Finite Element Analysis & Experimental Testing of Frame for Wall Mounted Indoor Swing

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Abstract: *Nowadays, due to the shortage of time & also rush at the gardens, children are not able to play swings. Few indoor swings are available but they are having some drawbacks. Hence a wall mounted swing has been analytically designed. Finite element analysis & experimental testing of the frame of the wall mounted swing is done. Two dimensional analysis is done initially to validate the design by comparing the deflection of the beam. Then three dimensional analysis is done to study the stresses. Software ANSYS is used for the analysis. Experimental testing is done by mounting the the swing on the wall. Horizontal deflections of beam during swinging action & vertical deflections of the beam in static loading are noted during experimental testing.*

Key Words: *wall mounted swing, finite element analysis, cantilever beam, Von Mises stresses*

1. INTRODUCTION:

Many times children can't be taken to gardens for playing swing & other equipments. Also during the rainy seasons the gardens are closed. This leads to more use of games related to mobiles & computers. Disadvantages of these games are involvement in unwanted things, sleepless nights and fatigue, reduced time with family, nostalgia, eyesight issues, and isolation. A swing can be calming or alerting. It can create a space & time for socializing or provide a great workout. Some of the benefits of swinging are Coordination & motor planning, Body awareness, Rock-a-bye- baby, Focus & attention, Core control & upper body workout, Sensory integration & Mood booster.

2. DESIGNED FRAME OF WALL MOUNTED SWING:

The complete frame consists of one main cantilever beam to which hooks for chains are welded. Two supporting members are attached to the main beam to reduce the deflection of the cantilever beam at the free end & also to avoid the deflection of the main beam in the horizontal plane during swinging action. Using the analytical formulae the bending stresses, deflections are determined & dimensions are finalized.

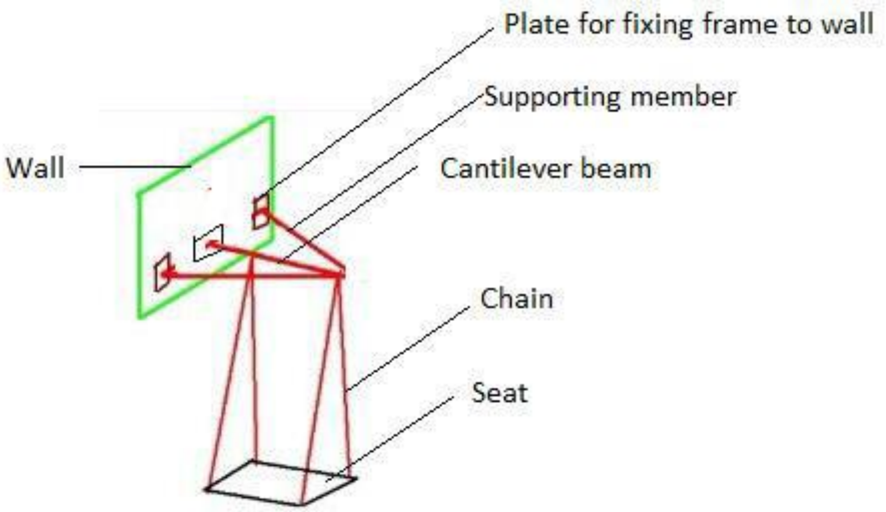

Figure 1 Proposed wall mounted indoor swing

The cantilever beam & support members are angles of 50 mm x 50 mm x 3 mm thick [1]. The length of the main cantilever beam is taken as 500 mm. Keeping a distance of 150 mm from wall (i.e. fixed end of beam), one chain is attached to beam. Another chain is attached at the free end of beam. Thus distance between loading points of chain is 350 mm. The design of swing is done for a capacity of 50 kg. However a factor of safety of 4 is chosen for the same.

3. FINITE ELEMENT ANALYSIS:

Finite element analysis is a good method to reduce the number of experiments during product development. [2][3].

1) **Finite Element Analysis of simple cantilever beam (2D):** Initially to decide the element edge length a simple cantilever beam is analyzed. The details are as follows.

