ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 1, July 2014

Development of a 3-Seater Chair-Bed

*Akinola A. O., **Olugbade, T. O., ***Adamolekun T. M.
Department of Mechanical Engineering
The Federal University of Technology, Akure, Nigeria

Abstract*— The unavailability of decent housing is more pronounced in developing countries where rapid rate of population growth and urbanization is unmatched by corresponding and commensurate change in social, economic and technological development. The number of housing units is limited by some factors which include high cost of land, insufficient funds, and improper management. Thus, the use of convertible space saving furniture such as the chair-bed reduces housing costs as well shrink the house size required (by up to 50%) since spaces like bedrooms might no longer be needed. The purpose of this work is to design and construct a 3-seater chair bed that minimizes the problem of space crunch in homes and offers a rentable means of optimizing the available space by converting the sitting room to makeshift bedroom at night. The construction of the chair bed include the chair frame (1830 mm x 610 mm) and bed frames (1830 mm x 915 mm) with support legs, net bars (each of 48 mm x 148 mm) and foam which was carefully riveted into the bed frame. The cushioning effect, foldability, ergonomics, aesthetic and anti-corrosion properties were considered in the design resulting into a durable and with little effort, converts into a comfortable bed to ensure great sleep. The chair bed was designed for a load of 200 kg. It is a veritable solution to the problem of space unavailability.

***Index Terms:* bed frames, chair-bed, chair frame, ergonomics, housing units, support legs.**

I. INTRODUCTION

The unavailability of decent housing is more pronounced in developing countries where rapid rate of population growth and urbanization is unmatched by corresponding and commensurate change in social, economic and technological development. [1]. Adequate and affordable housing and infrastructure are in short supply in most cases. While the task of housing the nation rest squarely on the shoulder of the government, the individual and the private sector, most of the available spaces around us must be judiciously used. Hence, the manufacture and use of dual purpose furniture like the chair bed is inevitable. It is a veritable tool in solving the problem of space unavailability.

The magnitude of housing needs is manifested in the number of households residing in substandard housing units [2]. The chair bed is of vital importance in today's world in which the rent and housing costs are prohibitively high and some homes spend 75% of their annual income on housing and related issues. This is most especially true for the low-income earners. The number of housing units is limited by some factors such as high cost of land, insufficient funds, improper distribution of funds and improper management [3].Durability of the chair-bed is dependent on some properties such as; the cushioning effect, foldability, ergonomics, aesthetic and anti-corrosion properties. This work was necessitated to practically and economically refrain and reduce the unavailability of space in homes or any form of places. It really account for the maximal utilization of the necessary existing spaces so as to serve the dual purpose of chair during the day and bed in the night. Apart from ergonomics and cushioning effect properties, another factor that must be considered is the issue of loading capacity. The loading capacity of the chair bed is the maximum bearable load it can hold before failure. This determines the durability and the functionability of the chair bed.

Researchers have worked on different chairs and beds in the past. [4] studied the trend and mode of sleeping of man, ranging from sleeping on the floor to the time chair and bed was introduced. The results showed that in all these forms of building or man abode, the modes of sleeping also changes with time. [5] and [6] previously designed a dual purpose chair. [7] Worked on water bed and the six most popular designs of furniture which are traditional, early American or colonial, French provincial, Italian

II. MATERIALS AND METHOD

A. Materials

The materials used for the construction are mild steel, spring steel, synthetic foam, nails, bolt and nut, padding (from thick paper material), rug cloth material for cover and Iron. The tools used to carry out the chair main body construction are welding machine, drilling machine, hand grinding machine, hammer, hacksaw, and hammer.

1. Design Analysis of Bed

The forces acting at the supports are determined by applying the equations of equilibrium to each frame member. Two bed frames were considered of 1830 x 915 mm^2, i.e. the sit area and the back rest which when declined formed complete Bed. The analysis was done with bed framed having just two hinges and two supporting legs. The weight of the prospective user (which was considered to be a maximum of 200 kg) was uniformly distributed over the perimeter of the bed frame. The bed frame is assumed to have a negligible weight compared to other load to be analyzed and the bed frames are statically loaded. The load and the bending moment at the supporting legs were determined.

