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Physically Touching the Concepts of Structural Engineering

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Abstract:- The way to become familiar with the structural engineering is to understand the structural engineering concepts and principals. For instance, resonance is the key to understand the vibration characteristic of the structure due to the dynamic load applied at the natural frequency to the structure, force path describes the transmission of the force at the supports, the concept of the prestress and many more. To make the students better understand the concepts and principles, we need to make such concepts more observable and touchable. Now computers had replaced many hand calculations so it is the need of today's era to discover new methods to understand the structural engineering concepts and principles. So we won't flawed by the incorrect computer analysis.

***Keywords**:- Structural engineering, model concept, frame, trusses, shear centre.*

I. INTRODUCTION

Structural concepts are crucial ingradient for students to understand structural engineering, for practicing structural engineers use in civil and structural engineering practice. The teach-in of structural concepts at university needs to be enhanced to meet changes and ever increasing challenges Structural engineering. Concepts through models will create appropriate research output and will definitely satisfy dubiety of young structural engineers. This approach will enable these three parallel themes.

- Providing a series of elementary demonstration models to illustrate structural concepts in traditional class teaching which allow students to gain a better understanding of the concepts.
- Providing associated engineering examples to demonstrate the application of the structural concepts, which help to bridge the gap between the student's knowledge and practice.

II. BASIC PHYSICAL MODELS

Fig1. (A) Shows a bottle of wine and a piece of wood with a hole. The bottle can be supported by the wood when the neck of the bottle is inserted into the hole to the maximum extent, and the two form a single wood–bottle system in equilibrium.

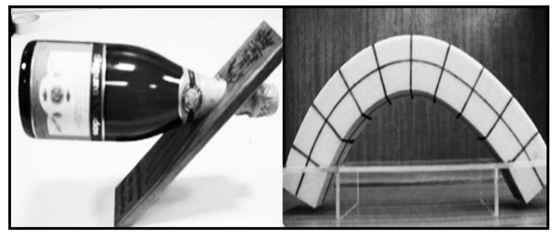


Fig 1:- Model for (a) Balancing of forces, (b) Bending of Beam

The wood–bottle system, backed on the narrow wooden edge, is and feels very stable, because:

- The two external forces from the weights of the bottle and the wood are equal to the reaction force generated from the table.
- The sum of the moments of the two action forces about the point where the support force acts are equal to zero.

Fig 1. (b) Demonstration examines some of the basic assumptions used in the theory of beam bending.

A symmetric sponge beam model is made which can be bent and twisted easily horizontal lines on the two vertical sides of the beam are drawn at mid-depth, indicating the neutral plane and vertical lines at equal intervals along the length of the sponge are made indicating the different cross-sections of the beam. With the help of this model, following things can be observed:

- All of the vertical lines, which indicate what is happening to the cross-sections of the beam, remain straight.
- The angles between the vertical lines and the centroidal line (neutral axis) remain at 90 degrees.
- The upper surface of the beam extends indicating tension and the bottom surface shortens, indicating compression.
- Plane sections before bending remain plane after bending

III. MODEL OF FRAMES

Frame analysis is one of the major parts of the analysis of the structural portal frames are frequently used over the entrance of a bridge and as a main stiffness element in building design in order to transfer horizontal forces applied at the top of the frame to the foundation. On bridges, these frames resist the forces caused by wind, earthquake, and unbalanced traffic loading on the bridge deck. Portals can be pin supported, fixed supported, or supported by partial fixity. The loading in the case of the portal frames are either symmetrical or unsymmetrical and this different type of loading produces different type of effects in the portal frame, different deflected shapes and shear force and bending moment diagrams. Sometime the loading creates the horizontal movement and sway. Frames are of two types:

- Symmetrical frames
- Anti-symmetrical frames
- Asymmetric system

Symmetrical frames: Consider a simple symmetric frame with no horizontal forces but subjected to a concentrated vertical load as shown in Figure. The beam has a length of L and rigidity of E.Ib and the two columns have the same length of h and rigidity of E.Ic.

