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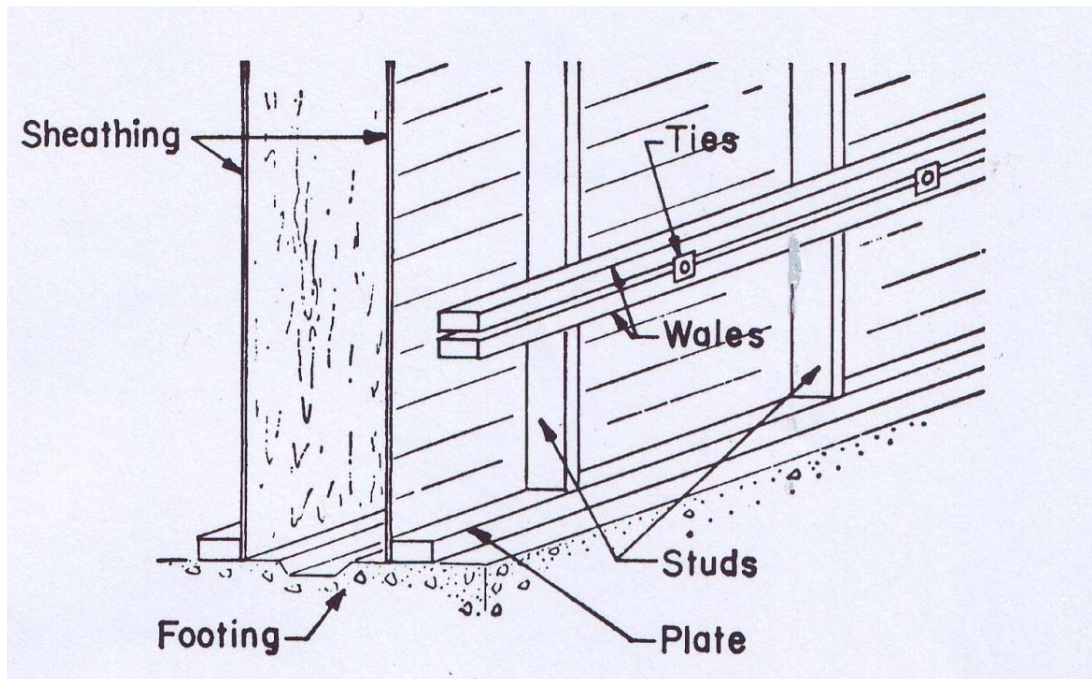


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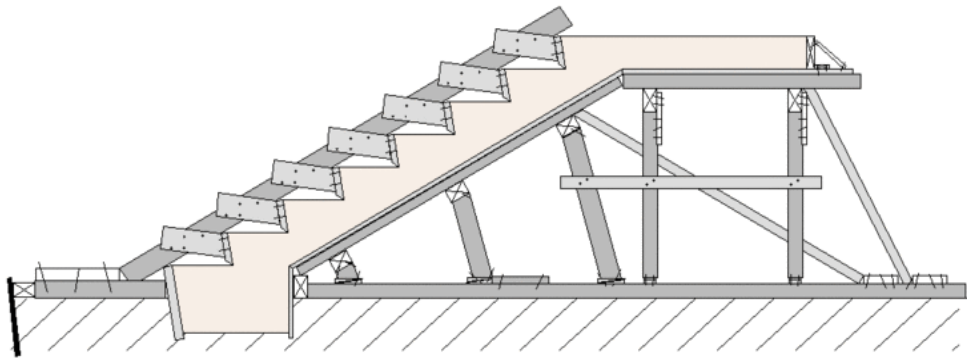
## APPENDIX A: FORMWORK SYSTEMS



**Figure 01:** Typical wall form with its components  
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**Figure 02:** Conventional type formwork



**Figure 03: Side view of traditional timber formwork for flight of stairs**



**Figure 04: Poor finish in conventional type formwork**



**Figure 05: Modern conventional formwork for a concrete column**



**Figure 06: Modern conventional formwork for slabs and beams**



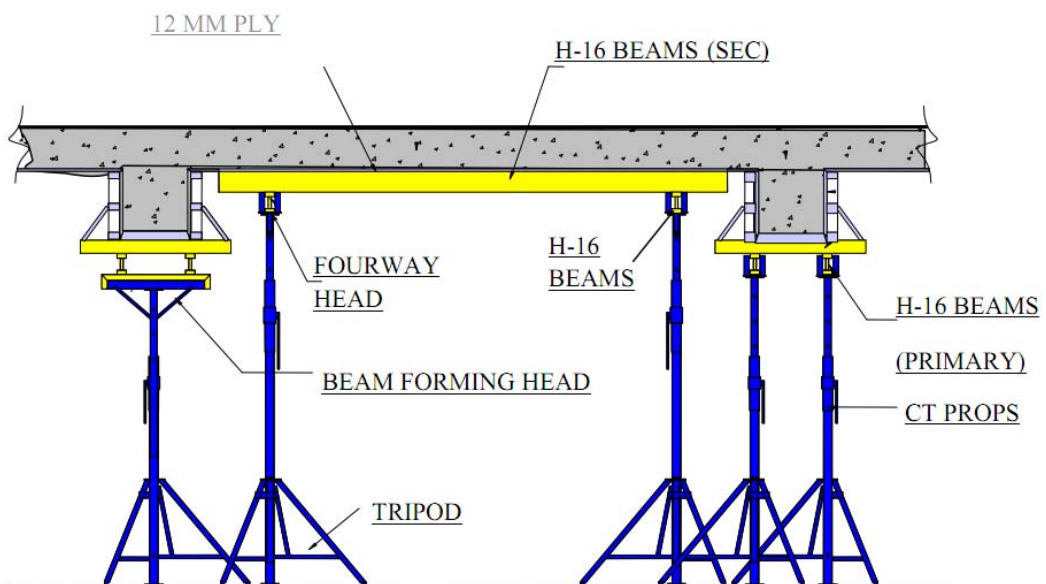
**Figure 07: Modern conventional formwork for a slab**



