DOI: http://dx.doi.org/10.24018/ejers.2017.2.1.265
EJERS, European Journal of Engineering Research and Science
Vol. 2, No. 7, January 2017

Design of Wooden Skids for Transportation of Batteries

Madhava Rao B., Sreenivas Kosaraju, Murthy KSN and Jagadish M.

***Abstract*—The basic objective of the present work is to arrive at the optimal design for wooden skids used for the "storage and transportation" of the batteries to the ware houses and customers. The wooden skid was designed taking account of load conditions that it experiences during transportation and storage. In this context, the most vital parameters like nature of load that influences the performance of the wooden skid was considered. With the help of simple design approach, the reliability of the design was studied and the importance of influencing parameters was discussed.**

***Index Terms*—Dynamic Fatigue Load; Dynamic Static Load; Dynamic Load; Transportation; Storage; Wooden skid.**

I. Introduction

Skids are horizontal and rigid platforms, designed to store and transport products. Skid construction is like a frame of parallel pieces and the top deck boards are then affixed to the pieces to create a Skid Structure. Skids are made from numerous materials such as Metal / Aluminum, Light weight Plywood, Wood, Press wood, Plastic etc. [1].

In case of transportation of batteries wooden skids are the most preferred for reasons such as:

- Strong and robust
- Apt for rack storing
- Cost effective

However, a few disadvantages are also associated like

- Difficult to reuse if they become wet which leads to the growth of bacteria and fungus.
- Extra maintenance cost due to the rework of the damaged skids [2].

Taking account of pros and cons it is still a common practice to use wooden skids. Every attempt shall be made to choose the right wood with right design parameter. It is from view point of the role played by design on skid performance. Although Skids are available in different sizes and configurations primarily they fall into two very broad categories namely, Block and Stringer Skids [3].

Block Skids are treated as "four-way" Skids and can be lifted from any direction whereas Stringer Skids also known as "two-way" Skids as the forklift can be lifted from any two ends. For the purpose of present study, Block Skids (Four – Way) were chosen for the design optimization.

Published on January 30, 2017

Madhava Rao B is an Assistant Manager looking after Material Development in Amara Raja Batteries – Tirupathi (e-mail: mdr@amararaja.co.in).

Sreenivas Kosaraju is a senior Manager in Amara Raja Batteries looking after the materials development division (e-mail: ks@amararaja.co.in).

Murthy KSN is a General Manger heading R&D, Amara Raja Batteries– Tirupathi (e-mail: ksnm@amararaja.co.in).

Jagadish M is the Chief Technology Officer heading Technology in Amara Raja Batteries– Tirupathi (e-mail: mj@amararaja.co.in).

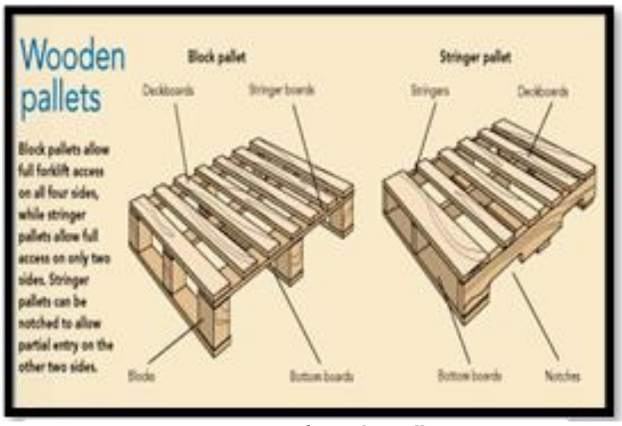

Fig. 1. Types of Wooden Pallets

II. Moisture Content in the Wood

A. *Types of Wood Moisture*

- As mentioned earlier, Quality of wood is an important parameter. The quality or Strength of Wood depends on several factors. They are not only density, moisture content, and grain size of the wood but also ambient temperature. Among these factors, moisture content is an utmost important parameter [4].
- Different kinds of moisture exists in the wood, Such as
  - Free Water i.e. the water present in the wood cell cavities
  - Bound Water i.e. the water chemically bound with hydrogen bonding to the cellulose of the wood cells [5].