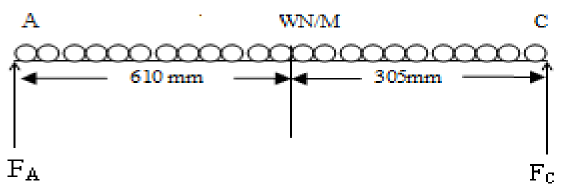

Fig.1: Free-body diagram for side AB

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 1, July 2014

2. *Material Selection*

Table 1: Favorable properties of materials actually used for the chair bed

S/N	Component	Criteria for selection	Most suitable material	Material actually selected	Reason for selection
1.	Bed frames	Strength, rigidity, weldability and general machinability	AISI 1040	AISI 1020	Readily available
2	Bed iron bar	Stiffness	Spring steel	Mild Steel	Readily available
3	Draw bolts	Strength and resistance to fatigue and creep under loading	Stainless steel	Mild steel	Readily available
4	Supporting legs	strength, rigidity and machinability	AISI 1040	AISI 1020	Cheap and readily available
5	Chair frame	Good compressive strength, and machinability	Mild Steel	Mild Steel	Readily available
6	Chair cover	Aesthetic, strength, stiffness and wear resistance	Morocco leather	Commercially available rug cover	Readily available
7	Rubber foam	Elasticity and compactness	Styrofoam	rubber foam	Readily available
8	Hinges	Hardness, strength, and toughness	Stainless steel	Mild steel	Cheap and readily available

The weight per unit length distributed over the perimeter of bed frame (W) was determined using,

$$W = \frac{\text{Mass of user} \times g}{\text{Perimeter of Bed Frame}} \qquad (1)$$

$$W = 357.38N/M$$

The total load on member, L, was calculated using,

$L = W \times g$ (2)

Where g = acceleration due to gravity

$$L = 350N$$

The equilibrium condition was given as;

$\sum F_y = 0$

It was assumed that this load was at the geometric centre of the member (Fig. 2)

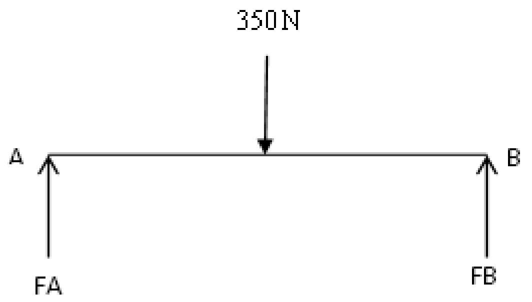

Fig. 2: Modified Free Body Diagram for side AB condition for equilibrium

$\therefore F_A + F_B - L = 0$ (3)

$\sum M_F = O$ (M_F is moment about F_B) taking clockwise moment to be positive

$$F_A \times 0.61 = 350 \times 0.305$$

$$F_A = \frac{106.75}{0.61} = 175\ N$$

$$F_A + F_B = 350\ N$$

$$F_B = 350 - F_A$$

$$F_B = 350 - 175 = 175\ N$$

Therefore, supporting length each is 175N

The hinge was designed using,

Using $\sigma_y = \frac{Mc}{I}$ (4)

Where

$c = \frac{d}{2}$, d being length of axle;

$I = \frac{\pi d2}{32}$ is the area moment of inertia for axle

M = the maximum bending moment = 42.80 N/m

σ_y = the yield strength = 170 MPa

$$d = \frac{16M}{\pi \sigma_y}$$

$$d = 1.28m$$

The stress on the legs was calculated using,

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 1, July 2014

$$Stress\ on\ the\ leg = \frac{Load}{Area} \qquad (5)$$

$$= \frac{175}{1.28} = 137MPa$$

The weight of the user supported by the back rest was calculated using,

$W_b = 0.35 \times W_s$ (6)

Where

W_b = weight of the user supported by the back rest

W_s = weight of the user supported by the seat

The condition for stability was given by

$(W_s \times 5\ 2/2) \geq (W_b \times 3\ 4/2 \times \cos\theta)$ (7)

W = 25506 Ncm.

