1 (Strain) 0.2 % %	YP(%FS)_Stress 0.1 % N/mm ²	YP(%FS)_Ext.1 (Strain) 0.1 % %
Parameters	Unit			
1_1	21.7371	2.38031	—	—
1_2	—	—	—	—
1_3	15.7757	0.33505	—	—
1_4	—	—	—	—
1_5	—	—	—	—
Average	18.7564	1.35768	—	—
Standard Deviation	4.21535	1.44622	—	—
Range	5.96140	2.04526	—	—

Figure 8-1:Result of Tensile Test