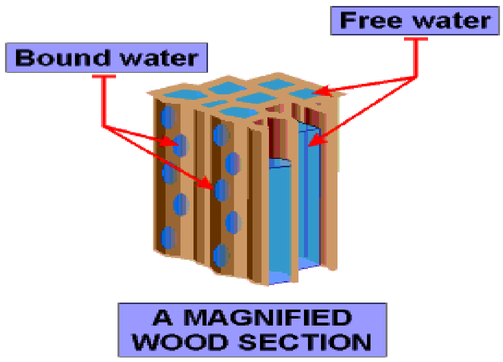

Fig. 2. Moisture Content in wood

- It is free water in wood that varies with atmospheric conditions whereas the bound water is the characteristic of wood.
- It is for this reason, after having chosen right quality of wood also, things can go wrong because of abnormal moisture pickup by the wood under adverse conditions.

DOI: http://dx.doi.org/10.24018/ejers.2017.2.1.265

- Skids have more chances to attain moisture easily during rainy seasons.

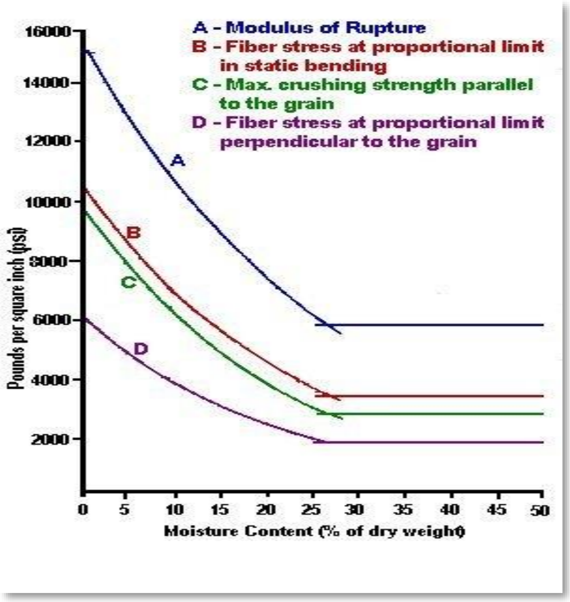

Fig. 3. Moisture vs. Wood Strength

- As per the figure 3, the strength of the wood in terms of modulus of rapture is inversely proposal to the free water content in the wood.

B. Method to achieve required Moisture Content in Wood

As mentioned previously, it is to be noted that free water can be removed by heating the wood but can't remove the bound water that is chemically bounded with hydrogen. Therefore, initially the specimens are soaked in water for 24 Hrs for attaining saturation point and calculated the percentage of moisture attained by the specimen [4]-[6].

TABLE I: 24 HOURS WATER SOAKED MOISTURE CONTENT

Parameter	UOM	Observation	Remarks
Initial weight	g	6.96	
Final weight	g	10.46	Water soaked for 24 Hrs
Moisture	%	50.29	

After that the specimens are oven dried at 80°C for different time periods and removed the required moisture content and subjected for testing.

TABLE II: REQUIRED MOISTURE CONTENT IN THE SPECIMEN

S.No	Req. Moisture Range	Sample Identification	Soak time	Oven Dry Time mins	Resultant Moisture %
1	0 to 5	1,2	24 Hours	120	3.1
2	6 to 10	3,4		110	7.69
3	11 to 15	5,6		100	12.72
4	16 to 20	7,8		90	17.91
5	21 to 25	9,10		80	23.23
6	26 to 30	11,12		70	28.78
7	above 30	13,14		60	34.04

The specimens are prepared with different % moisture ranges i.e. 0-5, 6-10, 11-15, 16-20, 21-25, 26 -30 and above 30. Subjected for flexural strength testing

III. FLEXURAL STRENGTH CALCULATION

A. Flexural Strength w.r.t Moisture Content

Flexural strength also known as modulus of rupture, bend strength, transverse rupture strength. It is a material property that defined as the stress in a material just before it yields in a flexure test .The flexural strength represents the highest stress experienced within the material at its moment of failure [7]-[8].