**Figure 08: Modern conventional formwork**

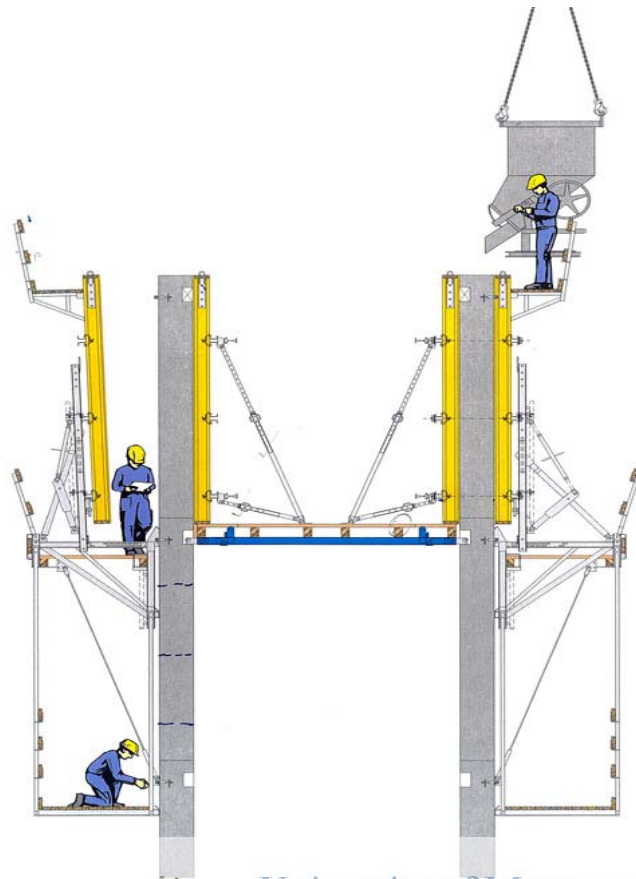


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**Figure 09: Semi system formwork for slabs and beams**





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**Figure 10:** Semi-system formwork for a column