Model of cantilever beam: Using the facilities in ANSYS, cantilever beam is modeled.
Meshing: For meshing, BEAM3 (2D Elastic 3) is used [4].
Load condition: A load of 245.25 N is applied at the end of the cantilever beam.
Boundary condition: All movements (rotary & linear) of left end of the beam are restricted.

Figure 2 shows model of simple cantilever beam with load conditions along with boundary condition

2) **Finite Element Analysis of cantilever beam of frame of swing**

The frame of the swing is a case of a cantilever beam with two point loads. Hence, again cantilever beam is modeled & two point loads of 245.25 N are applied at two points at which chains of swing are hanged. Figure 3 shows model of cantilever beam of frame with load conditions along with boundary condition.

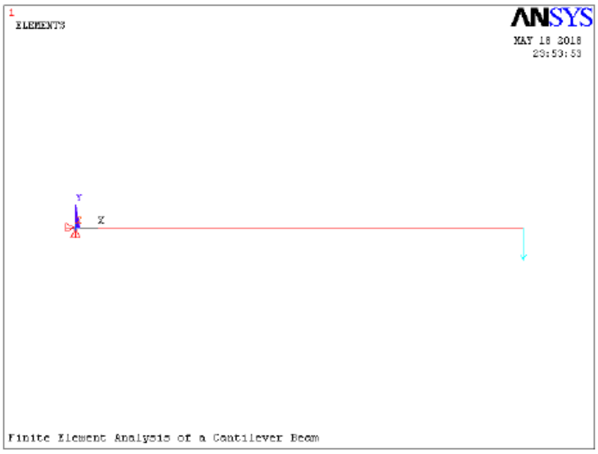

Figure 2 Model of simple cantilever beam with load condition & boundary condition

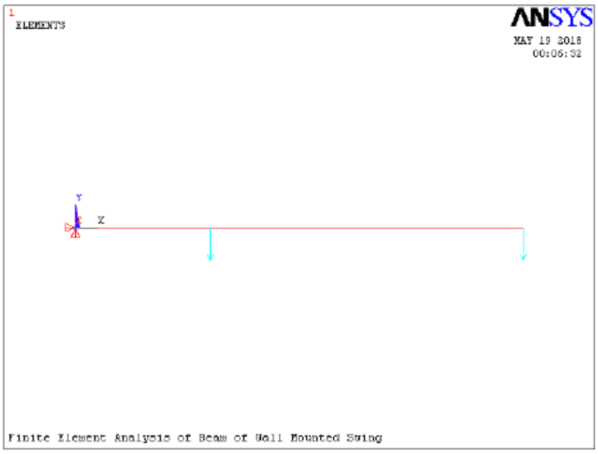

Figure 3 Cantilever beam of frame of swing with load & boundary conditions

3) **Finite Element Analysis of complete frame of swing**

The supporting members are analyzed for their inclination angle to the main cantilever beam. The deflection at the end of the beams is studied.

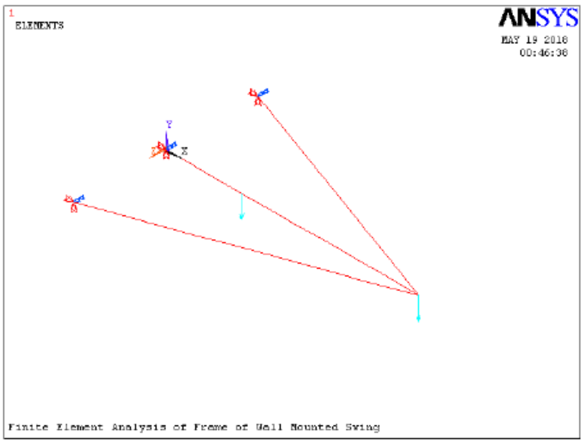

Figure 4 Complete frame of wall mounted swing with supporting members at 20^{o} to the main beam