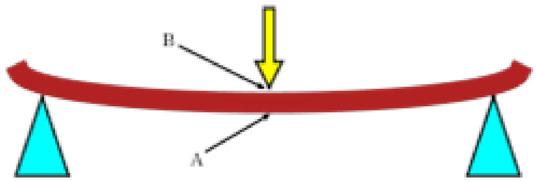

Fig. 4. Flexural strength of A beam

It is known that the mechanical properties of wood change based on the moisture content. Flexural Strength testing of wood has been carried out with different moisture Content % and different types of wood (Jungle, Rubber & jack). Prepared specimens with dimensions 127 x 12.7 x 3.2 mm (Reference Plastic Specimen as per ASTM Standard D790), and carried out a detailed experiment as mentioned previously to maintain the required amount of moisture within the specimens. The results are shown in figure 5.

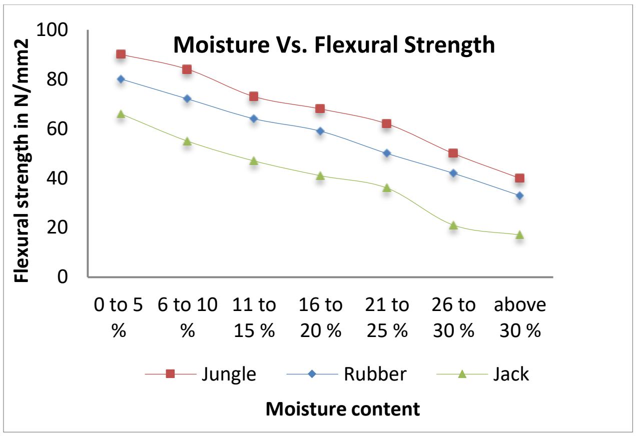

Fig. 5. Flexural strength w.r.t Moisture content

- Flexural Strength decreased with increasing Moisture Content.
- Flexural Strength observed more for the Jungle wood compared to Rubber & Jack wood.
- For the purpose of the present study, jungle wood containing moisture in the range of 11-15 % was considered for validating the design parameter. Therefore, the experiment was repeated once again with 11-15 % Moisture range to ensure the consistency in the test results.
- The flexural strength of jungle wood at 11-15% Moisture content is observed to be 70.22 N/mm2

Before initiating the load bearing capability calculation, like to know the type of loads are applied on the wooden skid during the battery Storage and transportation.

B. Unit Operations in Battery Storage and Transportation and the type of Load It Experiences:

- This study mainly focuses on the Calculation of maximum Allowable Dynamic Load and Fatigue Load over a Wooden Skid made up of 'Jungle Wood'.
- As per ASTM standard from 1915: Relation between long term strength & Short Term strength of wood.
    - Static fatigue is 56 % of Static Load
    - Dynamic Fatigue is 80 % of Dynamic Load