$W_b \times 32 \cos\theta = 686.7 \times 17 \cos\theta$

$= 11673.9 \cos\theta$

(If cos θ assumed to be maximum (when $\theta = O^0$)

Therefore $W_b \times \frac{32}{2} \cos\theta = 11673.9$Ncm.

Where θ = is the angle of inclination of the back rest to the horizontal.

The greatest backswing force possible in the chair was calculated using,

$$F_{bs} \times Xm = (M_c + M_b)g \times Xm,$$

$$F\_bs = (M\_c + M\_b)g \qquad (7)$$

Where

F_{bs} = the greatest backswing force possible

M_c = Mass of the chair

M_b = Mass of the bed

3. *Ergonomics and Anthropometry of Chair Design*

The design of a Chair requires some considerations depending on its intended functions. Considerations like Ergonomic (Comfortability), as well as non-ergonomic functional requirements such as size, stack ability, fold ability, weight, durability, stain resistance and artistic design. The desired seating position depends on what that chair is to be used for (i.e. Intended functions). For instance, "Task chairs", or any chair intended for people to work at a desk or table, including dining chairs, can only recline very slightly; otherwise the occiput is too far away from the desk or table. Some conditions are listed below.

(a) Hip breadth is used for chair width and armrest width.

(b) Elbow rest height is used to determine the height of the armrests.

(c) The buttock knee length is used to determine "leg room" between rows of chairs.

(d) "Seat pitch" is the distance between rows of seats.

III. RESULTS AND DISCUSSION

A. Evaluation of the Bed Frame

The whole structure that makes up the bed part of this design serves as a frame when it is in the unfolded state but serve as a machine in the inclining process (by virtue of the turning of the hinges). The weight of the prospective user was 200 kg.

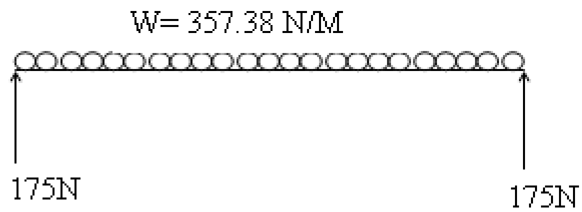

Fig. 3: Body Diagram of the Bed frame

In Fig. 3 above, the weight per unit length distributed over the perimeter of bed frame, (W) was 357. 38 N/m and the normal reaction produce by supporting legs was 175 N each.

B. Shear Force and Bending Moment Diagrams.

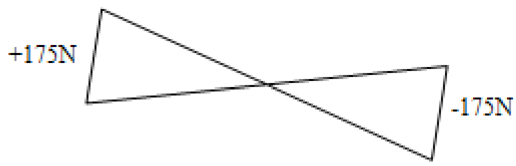

Fig. 4: Shear force diagram for side AB

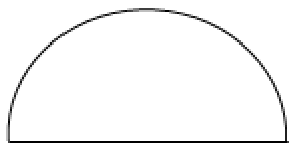

Fig. 5: Bending moment Diagram for side AB.

The shear force and bending moment diagrams are as shown in Figs. 3 and 4.

C. Evaluation of the Back Rest and Chair Analysis

The weight of the user supported by the back rest was obtained to be 11673.9 Ncm and the weight of the user supported by the seat was 25506 Ncm. It is obvious that 25506 Ncm > 11673.9 Ncm, so the chair will remain stable regardless of the angle of inclination of the back rest when the chair is loaded (Fig. 6). This allows for selection of this inclination to be based on aesthetics only. The result showed that when the chair is not carrying any load, it remains stable no matter the inclination of its back rest to the horizontal.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 1, July 2014

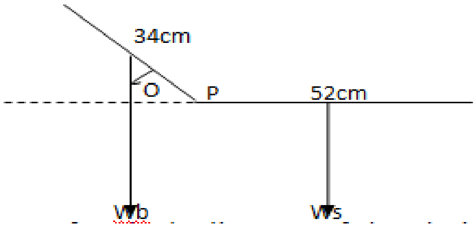

Fig. 6: Free body diagram of the chair

D. Evaluation of the Hinge Design

The maximum bending moment at the hinges was determined to be 42.80 N/m. The loads were carried by the hinge's axle and its size was designed using the theory of mechanics of materials.The fabricated chair-bed is shown in Fig. 7 and Plate 1 in bed form, and in Fig. 8 and Plate 2 in chair from.