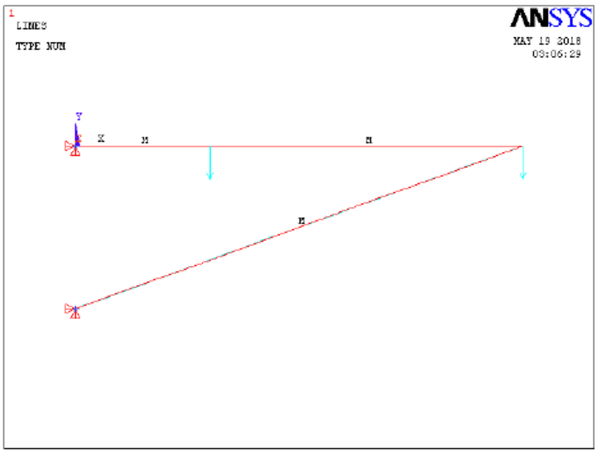

Figure 5 Cantilever beam with only one support member & loading in horizontal plane

Figure 4 shows model of complete frame with load & boundary conditions. As the supporting members are also fixed to the wall, all rotary & linear movements of the ends of the supporting members are also restricted similar to that of main cantilever beam. Three different angles between main cantilever beam & supporting members are taken for study. These are 20^o, 25^o & 30^o.

Deflection of cantilever beam in horizontal plane due to swinging action

As dynamic analyses are difficult to perform, strength of the supporting members is analyzed statically by considering higher values of the loads. For this, the contribution of only one supporting member is considered instead of two (actual) & deflection of the cantilever beam is determined.

The loads in horizontal plane applied at the two points of chain hanging are varied. These loads are 1000 N, 1500 N, 2000N, 2500 N & 3000 N at each point. The deflections of the cantilever beam in horizontal plane are noted. Figure 5 shows the model of cantilever beam with only one supporting member & two point loads.

4) Three Dimensional Finite Element Analysis of simple cantilever beam

After two dimensional analysis, further three dimensional analysis is done to study the stresses. Figures 6 to 9 show the details of the three dimensional analysis of cantilever beam.

Meshing of the cantilever beam:

For meshing of the model, 8 Node Brick 45 (SOLID45) elements are used [4]. Here the element edge length is varied from 10 mm, 20 mm, 25 mm, 30 mm, and 50 mm. The mesh density was finalized using element size of 10 mm. The geometry of this element is as shown in the Figure 7. The tetrahedral option is used for this model. Solid 45 is used for the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

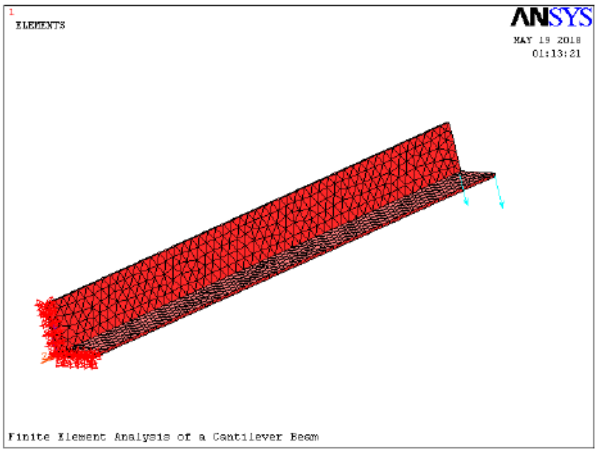

Figure 6 Simple Cantilever beam with load condition & boundary condition (3D)

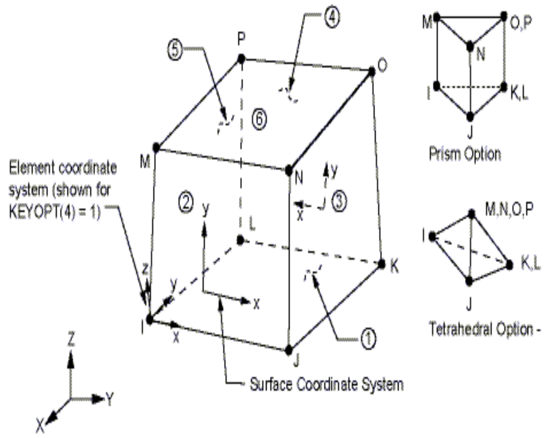

Figure 7 Geometry of SOLID45 element [4]