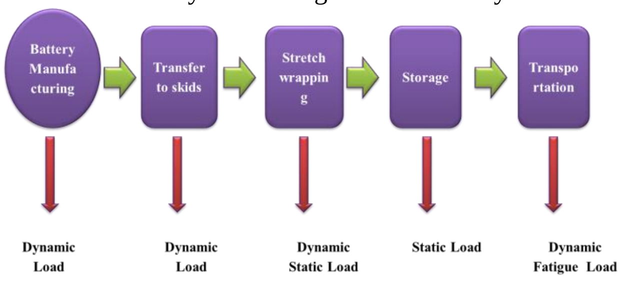

Fig. 6. Loads experienced by skid during the operations

IV. Design of Wooden Skid Optimization

A. Block Skid

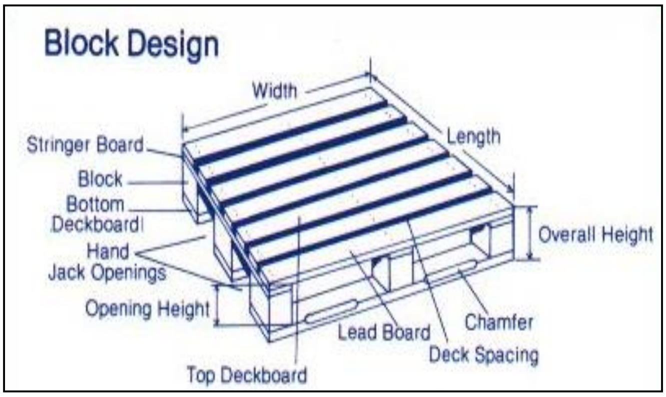

Fig. 7. Design of Block Pallet

- Block wooden skids have 3 major parts
    - Top Deck boards
    - Stringers
    - Bottom Deck boards
- While lifting the Skids with a forklift, the entire stresses under bending is directly applied on the deck boards i.e. no stresses are taken by the other Members of the Skids [10],[11]
- The Skid while lifting with a fork lift behaves like a series of Beams with equal overhangs.
- The Intermediate supports were adjusted in such a way that the bending moment is observed minimum at the mid of the span in order to maintain minimum Hogging [9],[10],[11]
- The Effective width of the Skid is taken as the sum of the widths of the Top Deck boards

B. Theoretical Calculations for Bending Moment of Skid

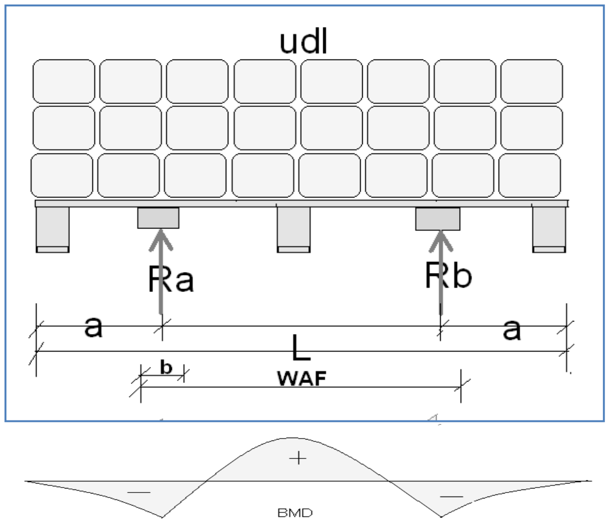

Fig. 8. Loading of Skids Bending Moment Diagrams

TABLE III: THEORETICAL BENDING MOMENT

S. NO	Particular	Formula, unit
1	Length of the Skid	L, mm
2	Uniformly distributed Load(UDL)	w, N/mm
3	Each vertical Reaction	wL/2 ,N
4	Distance from mid of support to edge of Skid	a, mm
5	Sagging BM at supports	$wa^2/2$, N.mm
6	Hogging bending moment at mid span	$w/2(l^2 - 4a^2)$, N.mm

From the Bending Strength Equation

$$M/I = MoR/y \qquad (1)$$

Where,

M = Maximum bending moment at mid of the span = $w/2\ (l^2 - 4a^2)$

I = Moment of Inertial = $bt^3/12$

MOR = Modulus of rupture under bending of the given species of wood

y = Distance from neutral axis

Equating the equation (1),

$$\frac{w/2(l^2 - 4a^2)}{bt^3/12} = \frac{MoR}{t/2} \qquad (2)$$

Where,

w = UDL, N/mm

b = Sum of the widths of deck board planks, mm

T = Thickness of deck board, mm

$$\Rightarrow W = \frac{MoR \times bt^2}{3(l^2 - 4a^2)} \qquad (3)$$

Total Dynamic load over the Skid, W = wL

Designed a wooden skid with jungle wood and calculated the theoretical calculation of load bearing capability for the same. Details are as follows [8],[10],[11].

