Shuttering Design & Cost Comparisons

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Abstract— Shuttering is the most ignored aspect in Indian Construction scenario. Formwork is carried out by the same age old methods. But there is advancement in formwork methods as well as types which require careful attention in order to arrive at efficient, economic & durable formwork design as well as formwork cost.

The temporary structure erected to support the concrete in its required shape, till it hardens and becomes self supporting is known as form-work or shuttering.

As the definition states that shuttering is a kind of mould created temporarily for the purpose of pouring concrete in it to have desirable geometrical structure. Also it helps in the strength gain of concrete member as early curing is permitted. From the stability point of view as well as from architectural point of view, Shuttering

Index Terms—shuttering design,

I. INTRODUCTION

In cities like 'Mumbai which have a considerable amount of humid atmosphere, there are chances that the shuttering may keep expanding and contracting due to change of atmosphere and the shuttering plywood may bend subjecting to bulging of sides of Column, Retaining Wall, Footing, Beams, Chajjas, etc. It may cause bending of beams and slabs which is unsafe from both structural point of view and also from architectural point of view if the plywood used for shuttering is not accounted for its properties for moisture content during extreme humid conditions and in monsoon season. If care is not taken in design then it may create blunder. Even the stacking of shuttering materials has an adverse effect on design of shuttering as the designer design the ply for its maximum available repetitions, but due to improper use of the shuttering materials the design may fail after repetitive improper use of the shuttering materials which also affects the cost factor of project.

Shuttering counts for 50% of the total project cost. So for the same purpose Cost Analysis of various systems of shuttering in various construction practices and depending on the type of project in hand, Cost Analysis has immense effect on the overall economy of the project. Cost Analysis of various types of systems gives an idea of comparative costing of various systems in comparison to the type of project. It may so happen that a shuttering system used for an institutional or commercial project may prove to be expensive for the use of it for residential purpose and vice versa. From all the briefing above, it concludes that both Design and Cost Analysis of Shuttering system for a particular project has to be done prior for going for a particular kind of shuttering system.

II. CASE STUDY

A. Dream Villa Bungalows at Goa

Shuttering Design of Conventional Timber Shuttering along with Cuplock System as Staging was undertaken. Project was just an assumption of G+2 Luxurious Bungalows. Design done for new shuttering materials.

B. New building of Shri Bhagubhai Mafatlal

Shuttering System was Cuplock System along with timber shuttering. Designing was done for this and checked. Project was an Institutional Building G+7 floors and 3 Basements having floor plate area of 25000ft^2(Approx). Design Checked for existing shuttering materials.

III. UNITS

Use of MKS Units is done for designing of entire formwork design

IV. MATERIAL SPECIFICATIONS

Marine Plywood as per IS 710: 2010, IS 1734: 1983

ISMB 100 & 150 as per IS-SP-6(1): 1964

Joint Putty as per IS-SP-6(1): 1964

MS Square Pipe as per IS 4923: 1972

Technical properties of Marine Plywood by Manufacturer

(Pragati Hightech Products Pvt. Ltd.)

Wooden Joists or Beam Technical properties as per book Design of Steel Structure (L.S.NEGI)

V. DESIGNING COMPONENTS

Slab & Beam Formwork Design

a) Materials used for Slab & Beam Shuttering.

i. Marine Plywood 2400mm*1200mm*12mm.

ii. Wooden Runner Beam of 10mm*7.5mm*1600mm.

iii. Vertical of 2m length, 48.3mm External Diameter, 2.6mm Wall thickness.

iv. ISMB 100 of 3200mm length.

v. Square Pipe 40mm*40mm C/S area, thickness of wall 2.6mm.

vi. Horizontal of 1.5m length, 48.3mm External Diameter, 2.6mm Wall thickness.

vii. U-Head of 600mm/300mm adjustable. 32mm diameter and 150mm*120mm*50mm*4/5mm.

viii. Base Plate of 300mm/600mm adjustable. 32mm diameter, 120mm*120mm*4/5mm.

b) Designing of Vertical of Cuplock System

1. Load Calculation.

2. Assuming the Spacing of Verticals @ 1.5m c/c & 1kg = 10N.

3. Dead Load of Concrete on Shuttering (w_1) = Length (m)*Breadth (m)* Height (m)* Density of Concrete (2500 kN/m^3).

4. Live Load Calculation (w_2) = Load of Shuttering materials above 2m Vertical (Including Self weight) + Load of labor + Load of Vibrators, etc + Load due to sudden heap of concrete (rarely).