**Figure 11:** Semi-system formwork



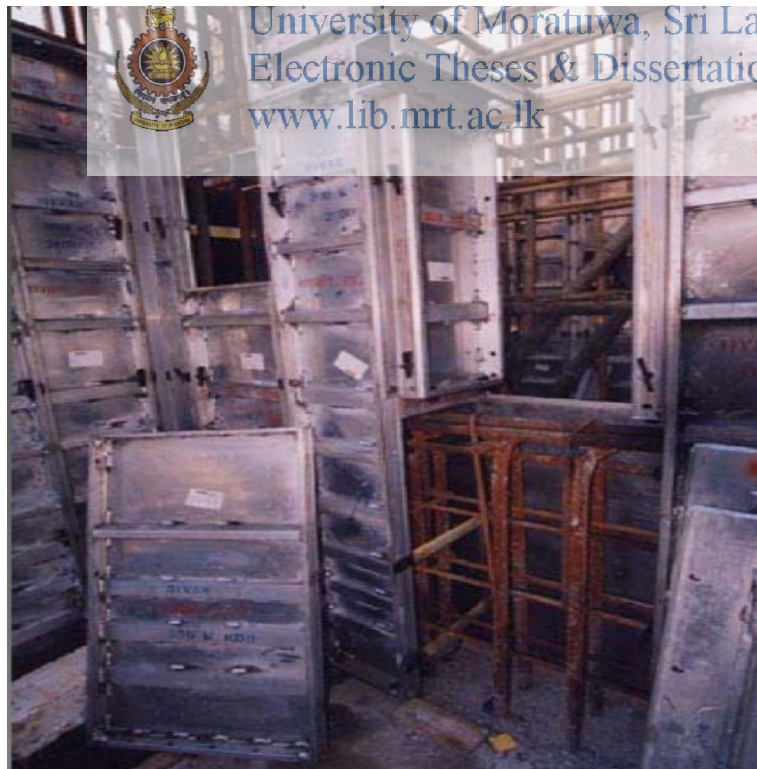
**Figure 12: Typical system formwork**



**Figure 13: System formwork for walls and slab**



**Figure 14: System formwork**



**Figure 15: System formwork for columns**

## APPENDIX B: SEQUENCE FOR STRIKING AND ERECTING OF SYSTEM FORMWORK

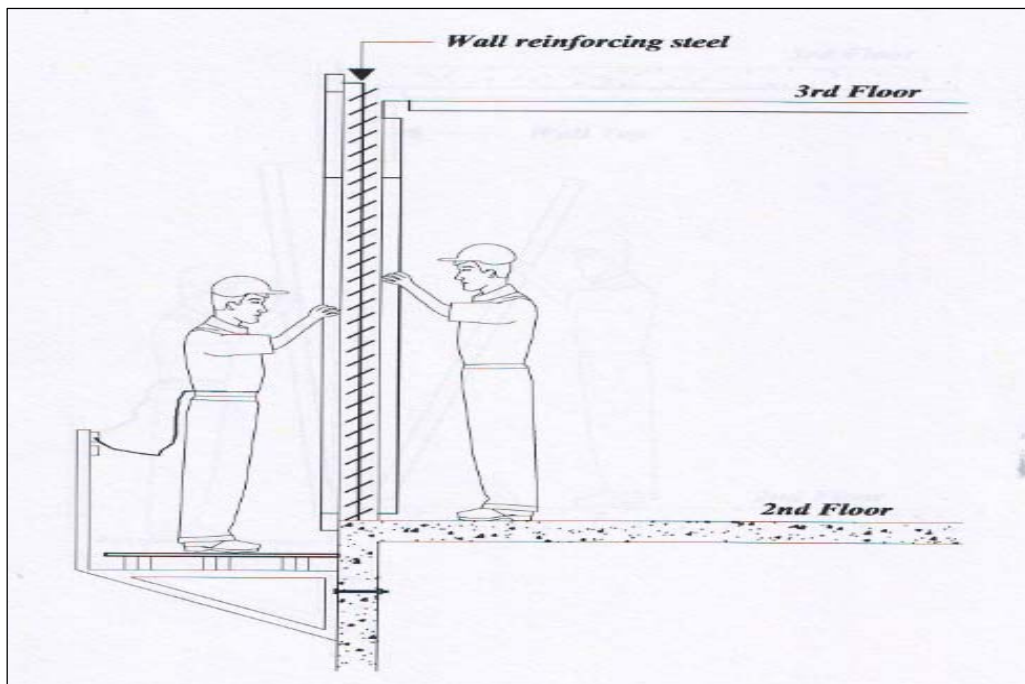


Figure 16: Sequence 1

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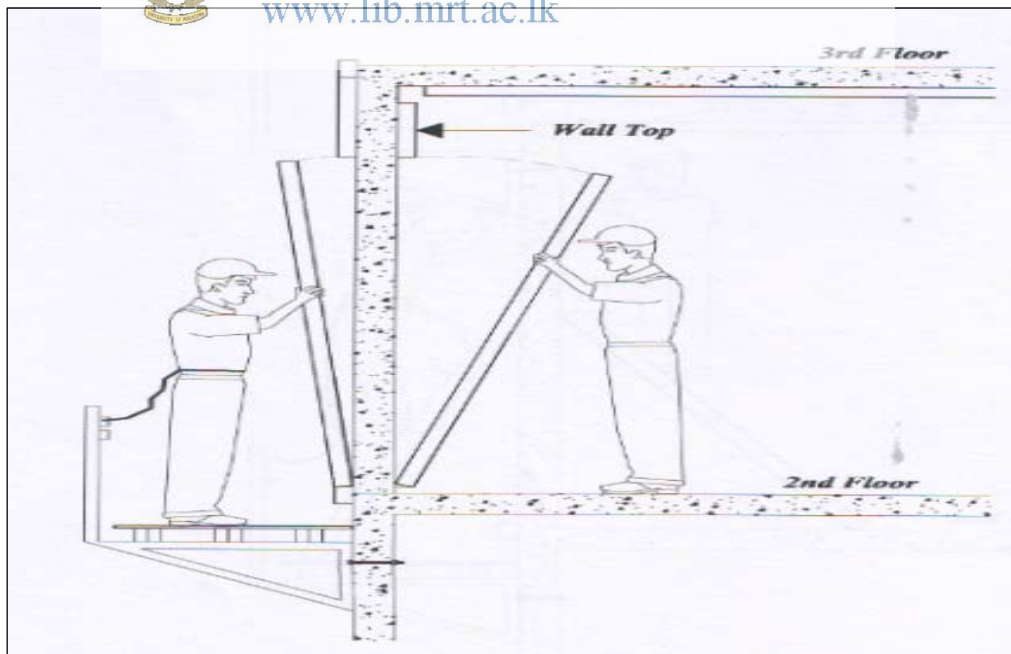
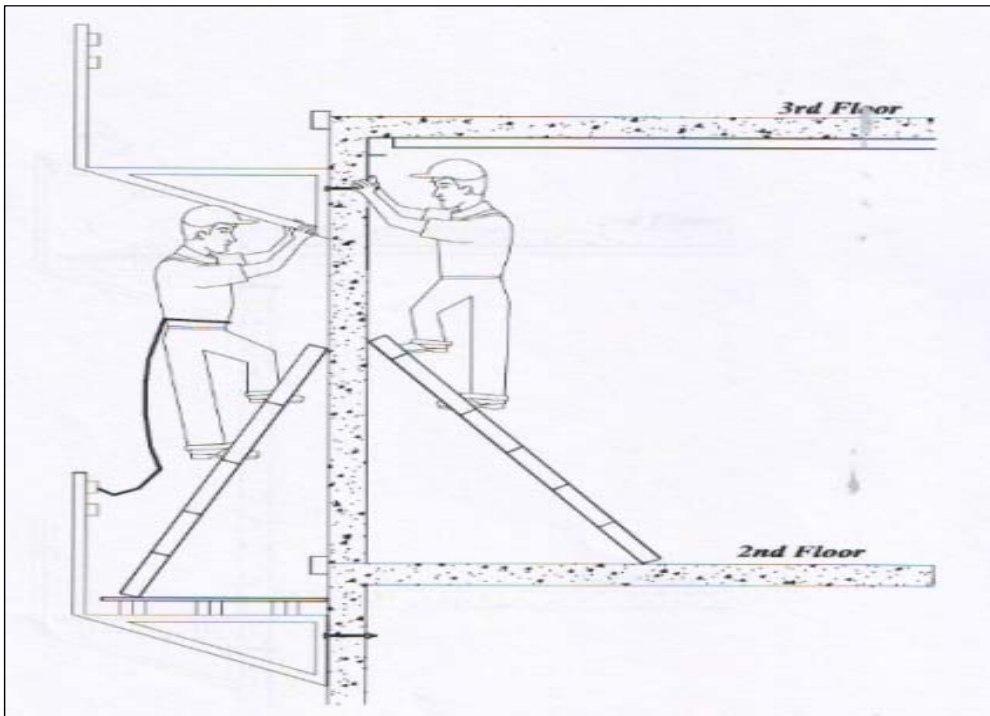