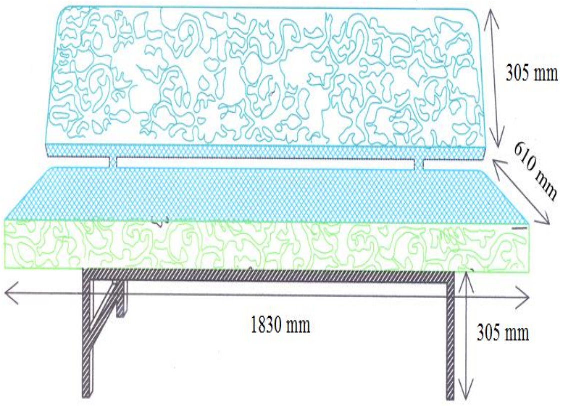

Fig. 7: Fabricated Chair- Bed in Chair Form

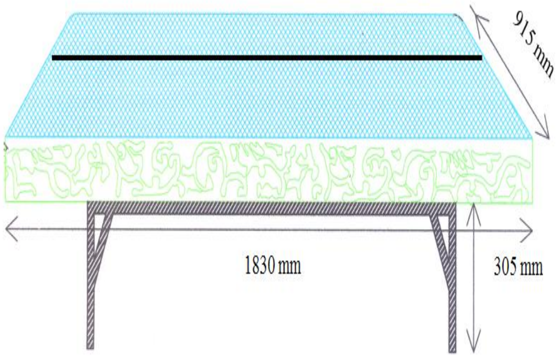

Fig.8: Fabricated Chair- Bed in Bed Form

Plate 1: 3-Seater Chair-Bed as a Chair

Plate 2: 3-Seater Chair-Bed as a Bed

IV. CONCLUSION

The aim of this work was to design and construct a 3-seater chair-bed, i.e., minimizing the problem of space crunch in homes and offers a rentable means of optimizing the available space by converting the sitting room to makeshift bedroom at night. The load and the bending moment at the supporting legs were determined. From the calculation and analysis above, it was obvious that the chair will remain stable regardless of the angle of inclination of the back rest when the chair is loaded. This allows for selection of this inclination to be based on aesthetics only. The result showed that when the chair-bed remains stable when carrying load and no matter the inclination of its back rest to the horizontal. It was designed for a load of 200 kg.

REFERENCES

[1] Mabogunje A.L, Hardoy J.E, Misra P. R, shelter provision in developing countries. Surrey the Gresham Press, 1978.

[2] Olotuah, A. O. Urban Housing and the heritage of earth architecture in Nigeria Proc. of Conference of International Network for Traditional Building, Architecture, and Urbanism (INTBAU), London, UK, 2005, pg. 10.

[3] Massoudi, A., and Simonian, W. The Problem of Housing in Developing Countries Housing Problems in Developing Countries. Dakhil H, Ural, O, Tewlik, M. F. (Eds) Interprint (Malta) Ltd. 1978.

ISSN: 2277-3754
ISO 9001:2008 Certified
International Journal of Engineering and Innovative Technology (IJEIT)
Volume 4, Issue 1, July 2014

[4] Awotona, A. A., Determination of the Quantitative Housing Need: A review of methodologies Nigeria Institute of Architects Journal, N.I.A.J. 1982 pp. 37-48.

[5] Ogumilade, A. J., Design of a Dual Purpose Chair. Unpublished final year project, Federal University of Technology, Akure, 2010.

[6] Adeoye, H. A., Design of a Dual Chair, Unpublished final year project, Federal University of Technology, Akure, 2002.

[7] Walton, J A., Woodwork in theory and practice, Australasian Publishing Company Sydney, 1979.

[8] Khurmi and Gupta, Machine Design, Eurasia Publishing House (PVT.) Ltd. Ram Nagar, New Delhi-1 10 055 2008.