C. Load Bearing Capability of the Design Chosen:

TABLE IV: DIMENSIONS OF WOODEN SKID CHOSEN

Particular	Symbol	UOM	Values
wood		Jungle wood	
Thickness of deck board	t	mm	10
Sum of widths of deck board planks	b	mm	675
Width of the Skid	B	mm	970
Length of the Skid	L	mm	1000
Length of overhang on either side	a	mm	260
Span length of supports	I	mm	600
Modulus of rupture with 15 % Moisture Content	MOR	N/mm2	70

Incorporated the designed skid values into the arrived equation to calculate the maximum allowable load on the wooden skid

- The equation for calculating the maximum allowable load over the Skid is

$$w = \frac{MoR \times bt^2}{3(l^2 - 4a^2)} \quad (4)$$

$$w = \frac{70 \times 675 \times 10 \times 10}{3((600 \times 600) - (4 \times 260 \times 260))}$$
$$= 17.5 \text{ N/mm}$$

- Maximum allowable UDL over Skid

w = 17.5 N/mm

- Total load over Skid

W = 15750 N

Considering the factor of safety 2, the UDL and the total allowable load over skid is as follows:

- Maximum allowable UDL over Skid

w = 8.75 N/mm

- Total Dynamic load over Skid

W = 7875N i.e. 803 Kgs

D. Load Bearing Capability with respect to types of Load:

TABLE V: MAXIMUM ALLOWABLE LOADS

Type of Load	Relation	With safety factor	Without Safety Factor
Dynamic Load	Total Load over Skid as per calculation as	803 Kgs	1606 Kgs
Dynamic Static Load	3 times of Dynamic Load	2409 Kgs	4818 Kgs
Dynamic Fatigue Load	80 % of Dynamic Load	642 kgs	1284 Kgs

E. Verification of Theoretical Calculations:

- Demonstration has conducted for the justification of theoretical calculations at Amararaja Batteries, Tirupati.
- Based on the theoretical findings the skids were placed over supports simulating the conditions of fork lift.
- The skids were loaded after keeping the skids in position with predetermined Span of fork lift arms. The width of each fork of fork lift was 100mm. The length of fork is approximately 1200mm.The skids were held exactly at horizontal position
- The skids were loaded for the predetermined total load of 1600 kgs, which is the total load over skid as derived in equation and the skids were examined for failures and deformation.
- The load applied in the wooden skid and lifted with the fork list to check the deformation
- Checked the deformation at different load intervals and observed the dynamic load bearing capability close to 1800 kgs.

Fig. 9. a. Verification of Load Bearing Capability

Fig. 9. b. Verification of Load Bearing Capability

To check the dynamic load deformation, Fork lift arms loaded with batteries were subjected to up and down motion for 5 times.

TABLE VI: DEMONSTRATION OF WOODEN SKID

S. No	Theoretical Load without safety factor	Tested Load In Kgs	Observation	Remarks
1	1600 kgs	1000	No damage	Ok
2		1300	No damage	Ok
3		1500	No damage	Ok
4		1800	Damaged the deck boards	Not Ok

The empirical value observed is differed from that of theoretical value by 12.5% and infer a good correlation between the two i.e. theoretical /empirical.

V. CONCLUSION

With the help of simulation study, the wooden skids can be designed to meet different hostile conditions; thereby customer satisfaction can be enhanced. Other salient observations of the study are:

- The load bearing capability of the wooden skid was calculated with the help of flexural strength & moisture content.
- Jungle wood appears to be the suitable skid material.
- The optimal moisture content is about 11 -15 %

ACKNOWLEDGMENT

The authors acknowledge with gratitude the resources and support provided by the Management of Amara Raja to carry out this study and the staff of carpentry and production teams of Amara raja Batteries Limited. Special thanks to Amara raja infra for their work towards the demonstration of the concept.