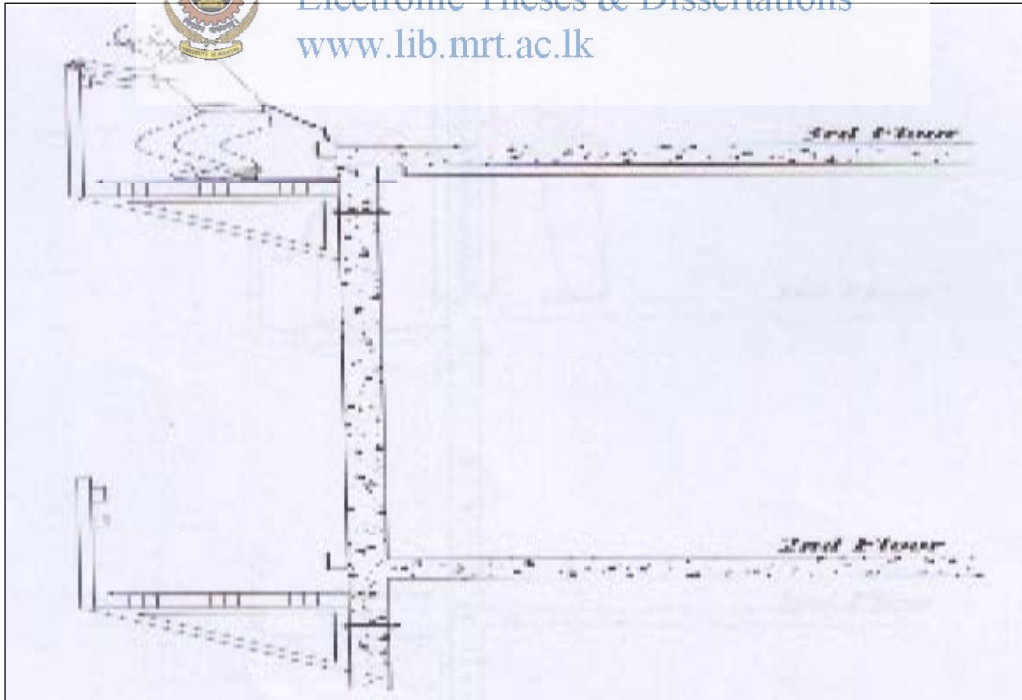
Figure 17: Sequence 2



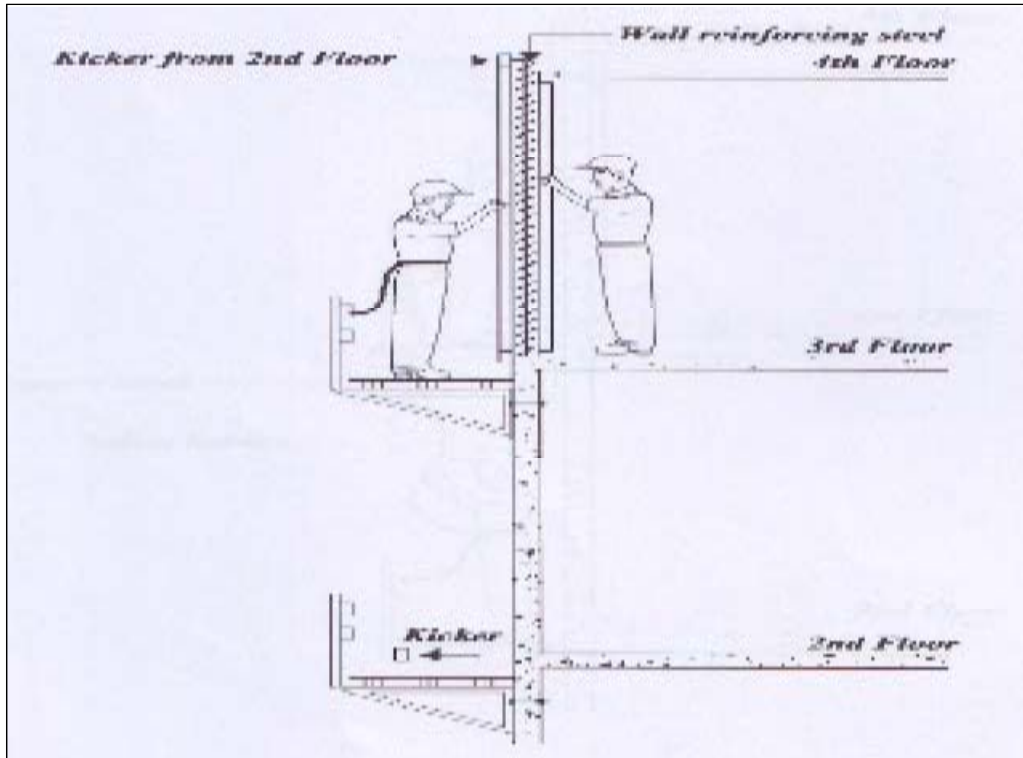
**Figure 18: Sequence 3**



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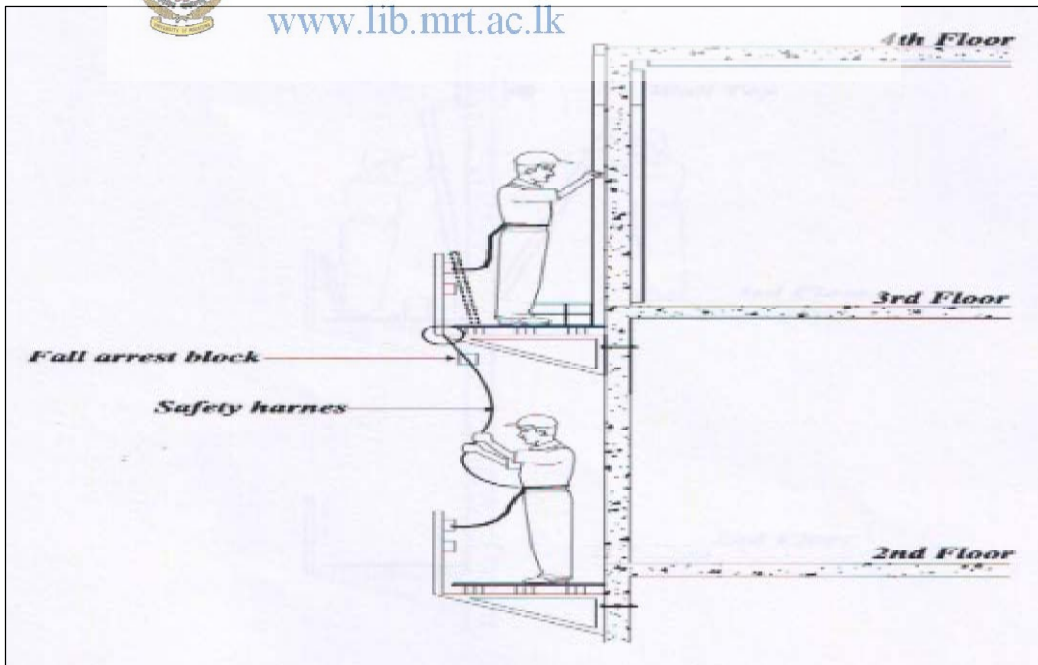
**Figure 19: Sequence 4**



