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Critical Analysis and Adaptation of Load Bearing (Resistance) Ability of Curve Engineering Member in Designs

Asha Saturday*, Akao Samuel, Agbadah Solomon Eze, Marcus Anakuagbo Dickson
National Engineering Design and Development Institute (NEDDI), BOX 5082, Nnewi, Anambra State Nigeria
*Corresponding Author: ashiga4oxide @ yahoo.com

Abstract: *Engineering design is made functional and durable by applying some engineering considerations such as material selection, availability, formability, besides the geometric shape orientation that is considered in this paper. Many designs especially the world class cars in the automotive industries, aircraft and aerospace technology use shape as basis for designing with consideration for fuel economy and speed. This also is / could be applied in structural engineering and mechanical components for load resistance ability. Geometric shape orientation becomes significant by considering the load resistance ability of the flat or straight beam and a curve beam of the same material – using solid Work 2014 verified with the well-known Hooke's law of elasticity.* $P = K\lambda_{max}$ *is the relation for the investigation. Studies revealed that curve beam has high stiffness, K ,(N/m), than the flat under a point (P) load 1200N. Verification conducted using Ansys Workbench with mild steel, the curve and the flat bars have equivalent Von Mises stress of* $1.8799 \times 10^6 Pa$ *and* $1.3092 \times 10^7 Pa$ *respectively and total deformation of* 9.6896×10^{-6} *m and* 2.2582×10^{-7} *m respectively. Therefore, besides the consideration for conservation of space, geometric curve orientation should be adapted when designing for a load carrying member in Engineering designs and systems where space is not a constrain.*

Keywords: *load resistance and resistance ability, curve and flat beam, solid work 2014*

INTRODUCTION

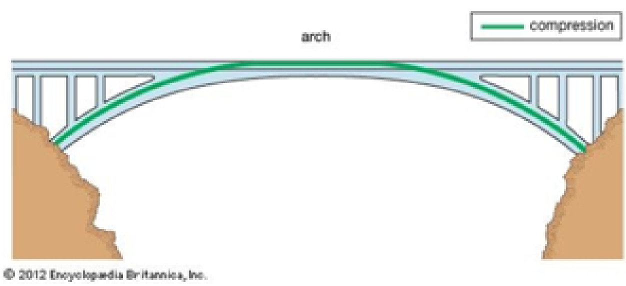
Load resistance ability becomes paramount when designing for load carrying members in engineering designs, structural and mechanical works [4]. Besides the material selection, material composition, micro structure and the particle binding forces, shape orientation becomes vital when designing for load carrying members. Studies reveal that geometrically, curve orientation had long been adapted for load carrying member of a mechanical or structural system but this work buttressed and x-rayed the necessity for this adaptation for reliability, spring effect, durability and load carrying capacity. In automobiles, the leaf springs, and Beeville springs are used. In a research work by Haruna M. S et al. (2015), [2], it was observed that the radius of curvature of Master leaf spring played a role on its load carrying ability. The doom shape in cathedrals and mosques are good examples of load carrying member that carries load of monuments. Curve beams are applied in bridges for load bearing but not mostly for the artistic hetaeristic side of design in engineering work, both mechanical and structural works [5]. Bridges in ancient times even at present have curved member to carry load, examples are shown in figure 1.

i.Osaka (Osaka Prefecture).Japan

ii.Foz do Iguaçu (Paraná (state) - Ciudad del Este (Alto Paraná Department, Paraguay, and Brazil

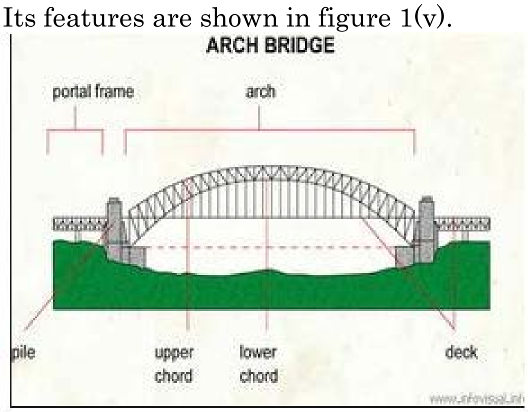
iii.Malmedy - Verviers (Liège).Belgium

***See others at List of long arch bridge spans – [3]



iv. Arch

An Arch is basically a curved structure that is used to bridge an opening. It is able to support heavy load and forces that act from above it [3]. Its features are shown in figure 1(v).