5. = 350Kg/ 3.5kN.

6. Total Load on Vertical of 2m (w) = 3+4

7. Formula used for determining

8. σac (actual) = 0.5* $\{(fcc*fy)/[(fcc^n+fy^n)^{1/n}]\}$ where

9. σac = Permissible stress in axial compression MPa.

10. fy = yield stress of steel in MPa.

11. fcc = elastic critical stress in compression = π^2*E/ λ^2

12. λ = slenderness ratio = l/r,

13. l = effective length of compression member

14. r = appropriate radius of gyration of member

15. E = Elastic Modulus = 2*10^5 MPa, n = a factor assumed as 1.4

16. Permissible stress in axial compression as per Table 5.1(L.S.Negi, Design of Steel Structure) σac = 33 Mpa

17. Load on each vertical (P permissible)

18. = σac (permissible)*Area (Area as per provided by manufacturer)

19. So, use Cuplock of 2m height, OD 48.3 at the spacing of 1.5m/1m c/c as per required.

c) Designing ISMB

1. Load Calculation.

2. Assuming the Spacing of ISMB 100 @ 1.5m c/c & 1kg = 10N.

3. Dead Load of Concrete on Shuttering (w_1) = Breadth (m)* Height (m)* Density of Concrete (2500 kN/m^3). = 1.5m*0.15m*25kN/m^3

4. = 5.62kN/m^2.

5. Live Load Calculation (w_2) = Load of Shuttering materials above ISMB 100 (Including Self weight) + Load of labor + Load of Vibrators, etc + Load due to sudden heap of concrete (rarely). =3.5kN/m^2.

6. Total Load on ISMB 100 (w) = 3+4

7. Assuming the horizontal spacing of ISMB at 1.5m c/c & using ISMB 100 for shuttering. Assuming that ISMB 100 is simply supported at 1.5m c/c.

8. Calculating Maximum Bending Moment (M.max) = $wl^2/8$

9. Permissible Compressive stress (σbc) or Permissible tensile stress (σbt) = 0.66*fy

10. …where fy = yield stress of steel in MPa. And formula is derived from the book, Design of Steel Structure (L.S.Negi)

11. Now the elastic section modulus required (Zreq) = Max. Bending Moment/ σbt or σbc

12. Check the Shear action on ISMB 100, Maximum Shear force (vactual) = wl/2

13. Average Shear Stress (ζva provided) = vactual/ ƫ w*d .where ƫ w = thickness of web. But permissible shear stress (ζva permissible) = 0.4fy

14. Checking ISMB 100 for deflection (δ),

15. Maximum Deflection (δactual) = $K*(W*l^3/E*Ixx)$ .where W = concentrated load on support in kN = w*l

16. l = effective length in meters

17. Ixx = Moment of Inertia about X-X axis

18. E = Modulus of elasticity in N/cm²

19. K = coefficient of maximum deflection

20. But, allowable deflection (δallowable) = l/325

21. Checking web crippling for ISMB 100,

22. Bearing stress at supports = R/ {[ƫ w*(a+h_1√3)]}

23. .where R = Reaction at supports in kN = wl/2 a = length of support i.e. U-Head base length in mm

24. h_1 = height of ISMB 100 including flange

25. But, Permissible Bearing Stress (σb) = 0.75fy

26. So, use ISMB 100 at horizontal spacing of 1m and simply support ISMB 100 at 1.5m c/c on U-head of base length 150mm.

d) Designing Square Pipe

1. Assuming the horizontal Spacing of Square Pipe @ 300mm c/c on ISMB 100, using square pipe 40mm*40mm*2.6mm wall thickness & 1kg = 10N.

2. Dead Load of Concrete on Shuttering (w1) = Breadth (m)* Height(m)* Density of Concrete (2500 kN/m2).

3. Live Load Calculation (w2) = Load of Shuttering materials above Square Pipe (Including Self weight) + Load of labor + Load of Vibrators, etc + Load due to sudden heap of concrete (rarely). = 1kN

4. Total Load on Square Pipe (w) = 2+3

5. Assuming the horizontal spacing of Square Pipe at 300mm c/c & using Square Pipe 40mm*40mm*2.6mm wall thickness for shuttering. Assuming that Square Pipe is simply supported at 1m c/c on ISMB 100.