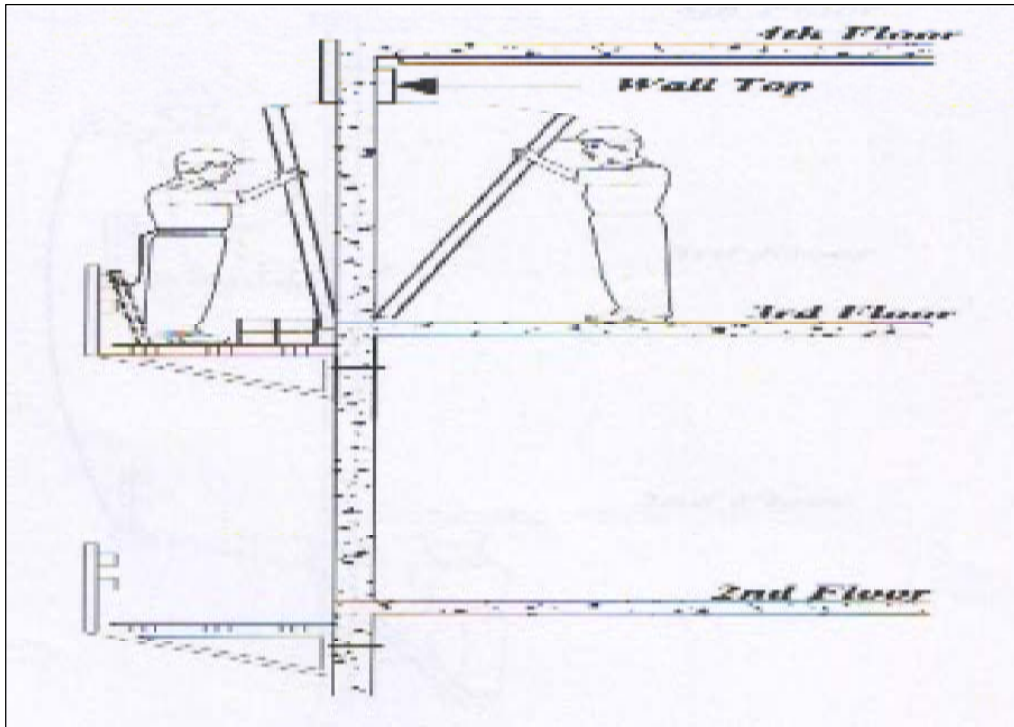
**Figure 20: Sequence 5**



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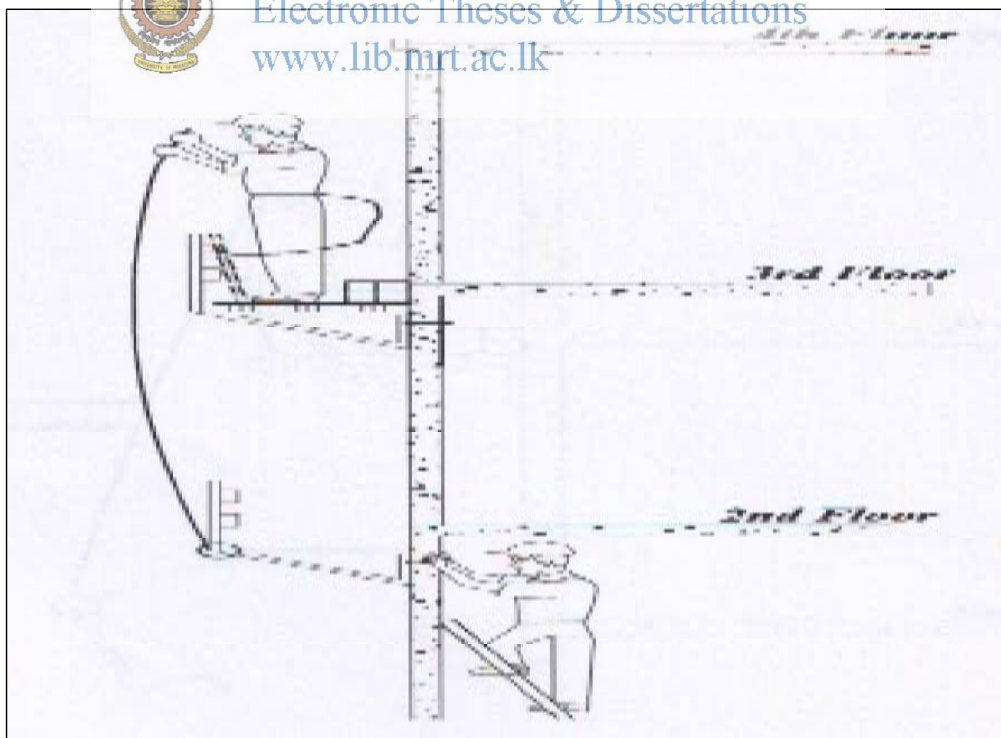
**Figure 21: Sequence 6**