v.Features of Arch [3]

Fig 1. Pictorial Views of Bridges with Curve Supports

A parabolic arch utilizes the principle that if a weight is uniformly applied to an arch, the internal compression deriving from that weight will follow a parabolic profile. Among all the basic arch types, parabolic arches produce the most thrust at the base, but can span the largest areas [3]. This type of arch is usually used in designs for bridges where long span is needed like between valleys or high areas. It has been found advantageous to use curved beams or bow girders in building design and bridge design. Recently many architects and designers have become more interested in using them. The difference in analysis and design between the curve beams and the straight beams is mainly due to the presence of torsional movement induced by vertical load. Therefore, for such members, it is necessary to design for internal bending moment, and twisting moment as well as transverse shear. Curve beams, either made of steel or reinforced concrete, can be continuous or monolithic at both ends (Wikipedia, the free encyclopedia.htm).

2.Scope

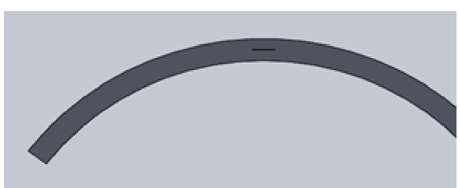
Loading is a critical point to consider when designing for engineering component. Its durability, functionality, and efficiency center on its ability to carry load-pressure, force, heat, electromagnetic or shocks in flow, etc. Mechanical and structural engineering members are most often subjected to loads especially force or pressure loads and the ability to withstand these loads without failure does not only depend on the material composition, manufacturing conditions, micro structures but also the geometrical parameters and configuration. Hence this work is done to show the load bearing ability between curve metal bar and flat metal bar that both are AISI 1035 Steel (SS) suggested in the solid works materials library. And this is investigated with Ansys Workbench.

3.Problem Statement

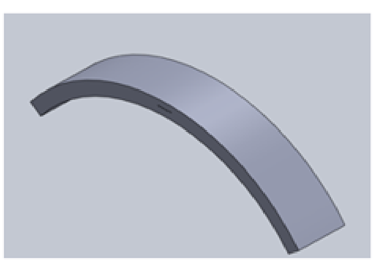
Many analyses have been done on the failure of engineering members. This cuts across material selection, atomic micro structure composition of bodies, degree of mealability and brittleness of the bodies as well as hardness. Failure analysis has not been done on the effect of the geometric adaption on an engineering member. This study reveals that geometric orientation of engineering member is necessary in considering its load carrying ability, stiffness and the ease of failure. Hence, this CAD and CAE work with solid work 2014 X-rayed the effect of curve orientation on stiffness – load carrying ability of a beam, through analysis of curve bar and its equivalent flat straight bar.

4.Aims and Objectives

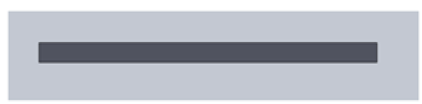
Primarily, this paper work is done to show the effect of geometry in the load carrying ability of an engineering member and also suggest the use of curve shape or geometry in load carrying members in structural and mechanical designs.



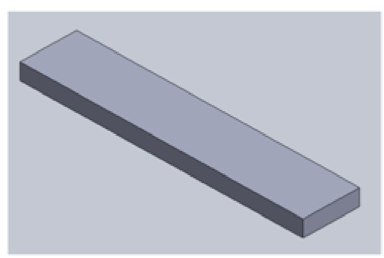
i. Curved bar AISI 1035 Steel (SS)