If the axial deformations of the columns and the beam of the frame can be considered to be negligible, the structure has three degrees of freedom; the horizontal displacement, u, and the rotations, θA and θB at the connections of the beam and columns. Thus, the equations of static equilibrium of the frame are given by.

$$\frac{EI_c}{h^3}\begin{bmatrix} 24 & 6h & 6h \\ 6h & 4h^2(\alpha\beta+1) & 2h^2\alpha\beta \\ 6h & 2h^2\alpha\beta & 4h^2(\alpha\beta+1) \end{bmatrix}\begin{Bmatrix} u \\ \theta_A \\ \theta_B \end{Bmatrix} = \begin{Bmatrix} 0 \\ M_A \\ M_B \end{Bmatrix}$$

Where

$$\alpha = h/L \quad \beta = EI_b/EI_c$$

MA and MB are the fixed end moments of the beam produced by the vertical loading. By convention, the positive sign occurs when the end moment induces clockwise rotation. As the coefficient matrix in equation (I) is fully populated, the horizontal displacement is coupled with the rotations. Expanding the first row of equation gives.

$$u = -\frac{h(\theta_A + \theta_B)}{4}$$

Therefore u is zero when θA = -θB. This occurs when symmetric loads are applied to the beam. Solving equation gives the horizontal movement of the frame due to the vertical load.

$$u = \frac{-(M_A + M_B)}{4(6\alpha\beta+1)\alpha L}\frac{h^3}{EI_c}$$

The negative sign indicates that the movement of the frame is to the left.

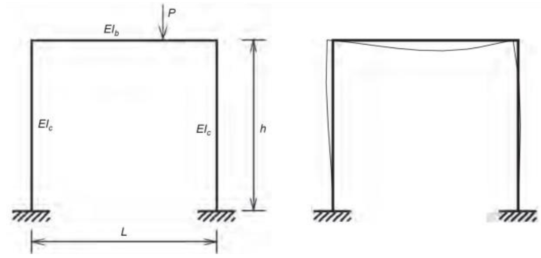


Fig 2:- A symmetric frame subjected to asymmetrical vertical load.

Anti-Symmetrical Frame: If the left column of the frame shown in Figure 2 is rotated through 180° about its connection to the beam, the frame becomes anti-symmetric as shown in Figure 1(a).

$$F = \frac{(M_B - M_A)}{4(2\alpha\beta+1)\alpha L}\frac{12(2\alpha\beta+1)}{(\alpha\beta+2)}$$

$$= \frac{(M_B - M_A)}{LP_{TV}}\frac{3}{(\alpha\beta+2)\alpha}P_{TV} = C_L C_S P_{TV} = C_{LS}P_{TV}$$

where

$$C_L = \frac{M_B - M_A}{LP_{TV}}$$

$$C_S = \frac{3}{(\alpha\beta+2)\alpha}$$

In addition to the conclusions drawn from section which are also valid for the anti-symmetric system, it can be deduced that:

- The load factor CL and structure factor CS for the anti-symmetric systems are significantly larger than those for the symmetric system. Hence, the magnitude of the horizontal movement due to vertical loads depends primarily on the structural form.
- Equation above indicates that the antisymmetric frame has no horizontal movement when MA = MB, which requires a particular distribution of anti-symmetric vertical loading. For any other vertical loading there will be a resulting horizontal movement.

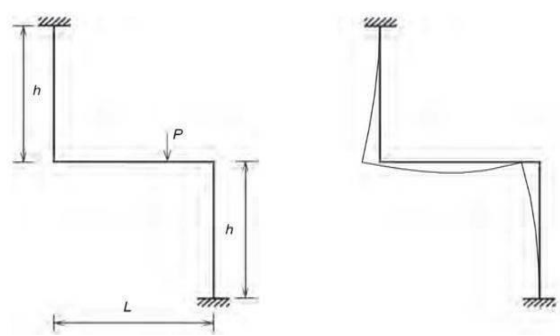


Fig 3:- An anti-symmetric frame with an asymmetrical load.