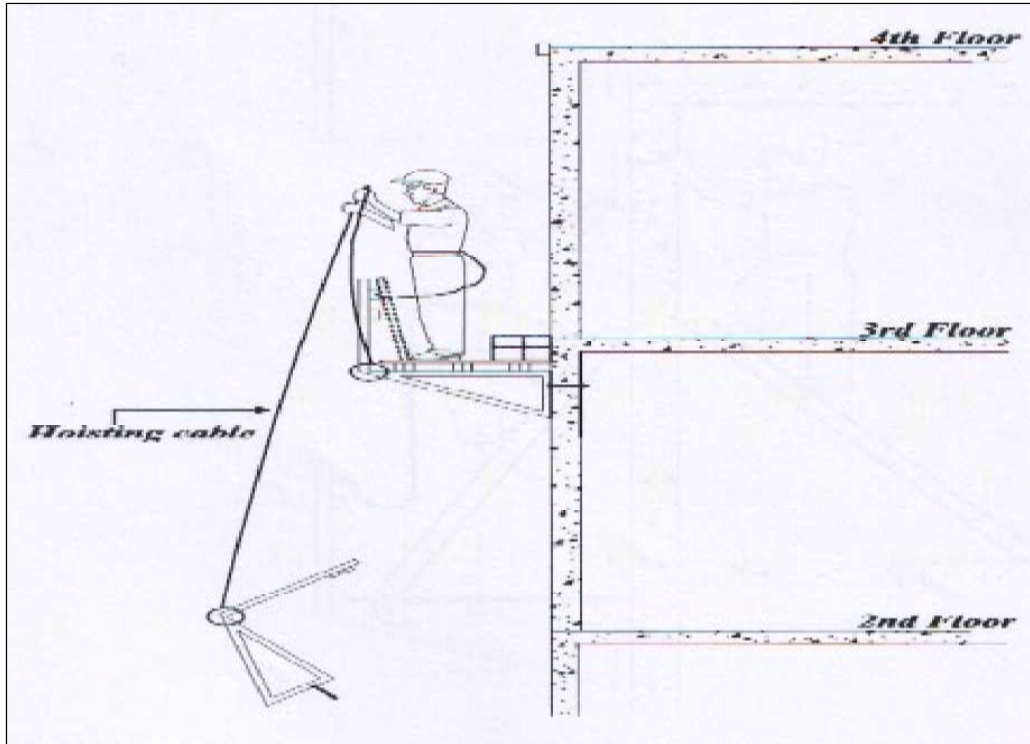
**Figure 22: Sequence 7**



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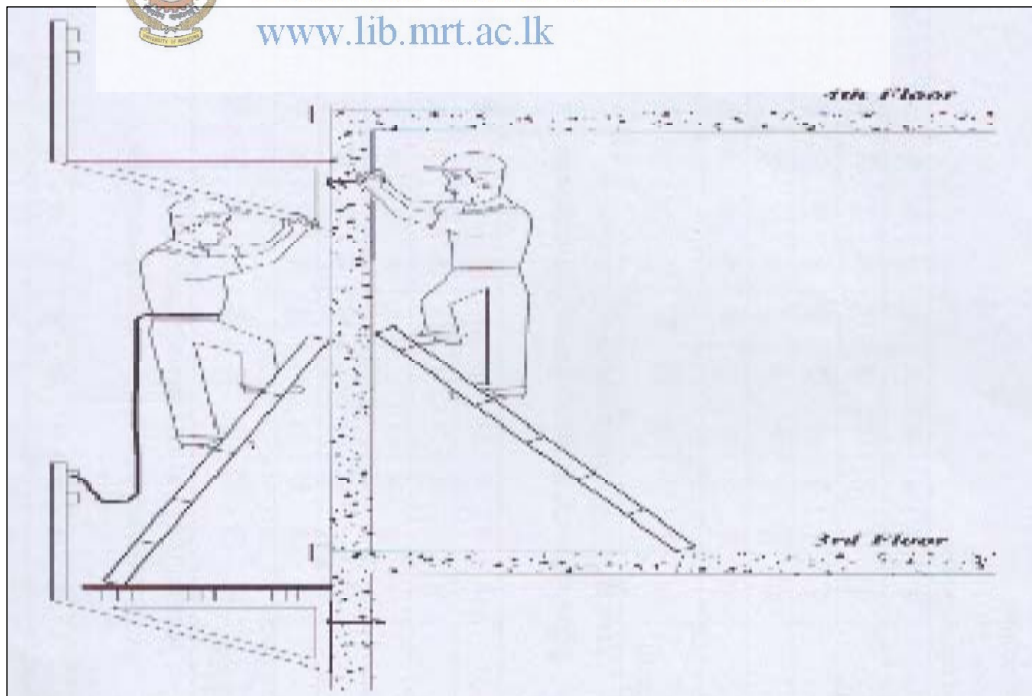
**Figure 23: Sequence 8**



**Figure 24: Sequence 9**



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**Figure 25: Sequence 10**



## APPENDIX C: FORMWORK COST CALCULATIONS

### Case Study-1

#### Calculating the preliminary running cost

According to the BOQ,

The total preliminary cost	= Rs. 216,104,452.20
Preliminary cost per day	= Rs. 216,104,452.20 / (21 x 30)
	<b>= <u>Rs. 343,022.94</u></b>

Assume the preliminary running cost per day is same for all the three occasions.

#### Cost break-down for semi system (DOCA) formwork

According to the BOQ and actual data from the project,

Total project cost : Rs. 2,203,680,746.50

Duration of the project : 14 days

Floor Cycle = 14 days

Duration of the project = 21 months

This was the actual time taken to complete the project.