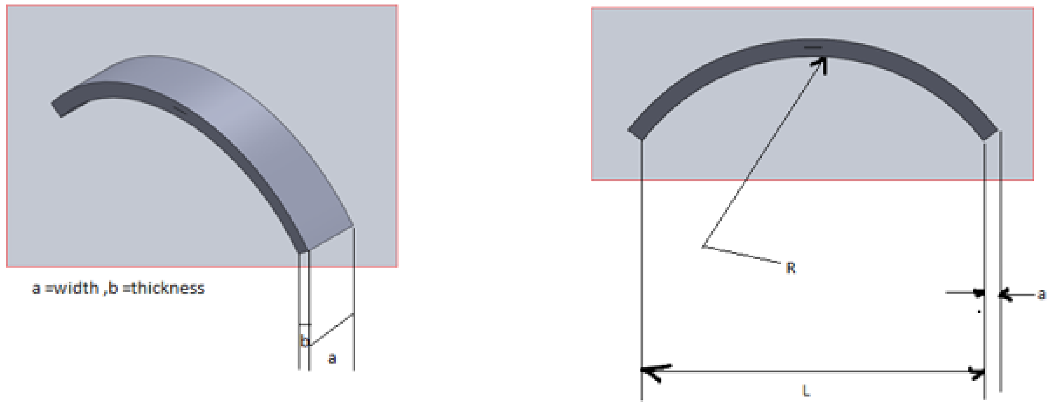
ii. Isomentry of Curved bar AISI 1035 Steel (SS)



iii. Flat bar AISI 1035 Steel (SS)



iv.Isomentry of flat bar AISI 1035 Steel (SS)



i.

ii.

fig 2. Curve and flat model with Parameters describing the curved beam member

Considering the parameters in figure 2, where;

$L = span\ of\ the\ beam\ (mm)$
$\ell = length\ of\ the\ beam\ (m0$
$R = radius\ of\ the\ beam\ (mm)$
$a = width\ of\ the\ beam\ (mm)$
$b = thinkness\ of\ the\ beam\ (mm)$
$P = point\ load\ (1200N)$

6.METHOMOLOGY

This work is made simplified by the adoption of the Hooke's law of elasticity

$P = K\lambda_{max}$ (1)

Where ,$P = stiffness(^N/_m)$

$\lambda_{max} = maximum\ deflection\ (m)$

The stiffness (K) N/m is deducted mathematically.

$K = P/\lambda_{max}$ (2)

This is the load bearing ability or capacity and it can also be verified using Von Mises stress on the body.

Assumption

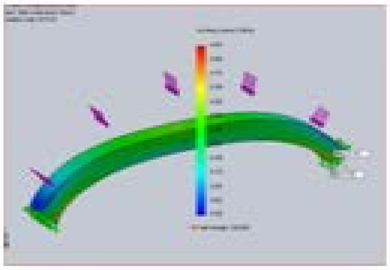
This work is done based on the following assumptions:

i. The material selected is assumed to be elastic.
ii. The cross section of the beam is uniform and small compared with the radius of curvature.
iii. The load (p) applied is not impact.
iv. There is no sliding on application load.
v. There is no rebounce on application of load.
vi. The material used for the simulation is:

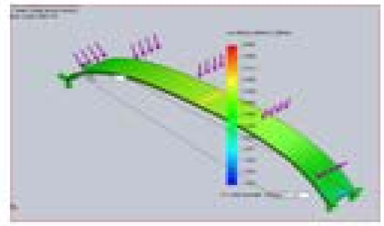
Table 1. Mechanical Properties

Name:	AISI 1035 Steel (SS)
Model type:	Linear Elastic Isotropic
Default failure criterion:	Max von Mises Stress
Yield strength:	282.685 N/mm^2
Tensile strength:	585 N/mm^2

From the works, the radius of curvature is arbitrarily chosen, R, (m) where the span L is equal to the length of the beam and is kept constant. The width (a) and thickness (b) are varied equally to verify the effect of the curvature on the load carrying ability.

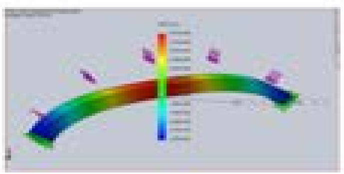


a

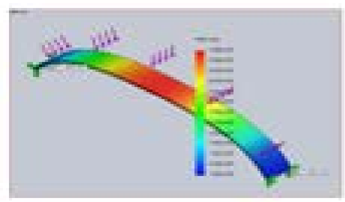


b

fig3 , a and b Showing The Von Mises Stresses On The Curve Member Due To The Load F ,1200N

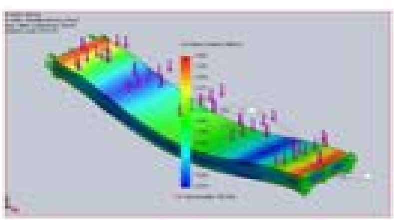


i.