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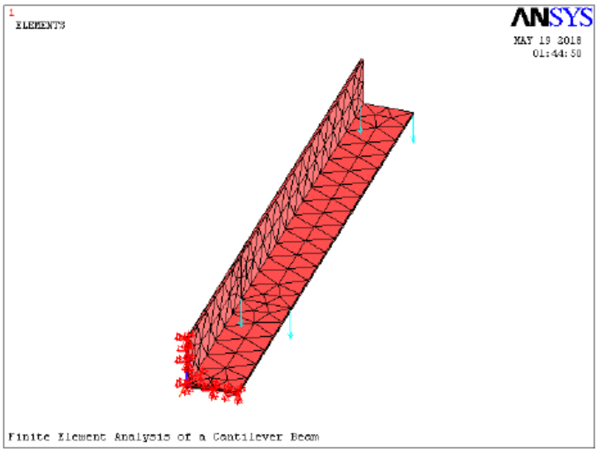

Figure 8 Cantilever beam of frame of swing with load & boundary conditions

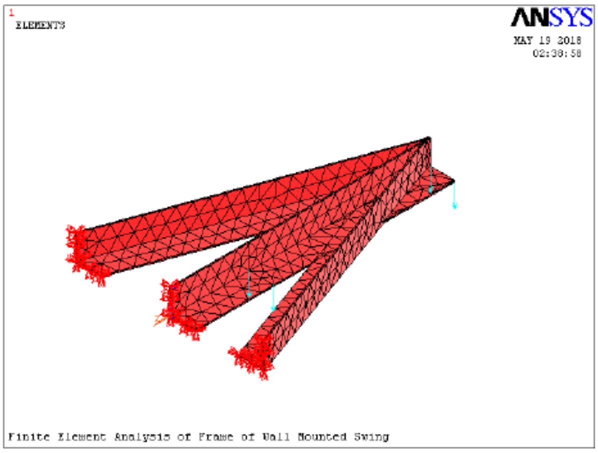

Figure 9 Complete frame of swing with load conditions & boundary conditions

Three dimensional finite element analysis of complete frame of swing

Further model of complete frame of wall mounted swing is prepared. The figure 9 shows model of complete frame with load conditions & boundary conditions applied to complete frame of the swing.

4. RESULTS & DISCUSSION:

Effect of mesh size of defection: Element size is varied & its effect on the deflection of cantilever beam is studied. As there no effect on the deflection of the beam for number of elements 1 to 100, a reasonable number of element is finalized as 10, which gives an element size of 500/10 = 50 mm. The same element size is taken throughout the two dimensional analysis. This deflection is 0.705228 mm. analytical value of deflection is also 0.7 mm [5]. Hence error is less than 1%.