6. Calculating Maximum Bending Moment (M.max) = wl2/8

7. Permissible Compressive stress (σbc) or Permissible tensile stress (σbt) = 0.66*fy where fy = yield stress of steel in MPa. And formula is derived from the book, Design of Steel Structure (L.S.Negi)

8. Now the elastic section modulus required (Zreq) = Max. Bending Moment/ σbt or σbc

9. Check the Shear action on Square Pipe 40mm*40mm*2.6mm, Maximum Shear force (vactual) = wl/2

10. Average Shear Stress (ζva provided) = vactual/ area

11. Checking Square Pipe 40mm*40mm*2.6mm for deflection (δ),

12. Maximum Deflection (δactual) = K*(W*l3/E*Ixx)

13. So, use Square Pipe 40mm*40mm*2.6mm at a horizontal spacing of 300mm c/c and simply support it on ISMB 100 at 1m c/c.

14. Designing Wooden

e) Runner Beam

1. Assuming the horizontal spacing of Wooden Beam 100mm*75mm*1600mm at 300mm c/c and the wooden beam is simply supported on ISMB 100 at 1m c/c. Timber used for all the Joists is Bijasal of Grade B and Wet Condition.

2. Dead Load on Wooden Beam (w1) = R.C.C beam load in terms of U.D.L

3. Live Load on Wooden Beam (w2) = Load due to movement of labour + Load due to heap of concrete (rarely) + load due to equipments + Self weight of Wooden Beam

4. Total load on Wooden Beam (w) = 2+3

5. Calculating Maximum Bending Moment on Wooden Beam (M.max) = wl²/8

6. But, permissible bending stress for Bijasal timber in wet condition as per table of book, Design of Steel Structures (L.S.Negi) (σb) = 9.8 N/mm²

7. Elastic Section Modulus required (Zreq) = M.max/ σb

8. Checking Bijasal timber Beam for Shear agency,

9. Permissible Shear Stress from the table given for Bijasal timber = 0.9 N/mm² But, Actual Vertical Shear Force on timber beam (V) = w [(l/2)-d]

10. Maximum Horizontal Shear Stress (ζmax) = 1.5V/bd

11. Checking Bijasal timber joists for deflection,

12. Maximum Deflection (δmax) = K*(W*l3/E*Ixx)

13. Checking the bearing strength at supports,

14. Bearing Area (a) = 75mm*100mm .... (where 75mm = width of ISMB 100, 100mm = width of timber beam)

15. Bearing area required (a.req) = End reaction/ σc

So, use Bijasal timber of c/s 100mm*75mm, length 1600mm, simply supported at 1m c/c on ISMB 100 and horizontal spacing of 300mm c/c.

VI. COST ANALYSIS & COST COMPARISON

Comparitive: Mivan Shuttering v/s Conventional + Peri Shuttering						
Sr. No.	Description	Aspect in Consideration	Mivan Shuttering	Conventional Shuttering (Only Slab)	Peri Shuttering (Only Columns)	Conventional + Peri Shuttering (Column & Slab)
1	Material Cost	Cost/Sq.ft	41.29	105.00	13.24	118.24
		Cost/Sq.Mtr	444.41	1,131.00	142.50	1,273.50
2	Labour Cost	Cost/Sq.ft	24.53	22.46	9.68	32.14
		Cost/Sq.Mtr	264.01	241.68	104.17	345.84
3	Repititions Considered	Nos/set of shuttering material	29.50	6.00	150.00	-
4	Minimum Duration of Slab Cycle	Days	7.00	15.00	7.00	15.00
5	Quality	Surface Finsh	Form Finish	Comparative Poor	Form Finish	Not Better than Mivan
6	Surface Application	Gypsum / Plaster / Naked	Internal Gypsum	Internal Gypum	Internal Gypum	Internal Gypum
			Direct Paint	External Plaster	External Plaster	External Plaster
7	Workability	Material Handling, etc	Ease	Harder than Mivan	Better than Conventional	Not as easy as Mivan

VII. CONCLUSION

At the end it can be concluded that though there is not much of literature available on Shuttering Design and Cost Analysis, it is available in an indirect way. It requires a search on top of various engineering basics to design shuttering. Cost analysis of shuttering also cannot be done without vigorous observation from place to place and from site to site to arrive at a conclusion.

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