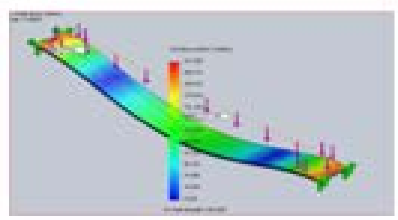


ii

fig 4 . i. and ii Deflection On The Curve Member Caused By Application Of Load, F,1200N

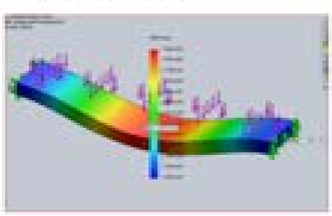


a.

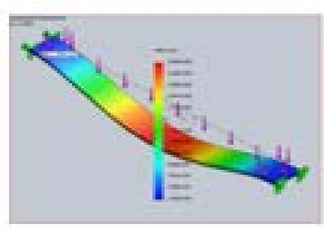


b.

fig 5. a and b Showing The Von Mises Stresses On The Flat Member Due To The Load F ,1200N



i.



ii.

fig 6. i. and ii Deflection On The Flat Member Caused By Application Of Load, F,1200N

Table2: Load Carrying Ability of a Curve Metal

RADIUS OF CURVATURE, R=313.39mm, Span=length=500mm

Load, F=1200N

MODELS	Thickness t(mm)	Width W(mm)	Deflection λ_{max} (mm)	Von Mises Stress N/mm²(MPa)	Stiffness K N/mm²
A	30	100	5.97E-04	0.443	2.01E+06
B	25	90	8.07E-04	0.502	1.49E+06
C	20	80	1.15E-03	0.729e	1.04E+06
D	15	70	1.77E-03	1.016	6.78E+05
E	10	60	3.12E-03	1.629	3.85E+05
F	5	50	7.57E-03	3.465	1.59E+05

Table3. A Table Showing the Effect of Load On a Flat Engineering Member

Flat member

Length =500mm

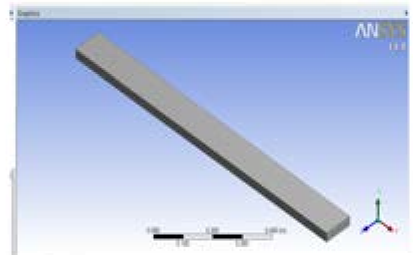
Load =1200N

MODELS	Thickness t(mm)	Width W(mm)	Deflection λ_{max} (mm)	Von Mises Stress N/mm²(MPa)	Stiffness K N/mm²
A	30	100	8.68E-03	2.952	1.38E+05
B	25	90	1.64E-02	4,718	7.30E+04
C	20	80	3.57E-02	8.342	3.36E+04
D	15	70	9.60E-02	17.595	1.25E+04
E	10	60	3.76E-01	44.77	3.20E+03
F	5	50	3.595	227.06	3.34E+02

Verification

Ansys workbench was used to satisfy these results and work a mild steel of the same span and thickness chosen for a curve and a flat bar.

i.Curve Model



Ii Flat Model

Fig.7. 3-D Models of the Curve Bar and Flat Bar

Table 4: Mechanical properties of medium carbon steel

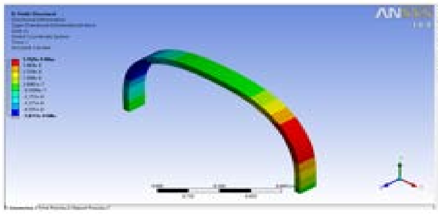
Density (kg/m³)	7800kg/m³
Young's modulus (GPa)	205
Yield strength (elastic limit) (MPa)	508
Tensile strength (MPa)	706
Poisson Ratio	0.28
Elongation (% strain)	10
Hardness (Vickers)	200

Source: Granta CES edu pack (2011)

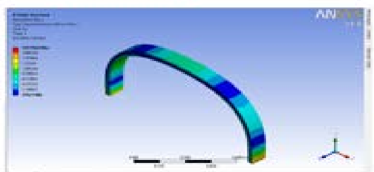
This table information was used to build the model of each of the bars with Ansys Workbench and simulated model.