Asymmetrical Frames: If the lengths of the columns of the frame shown in Figure 2 are different, the frame becomes asymmetric.

To get a feel of the various support conditions and the deflected shape in the frame due to different loading, it is very essential to prepare the models for the frames and the Staad-Pro Software Package validates the same models.

IV. PREPARATION OF MODEL

- To prepare the model of the simple frame, the most important aspect is to prepare the supports and selection of the right material for the same. Hence, wood was used for the same.
- For making the hinged support, first cut the wood in the trapezoidal form, and make a groove of v shape in between the same.
- To make the fixed support make a groove of circular shape in the trapezoidal wood piece and to make the connector for the two beam section in the frame, cut a wooden cube and make the grooves in all the faces of the cube.

Fig 4:- (a) Groove making for hinged support, (b) Cube for joint connection (c) Drilling for joint connection

- After making the support, the next important task is making the frame for frame, for which we had used the orange colour plastic strip. The supports are fixed to the piece of the plywood with the help of nails.
- Subsequently for the hinged support, the nails are used to attach the plastic strip, with the support then the member is joined to the other element directly with the help of the drilled cube.
- By following the same procedure the following three combinations are prepared:
- ✓ Fixed-Fixed
- ✓ Hinged-Hinge
- ✓ Fixed-Hinged
- The loading is applied symmetrically and unsymmetrically.

For Fixed-Fixed

For Hinged-Hinged

For Fixed-Hinged

Fig 5:- (a) Dial gauge setup on frames (b) Deflected shape by symmetrical loading (c) Deflected shape by unsymmetrical loading

- Then Staad-Pro models are created for the same geometry and different support conditions shown below:

For Symmetrical loading
For Fixed-Fixed

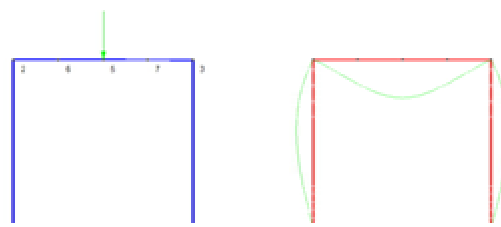
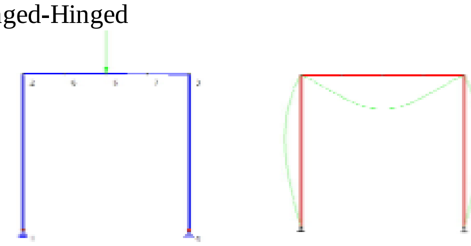


Fig 6:- Staad Output for Deflected Shape for Symmetrical Loading for (a) Fixed-Fixed

For Hinged-Hinged



For Fixed-Hinged

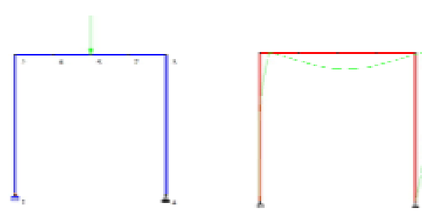
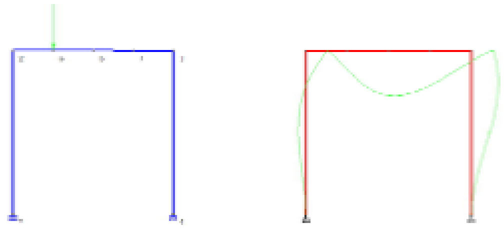
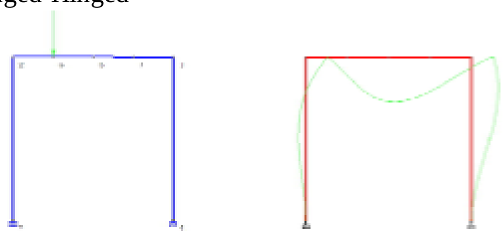