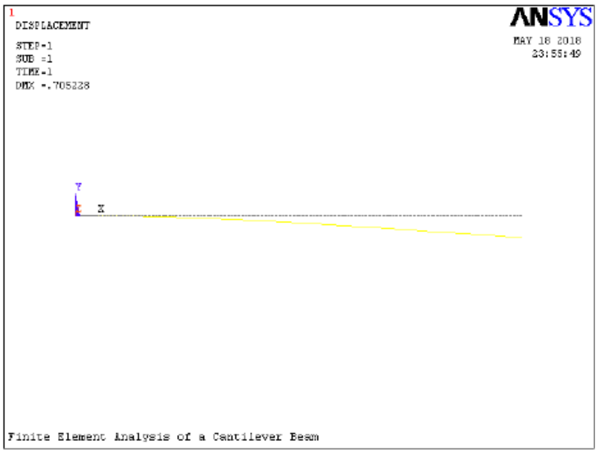

Figure 10 Deformed shape of simple cantilever beam along with un-deformed beam

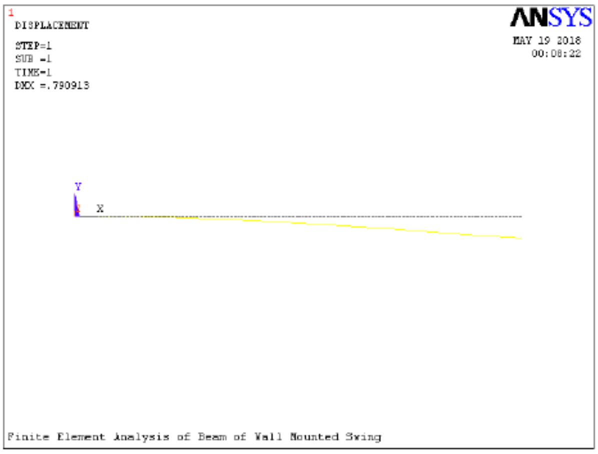

Figure 11 Deformed shape of beam of frame along with un-deformed beam

The deflection of cantilever beam of the frame without support members is obtained as 0.790913 mm by finite element analysis. The deformed shape of beam along with un-deformed beam is shown in Figure 11. Analytical value of deflection is 0.79 mm [6]. Hence, again error is within 1%.

The vertical downward deflection of the complete frame is shown Figure 12. This deflection of complete frame for different positions of support member is same. As 20^{o} angle between support member & main cantilever beam reduces the size of the swing, the same is finalized.

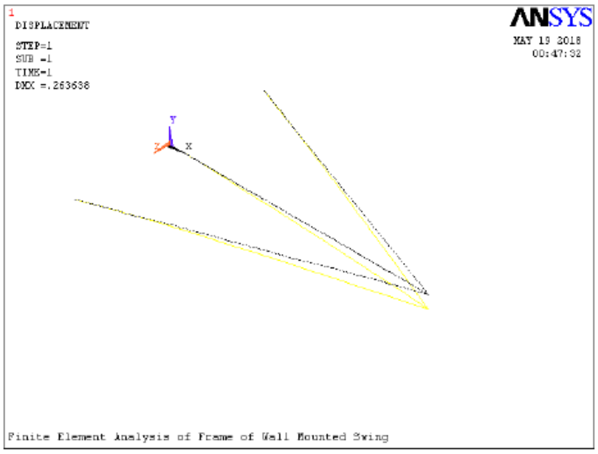

Figure 12 Deformed shape of complete frame with support members at 20^{o} to main beam

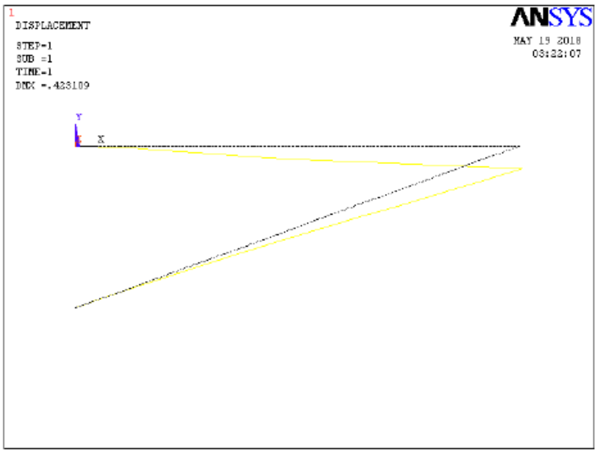

Figure 13 Deformation of cantilever beam in horizontal plane

Deflection of cantilever beam in horizontal plane due to swinging action

Here only one support member is considered for safety purpose. Actually one support member will be in compression while other will be in tension.
The deformed shape of the structure for the highest point load (3000 N) is shown in Figure 13.

Table 1 Deflection of cantilever beam in horizontal plane for different loads

Load (in horizontal plane) at each point (N)	Deflection of beam (mm)
1000	0.141036
1500	0.211555
2000	0.282073
2500	0.352591
3000	0.423109

Thus deflection of beam in horizontal plane is also negligible even for very high load & even with only one support member. Hence the dimensions of the support members also are found ok.

Deflection of simple cantilever beam (3D)

The deflection at the free end due to load, is summarized in Table 2.