Simulated Model of Curve Bar

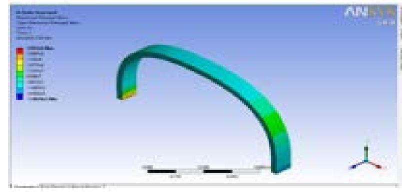
i.Total Deformation



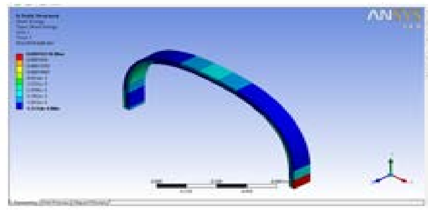
ii.Directional Deformation



iii.Von Mises Stress



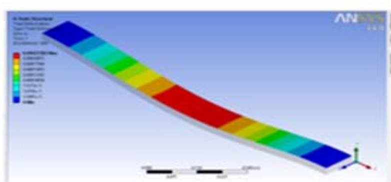
vi.Maximum Principal Stress



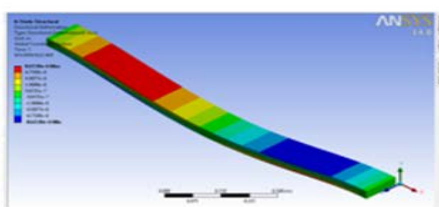
v.Strain Energy

Fig8. Simulated Models of the Curve Mild Steel Bar

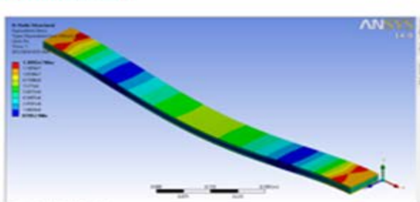
Flat Mild Steel Model



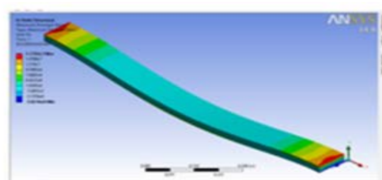
i.Total Deformation



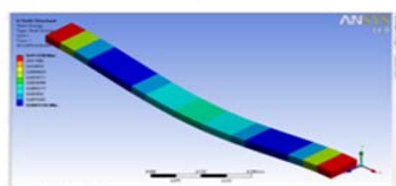
ii.Directional Deformation



iii. Von Mises Stress



vi. Maximum Principal Stress



v. Strain Energy

Fig 9. Simulated Models of the Flat Bars

Table 5: Results

S/N	OUTPUT PARAMETER	MILD STEEL	
		CURVE	FLAT
1	Total Deformation (m)	9.6896×10^{-6}	2.2582×10^{-7}
2	Directional Deformation (m)	5.169×10^{-6}	8.6539×10^{-6}
3	Equivalet Von mises stress (Pa)	1.8799×10^{6}	1.3092×10^{7}
4	Strain Energy (j)	0.00016136	0.013358

7.Discussion and Suggestion

From the CAD and CAE works done with Solid Work 2014, it was shown that the curve beam has more stiffness k N/m and less deflection (y) (m) than the flat beam; hence, its load carrying ability. However, other factors like its width, thickness may play vital roles on its load carrying ability but the curvature is significant and outstanding. The load carrying ability is its resistance to deflection, the lower the deflection the higher its ability to carry load, also the radius of curvature is a factor that affects the resistive ability to resist load. We therefore suggest that in design of load supporting members, curved shape should be adapted to increase the load resistive ability of the member and increase the life span (durability) of the body. Simple mechanical members leaf springs, and conical washers; structure architecture designs bridges, and buildings; are therefore suggested to have geometrical curve orientation in areas that demand loading and support.

8.Conclusion

Curve bodies have been seen to offer high resistance to loads; hence, this should be adapted in designing engineering members that will carry loads like static, dynamic or impact loads. This is seen in the load carrying ability of a beneville disc washer [1] that has vast application in valves and spring loading under shock loads.

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