#### Formwork cost of the project

Material cost (DOCA system)	= Rs. 22,635,470.58
Material cost (plywood sheets)	= Rs. 4,378,800.00
Material cost (other)	= Rs. 3,000,000.00
Total cost for the materials	=Rs.22,635,470.58+4,378,800.00+3,000,000.00
	= Rs. 30,014,270.58
Labour	= Rs. 13,800,000.00

The labour requirement for this type of formwork is about 30 skilled labours and 20 non-skilled labours per 100m<sup>2</sup>. At the same time supervisory staff requirement is

about 1 engineer, 2 assistant engineers, 1 supervisor, 2 assistant supervisors and 8 survey helpers for the whole construction per day.

Total cost for the formwork = Rs. 30,014,270.58 + 13,800,000.00  
= **Rs. 43,814,270.58**

#### Cost for finishes

Cost for painting = Rs. 31750 x 400.00 + 33250 x 425.00  
= Rs. 26, 831,250.00

The rates for painting on the walls (vertical surfaces) and on the ceiling (horizontal surfaces) are respectively Rs.400.00 per m<sup>2</sup> and Rs. 425.00 per m<sup>2</sup>.

Cost for skim coating = Rs. 31750 x 375.00 + 33250 x 400.00  
= Rs. 25,206,250.00

The rates for skim coating on the walls and on the ceiling are respectively Rs.375.00 per m<sup>2</sup> and Rs. 400.00 per m<sup>2</sup>. Always the rate for horizontal surfaces is a little higher than the vertical surfaces as the labour cost is a little bit higher there.

Other costs : Rs. 205,455.06  
Total cost for finishes :Rs.26,831,250.00+ 25,206,250.00+ 205,455.06  
: **Rs. 52,242,955.06**

#### Cost for waste disposal

The waste generated from this type of formwork is mainly plywood. Ply wood can be re-used only for 6 times. So there will be lot of waste generated in the site and have to dispose them. It will add lot of cost to the total project cost. According to the data obtained from the project;

Hire for the dump truck : Rs. 7500.00/day  
No. of loads : 700

Labour involvement	: 10 per load
Cost	: 700 x (7500.00 + 10 x 800)
	: Rs. 10,850,000.00
Other cost	: Rs. 2,606,000.00
Total cost for waste disposal	: Rs. 10,850,000.00 + 2,606,000.00
	<b>: <u>Rs. 13,456,000.00</u></b>

### Cost for machinery

When using the semi system formwork in the construction, the machinery involvement is as follows (only the machinery involvement for formwork related activities is considered).

- Tower crane : 1 No.

Monthly rent for the tower crane is Rs.650,000.00 and the cost for installation is 2,000,000.00. But here the installation cost for the tower crane shall not be considered as the tower crane should be used in the other construction activities.

Total cost = Rs. 14 x 35 x 650,000.00/30  
= Rs. 10,616,666.67

- Builder hoists : 3 No.

Monthly rent for a hoist is Rs.310,000.00 and have to use 3 hoists in the project.

Cost for hoists = Rs. 3 x 14 x 35 x 310,000.00/30  
= Rs. 15,190,000.00

Total machinery cost affected by the formwork,

**= Rs. 25,806,666.67**

Other machinery cost = Rs. 29,035,433.33

The cost for machinery = Rs. 25,806,666,67 + 29,035,433.33  
 = Rs. 54,842,100.00

Preliminary running cost = Rs. 343,022.94 x 21 x 30  
 = Rs. 216,104,452.20

**Cost break-down for Aluminium panel system formwork**

Duration of the project,

Floor cycle = 8 days  
 Saving of days than semi system formwork = 14 – 8  
 = 6 days  
 Total saving of time = 6 x 35  
 = 210 days  
 = 210/30  
 = 7 months

Duration of the project



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= 21-7  
 = 14 months

Cost for formworks of the project

When using Aluminium panel system formworks, one system is enough for the whole building as it can be re-used more than 100 times. So if there are similar buildings the system can be used for them also. At the same time after the project the system can be sold. Those are some extra benefits of this type of formwork. But in the calculation it has considered that the system is used only for the building considered.

Rate for the formwork (With first time erection) : Rs. 28,500.00 per m<sup>2</sup>  
 Total area of formwork needed : 1315 m<sup>2</sup>  
 Cost for formwork materials (With first time erection) : Rs. 28,500.00 x 1315  
 : Rs. 37,477,500.00

Labour for erection of other floors : Rs. 11,151,071.00  
 Total cost for formwork : Rs. 37,477,500.00 + 11,151,071.00  
 : **Rs. 48,628,571.00**

Cost for finishes

Cost for painting = Rs. 31750 x 400.00 + 33250 x 425.00  
 = Rs. 26, 831,250.00

The rates for painting on the walls (vertical surfaces) and on the ceiling (horizontal surfaces) are respectively Rs.400.00 per m<sup>2</sup> and Rs.425.00 per m<sup>2</sup>.

Cost for skim coating = Rs. 31750 x 244.00 + 33250.00 x 269.00  
 = Rs. 16,665,630.00

The rates for painting on the walls and on the ceiling are respectively Rs.244.00 per m<sup>2</sup> and Rs.269.00 per m<sup>2</sup>. Here this rate is lower than the rate for skim coating when semi system (DOCA) formwork is used. When using the Aluminium panel system formwork the concrete surface is smoother than the previous one.



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Other costs : Rs. 38,915.89  
 Total cost for finishes : Rs. 26, 831,250 + 16,665,630 + 38,915.89  
 : **Rs. 43,535,795.89**

Cost for waste disposal due to formworks used in the site

When using Aluminium panel system formworks there will not be waste generation in the site. So there will be no cost for waste disposal.

Cost for machinery

When using the Aluminium panel system formwork in the construction, the machinery involvement is as follows (only the machinery involvement for formwork related activities is considered)

- Tower crane : 0 No.

In this case it is not necessary to have a tower crane in the site. As the Aluminium formwork panels are not heavy they can be handled by manpower.

- Builder hoists : 5 No.

Monthly rent for a hoist is 310,000.30 and has to use 3 hoists in the project.