REFERENCES

[1] pallets.indinf.com/wooden-pallets-pros-and-cons.html
[2] http://www.aalhysterforklifts.com.au/index.php/about/blog-post/a_comparison_of_different_pallet_types?cv=1
[3] http://www.imua.org/Files/reports/999173.html
[4] http://timber.ce.wsu.edu/Supplements/Moisture/moisture%20page2.htm
[5] https://www.coursehero.com/file/66428/Wood-General/?cv=1
[6] Anon. (1986). *Methods of testing of small specimens of timber*, IS 1708. Bureau of Indian Standards, New Delhi
[7] Hoffmeyer., P 1990: *Failure of wood as influenced by moisture and duration of load.* State University of New York, College of Environmental Science and Forestry, Syracuse, New York
[8] Ramamurtham S. (1995). *Strength of Materials*, Dhanpat rai and sons, New Delhi
[9] https://www.allianceforestproducts.com/pallets101.html
[10] Anand Nandanwar, M.C. Kiran, Ch. Varada Rajulu and C. N. Pandey. *Evaluation of Suitability of Radiata Pine (Pinus Radiata) For Making Skids*
[11] Nandanwar Anand and Naidu M Venugopal (2007). *Study on the evaluation of safe working load and optimum width across the fork while lifting wooden Skids with fork lifts'* was published in J. Ind. Acad.Wood Sci., Vol. 4 (1&2).

Madhava Rao Byraboina was born in Nellore (1990), Andhra Pradesh State, India. He has Received Bachelor degree in Chemical Engineering (2011) from Sri Venkateswara University College of Engineering, Tirupathi Campus. Currently working as Assistant Manager in Material Development, Technology Division, Amara Raja Batteries - Tirupathi, India. He is currently taking care of new/ alternate materials development activities for lead acid battery technology. He is a certified signing authority for Dangerous goods packing and declarations in Amara Raja Batteries Limited.

Sreenivas Kosaraju is a senior member of Amara Raja Batteries Limited and is currently holding the position of Sr. Manager - Materials, Amara Raja Batteries Ltd. He is associated with the group for over 27 years. Prior to the current assignment, he held various positions in the organization in the areas of Battery Formation, Field Installation and Commissioning, Technical Service, CI Head, etc.
Sreenivas. Kosaraju obtained MS.C General Chemistry from Madurai Kamaraj University, Tamilanadu and PG Diploma in Industrial Relation and Personal Management from IIMS, Chennai. And also Six Sigma Black Belt Holder and he has been a life member of QCFI.

K S N Murthy was post graduated in chemistry discipline from Central University, Hyderabad in year 1988. Further, he obtained M.Sc. Engg (Metallurgy) and doctorate degrees from Indian Institute of Science in year 1991 & 1996 respectively.
He started his professional career by joining India Lead Zinc Development Association, New Delhi in year 1996. Subsequently, he joined R&D wing in Amara Raja Batteries Limited i.e. in year 2001. Currently, he holds the General manager position and pursue active research in the area of battery materials that include Lead/Lead alloys, Plastics, Additives, Separators, Nano materials etc. He presented several technical papers at National and International events, possesses scientific publications in journals of international status and also a co-author of 4 patents filed recently. He has been a life member of SAEST, QCFI and Indian institute of Metals.

Jagadish Mandava is a member of the Amara Raja Group Growth Committee and also a senior member of the Executive Committee of Amara Raja Batteries Limited and is currently holding the position of Chief Technology Officer, Amara Raja Batteries Ltd. He is associated with the group for over 20 years. Prior to the current assignment, he held various positions in the organization in the areas of Business leadership, Strategic Planning, New business development initiatives, Technology development, Project Management etc.
Mr. Jagadish obtained B. Tech Degree in Mechanical Engineering from Mysore University, Mysore and PG Diploma in Planning & Projects from Hyderabad University. He has also completed "General Management and Leadership Development" program from Indian Institute of Management, Bangalore. His areas of expertise include energy storage technologies, Green energy initiatives and Smart Grid integration.