Table 2 Deflection of cantilever beam for various element edge lengths (3D-FEA)

Element edge length (mm)	Deflection at free end (mm)
10	1.155
20	0.736778
25	0.686479
30	0.632812
50	0.147551

The deflection of the beam with element edge length of 25 mm is shown in Figure 14. As this element edge length of 25 mm gives value of the deflection near to the analytical value of deflection 0.7 mm, the same element edge length is taken for further three dimensional analyses.

Deflection of the beam of the frame of swing:

The deflection of the cantilever beam of the frame obtained by three dimensional finite element analysis is 0.810248 mm while analytical value of the same is 0.79.

Error =

=

= 2.53 %

As the error is less than 5%, the results obtained by finite element analysis are acceptable.
Figure 15 shows deformed shape of beam of frame of swing along with edge view of the un-deformed beam.

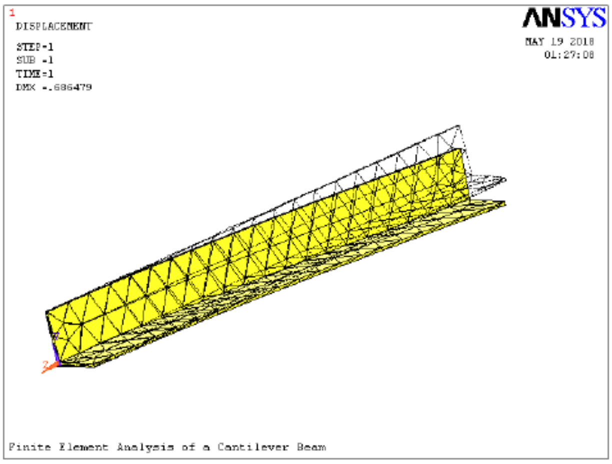

Figure 14 Deflection of the beam with element edge length of 25 mm.

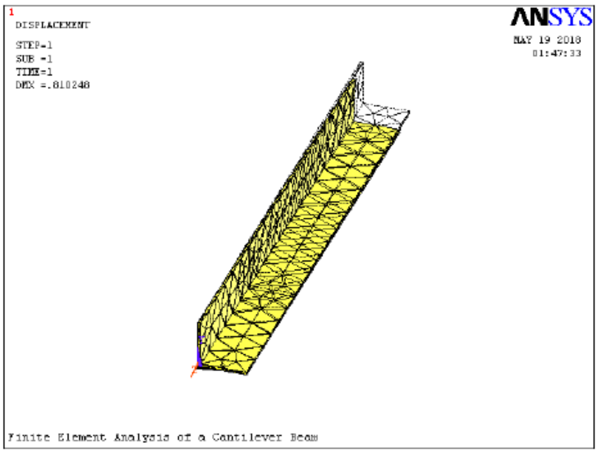

Figure 15 Deformed shape of beam of frame of swing

Deflection of the complete frame of the swing

The deflection in vertical downwards direction & Von Mises stresses in complete frame also observed.

Deflection of complete frame: Figure 16 shows vertical deflection of complete frame. The maximum deflection is 0.414945 mm. This deflection is very small & hence acceptable.

Von Mises stresses in complete frame: The maximum Von Mises stress is observed as 47.503 MPa which is well within the limit. Figure 17 shows Von Mises stresses in the frame for static loading.

Thus the dimensions of the frame of the wall mounted indoor swing are found ok.

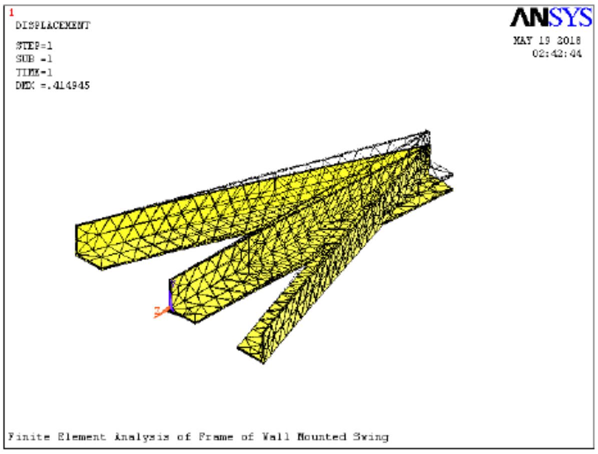

Figure 16 Deformed shape of complete frame with edge view of un-deformed shape (3-Dimensional)