Fig 7:- Staad Output for Deflected Shape for Symmetrical Loading for (a) Hinged-Hinged, (b) Fixed-Hinged

For Un-symmetrical loading
For Fixed-Fixed



For Hinged-Hinged



For Hinged-Hinged

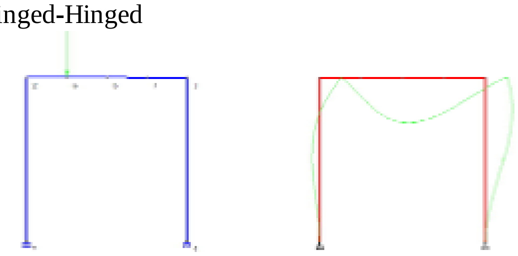


Fig 8:- Staad Output for Deflected Shape for Symmetrical Loading for (a)Fixed-Fixed (b) Hinged-Hinged, (c) Fixed-Hinged

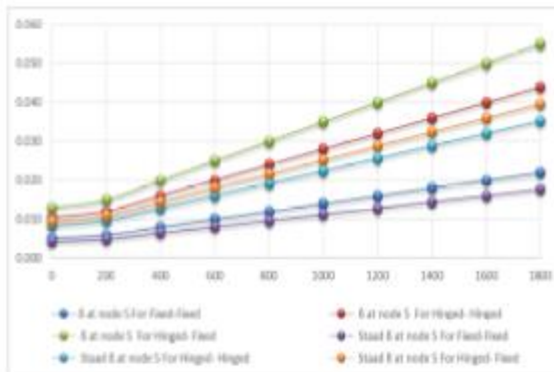
C. Comparison of the Experimental and Staad-Pro, deflected shape value Output for Node-5 for the Symmetrical Loading:

Wt in gm	δ at node 5 For Fixed-Fixed	δ at node 5 For Hinged-Hinged	δ at node 5 For Hinged-Fixed
0	0.005	0.010	0.013
200	0.006	0.012	0.015
400	0.008	0.016	0.02
600	0.010	0.020	0.025
800	0.012	0.024	0.03
1000	0.014	0.028	0.035
1200	0.016	0.032	0.04
1400	0.018	0.036	0.045
1600	0.020	0.040	0.05
1800	0.022	0.044	0.055

Table 1. Deflected shape value Output for Node-5 for the Symmetrical Loading

Wt in gm	Staad δ at node 5 For Fixed-Fixed	Staad δ at node 5 For Hinged-Hinged	Staad δ at node 5 For Hinged-Fixed
0	0.004	0.008	0.009
200	0.004	0.009	0.010
400	0.006	0.012	0.014
600	0.008	0.016	0.018
800	0.009	0.019	0.021
1000	0.011	0.022	0.025
1200	0.012	0.025	0.028
1400	0.014	0.028	0.032
1600	0.016	0.032	0.036
1800	0.017	0.035	0.039

Table 2. Deflected shape value Output for Node-5 for the Symmetrical Loading by staad model



Graph-1 Graph for Deflected shape value Output for Node-5 for the Symmetrical Loading

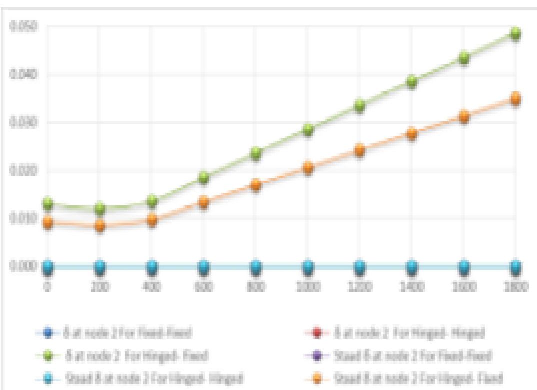
D. Comparison of the Experimental and Staad-Pro, deflected shape value Output for Node-2 for the Symmetrical Loading:

Wt in gm	δ at node 2 For Fixed-Fixed	δ at node 2 For Hinged-Hinged	δ at node 2 For Hinged-Fixed
0	0.000	0.000	0.013
200	0.000	0.000	0.012
400	0.000	0.000	0.0136
600	0.000	0.000	0.0186
800	0.000	0.000	0.0236
1000	0.000	0.000	0.0286
1200	0.000	0.000	0.0336
1400	0.000	0.000	0.0386
1600	0.000	0.000	0.0436
1800	0.000	0.000	0.0486

Table 3. Deflected shape value Output for Node-2 for the Symmetrical Loading

Wt in gm	Staad δ at node 2 For Fixed-Fixed	Staad δ at node 2 For Hinged-Hinged	Staad δ at node 2 For Hinged-Fixed
0	0.0000	0.0000	0.0094
200	0.0000	0.0000	0.0086
400	0.0000	0.0000	0.0098
600	0.0000	0.0000	0.0134
800	0.0000	0.0000	0.0170
1000	0.0000	0.0000	0.0206
1200	0.0000	0.0000	0.0242
1400	0.0000	0.0000	0.0278
1600	0.0000	0.0000	0.0314
1800	0.0000	0.0000	0.0350

Table 4. Deflected shape value Output for Node-2 for the Symmetrical Loading



Graph-2. Graph for Deflected shape value Output for Node-2 for the Symmetrical Loading

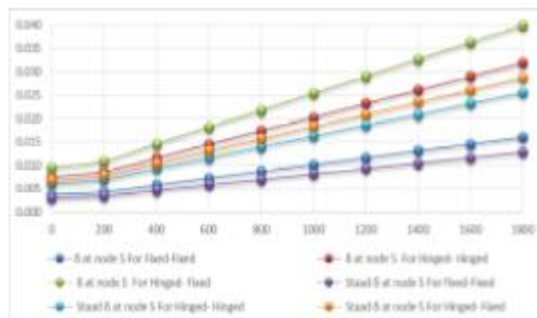
E. Comparison of the Experimental and Staad-Pro, deflected shape value Output for Node-6 for the Un-symmetrical Loading:

Wt in gm	δ at node 5 For Fixed-Fixed	δ at node 5 For Hinged-Hinged	δ at node 5 For Hinged-Fixed
0	0.004	0.008	0.009
200	0.004	0.009	0.011
400	0.006	0.012	0.015
600	0.007	0.015	0.018
800	0.009	0.017	0.022
1000	0.010	0.020	0.025
1200	0.012	0.023	0.029
1400	0.013	0.026	0.033
1600	0.015	0.029	0.036
1800	0.016	0.032	0.040

Table 5. Deflected shape value Output for Node-5 for the Un-symmetrical Loading

Wt in gm	Staad δ at node 5 For Fixed-Fixed	Staad δ at node 5 For Hinged-Hinged	Staad δ at node 5 For Hinged-Fixed
0	0.003	0.006	0.007
200	0.003	0.007	0.008
400	0.005	0.009	0.010
600	0.006	0.012	0.013
800	0.007	0.014	0.016
1000	0.008	0.016	0.018
1200	0.009	0.019	0.021
1400	0.010	0.021	0.024
1600	0.012	0.023	0.026
1800	0.013	0.026	0.029

Table 6. Deflected shape value Output for Node-5 for the Un-Symmetrical Loading



Graph-3. Graph for Deflected shape value Output for Node-5 for the Un-Symmetrical Loading

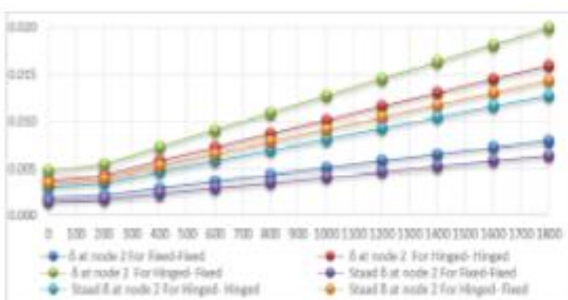
F. Comparison of the Experimental and Staad-Pro, deflected shape value Output for Node-2 for the Symmetrical Loading:

Wt in gm	δ at node 2 For Fixed-Fixed	δ at node 2 For Hinged-Hinged	δ at node 2 For Hinged-Fixed
0	0.002	0.004	0.005
200	0.002	0.004	0.005
400	0.003	0.006	0.007
600	0.004	0.007	0.009
800	0.004	0.009	0.011
1000	0.005	0.010	0.013
1200	0.006	0.012	0.015
1400	0.007	0.013	0.016
1600	0.007	0.015	0.018
1800	0.008	0.016	0.020

Table 7. Deflected shape value Output for Node-2 for the Un-Symmetrical Loading

Wt in gm	Staad δ at node 2 For Fixed-Fixed	Staad δ at node 2 For Hinged-Hinged	Staad δ at node 2 For Hinged-Fixed
0	0.00151	0.00302	0.00340
200	0.00174	0.00348	0.00392
400	0.00232	0.00465	0.00523
600	0.00290	0.00581	0.00653
800	0.00348	0.00697	0.00784
1000	0.00407	0.00813	0.00915
1200	0.00465	0.00929	0.01045
1400	0.00523	0.01045	0.01176
1600	0.00581	0.01162	0.01307
1800	0.00639	0.01278	0.01437

Table 8. Deflected shape value Output for Node-2 for the Un-Symmetrical Loading



Graph-4. Graph for Deflected shape value Output for Node-2 for the Un-Symmetrical Loading

G. Horizontal Deflection at in frames symmetric Frame

Symmetric frame Figure 9(a) shows a simple anti-symmetric plastic unloaded frame (a) and carrying an asymmetrically concentrated load positioned close to the right-hand column (b). It can be observed that the horizontal member deflects vertically and the loaded frame moves to its left. Once again it is noted that, the movement is to the left for the load placed to the right of the centre line of the frame.

Anti-Symmetric Frame Figure 9(b) shows a simple anti-symmetric plastic unloaded frame and carrying an asymmetrically concentrated load positioned close to the right-hand column. It can be observed that the horizontal member deflects vertically and the loaded frame moves to its left. Again, the movement is to the left for the load placed to the right of the centre line of the frame.

Asymmetric Frame Figure 9(c) shows a simple asymmetric plastic frame unloaded and carrying a concentrated load positioned close to the right-hand column. The horizontal member deflects vertically and it can be observed that the loaded frame moves to the left. Again, the movement is to the left for the load placed to the right of the centreline of the frame.

Fig 9:- Horizontal movement on (a) Symmetrical frame (b) Anti-symmetric frame (c) Asymmetrical frame.

H. Results

The results shows the deflected shapes of portal frames (symmetrical, anti-symmetrical, and asymmetrical) under different loading and support conditions. It is proved from the above study that the fixity results in the less deflection, whereas the hinged end causes more deflection. The above study also shows that the horizontal nodal deflection occurs only when there is any un-symmetry in the case of the portal frames. The validation of the results is done by software analysis and the nature of the deflection obtained by the experimental results is varying within the limit not greater than 10 percent, which shows that models truly explains the behaviour in case of the portal frames.

V. CONCLUSION

If structural concepts could be made more observable and touchable, students would be better able to understand them and would be more attentive in class learning situations. The models prepared by us ably demonstrate the clear visualization of the structural concepts and principles.

The models prepared for frames clearly shows the deflected shapes for different support condition and for different loading condition. By the help of this models we can clearly see the effect of the support condition on the deflection of the nodal points.

Definitely this type of user friendly and appropriate technology models will level up the structural engineering concepts, smooth learning process and bridge up the gap between the mathematical concept and structural behaviour.

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