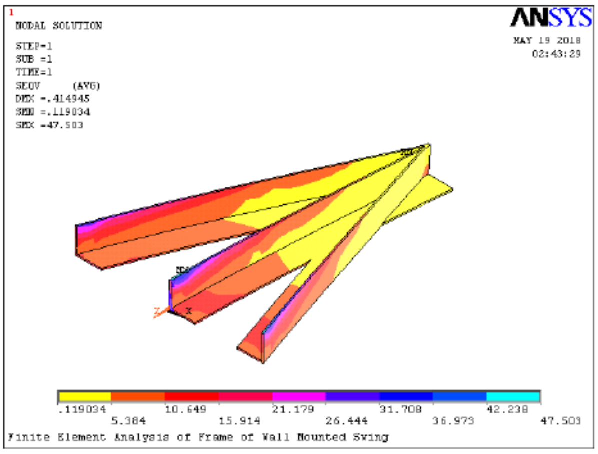

Figure 17 Von Mises stresses in complete frame

As all the dimensions determined analytically are validated by finite element analysis, manufacturing of the swing is done. Experimental testing of the same is done to check once more the deviations if any. The results of the experimental tests are also represented in this paper.

5. EXPERIMENTAL TESTING OF WALL MOUNTED SWING:

The wall mounted swing is manufactured after finalizing the dimensions in the design stage & confirming them using Finite Element Analysis. After mounting it on the wall, the vertical deflections of the cantilever beam are measured using dial gauge indicator. Also the deflections of the cantilever beam in horizontal plane due to swinging action are measured during this testing.

Wall mounted indoor swing

The designed swing is actually manufactured. Figure 18 (a) shows the same in the mounted condition.

Experimental set up for measurement of vertical & horizontal deflections of cantilever beam

A dial gauge indicator is used to measure the deflections of the cantilever beam in horizontal & vertical plane. Figures 18 (b) & (c) show the arrangements for the same.

Wall mounted indoor swing

Experimental set up to measure vertical

Experimental set up to measure deflection of cantilever beam in

(a)	deflection of beam of frame (b)	horizontal plane (c)

Figure 18 Wall mounted swing & experimental set up for deflection measurement

A dial gauge indicator of least count 0.01mm is used for the deflection measurement. The range of the dial gauge was 0-10 mm. The deflections are noted for various values of loads. The values of deflection are slightly on higher side as compared to the one given by finite element analysis.

Table 3 Horizontal & Vertical deflection of cantilever beam of frame - Experimental

Load (kg)	Horizontal Deflection (mm)	Vertical Deflection (mm)
16.05	0.00	0.79
21.93	0.00	0.94
44.02	0.03	1.89
56.14	0.05	1.91
65.60	0.06	1.95

6. CONCLUSIONS:

In this research work, analysis and experimental testing of wall mounted indoor swing is done.
Following are the conclusions.

- The deflection of the main cantilever beam of the frame of the swing is found to be reduced by about 50% due to the supporting members.
- Supporting member's angular position within limit (20^o to 30^o) with main cantilever beam is not having any effect on the deflection of the cantilever beam.
- The proposed wall mounted swing does not obstruct the path of travel like the one mounted at doors.
- Finite Element Analysis helps to reduce the time required for new product development.
- Von Mises stresses & deflection of the frame of the swing are well within limit.
- Experimental values of vertical deflection are found to be slightly on higher side as compared to that of finite element analysis. This may be due to the rough surface of the wall because of which the holding force applied by nail will get reduced slightly.
- Negligible deflection of the beam occurs in the horizontal plane during swinging action. This is due to the strength of the supporting members.
- The only limitation of the proposed swing is requirement of strong walls for its mounting.

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