Cost for hoists = 5 x 8 x 35 x Rs.310, 000.30  
= Rs.14, 466,666.67

Total machinery cost affected by the formwork

**= Rs. 14,466,666.67**

Other machinery cost = Rs. 22,276,333.33

The cost for machinery = Rs. 14,466,666.67 + 22,276,333.33  
= Rs. 36,743,000.00



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Preliminary running cost : Rs. 343,022.94 x 14 x 30  
: **Rs. 144,069,634.80**

Total project cost : **Rs. 2,102,930,299.00**

**Cost break-down for modern conventional type formwork**

Duration of the project,

Floor cycle = 22 days

Extra days than semi system formwork = 22 – 14  
= 8 days

Total saving of time = 8 x 35  
= 280 days  
= 280/30

= 9.33 months  
= 10 months


Duration of the project = 21 + 10  
= **31 months**

Formwork cost of the project

Material cost = Rs. 20,700,000.00  
Labour = Rs. 16,100,000.00

The labour requirement for this type of formwork is about 50 skilled labours and 80 non-skilled labours per 100m<sup>2</sup>. At the same time supervisory staff requirement is about 3 engineers, 8 assistant engineers, 8 supervisors, 12 assistant supervisor, 16 survey helpers for the whole construction per day.

Total cost for the formwork = Rs. 20,700,000 + 16,100,000  
= **Rs. 36,800,000.00**

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Cost for finishes  
Cost for plastering = Rs. 31750 x 600.00 + 33250 x 650.00  
= Rs. 40,662,000.00

The rates per plastering on the walls and on the ceiling are respectively Rs.600.00 per m<sup>2</sup> and Rs.650.00 per m<sup>2</sup>. The rate for plastering of horizontal surfaces is a little higher than the plastering of vertical surfaces as the labour involvement is a little higher there.

Cost for painting = Rs. 31750 x 400.00 + 33250 x 450.00  
= Rs. 27,662,500.00

The rates per painting on the walls and on the ceiling are respectively Rs.400.00 per m<sup>2</sup> and Rs.450.00 per m<sup>2</sup>. Paining on the plaster is a little more than the painting on the concrete.

Other costs	: Rs. 1,215,436.27
Total cost for finishes	: Rs. 40,662,000 + 27,662,500 + 1,215,436.27
	: <b><u>Rs. 69,539,936.27</u></b>

Cost for waste disposal due to formworks used in the site

The waste generated from this type of formwork is mainly plywood, 2 x 2, kickers...etc. Ply wood can be re-used only about for 4 times. So there will be lot of waste generated in the site and have to dispose them. It will add lot of cost to the total project cost. According to the estimates done,

Hire for the dump truck	: Rs. 7500.00/day
No. of loads	: 1100
Labour involvement	: 10 per load
Cost	: 1100 x (7500.00 + 10 x 800)
	: Rs. 17,050,000.00
Other cost	: Rs. 2,606,000.00

Total cost for waste disposal : Rs. 17,050,000.00 + 2,606,000.00  
 : **Rs. 19,656,000.00**



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Cost for machinery

When using the conventional type formwork in the construction the machinery involvement is as follows (only the machinery involvement for formwork related activities are considered)

- Tower crane : 1 No.  
 Monthly rent for the tower crane is 650,000 /= and the cost for installation is 2,000,000/=.  
 Total cost = 22 x 35 x 650,000.00/30  
 = 16,683,333.33
- Builder hoists : 3 No.



Monthly rent for a hoist is 310,000.00 and have to use 3 hoists in the project.

$$\begin{aligned}\text{Cost for hoists} &= 3 \times 22 \times 35 \times 310,000.00/30 \\ &= \text{Rs. } 23,870,000.00\end{aligned}$$

Total machinery cost affected by the formwork

$$= \underline{\underline{\text{Rs. } 40,553,333.33}}$$

$$\text{Other machinery cost} = \text{Rs. } 42,637,141.67$$

$$\text{The total cost for machinery} = \text{Rs. } 40,553,333.33 + 42,637,141.67$$

$$= \underline{\underline{\text{Rs. } 83,190,475.00}}$$

$$\text{Preliminary running cost} : \text{Rs. } 343,022.94 \times 31 \times 30$$

$$: \underline{\underline{\text{Rs. } 319,011,334.20}}$$

$$\text{Total project cost} : \underline{\underline{\text{Rs. } 2,325,263,241.00}}$$



**Case Study -2**

### *Calculating the preliminary running cost*

According to the BOQ,

Considering only one tower

$$\text{The total preliminary cost} = \text{Rs. } 227,364,678.90$$

$$\text{Preliminary cost per day} = \text{Rs. } 227,364,678.90 / (40 \times 30)$$

$$= \underline{\underline{\text{Rs. } 189,470.57}}$$

Assume the preliminary running cost per day is same for all the three occasions.

### *Cost break-down for Aluminium panel system formwork*

According to the BOQ and actual data from the project,

$$\text{Total project cost} : \underline{\underline{\text{Rs. } 1,849,425,000.00}}$$

### Duration of the project

Floor Cycle = 9 days

Duration of the project = 40 months

This was the planned duration to complete the project.

### Formwork cost of the project

Here the three towers are constructed together. Three system formworks for the three towers will be bought to the project. So the three towers can be considered as three projects and considered one tower for the purpose of the analysis. One system formwork is enough for a tower as the system formwork can be reuse over 100 times. The form work system will be re sale after use of 100 times and it will be an extra benefit of using system formworks. But in the analysis it will not be considered.

Total cost for the materials = Rs. 900 x 28500  
= Rs. 25,650,000

Labour = Rs. 9,950,000

Total cost for the formwork = Rs. 25,650,000 + 9,950,000  
= Rs. 35,600,000



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### Cost for finishes

Cost for painting = Rs. 36050 x 400.00 + 20600 x 450.00  
= Rs. 23,690,000

The rates for painting on the walls (vertical surfaces) and on the ceiling (horizontal surfaces) are respectively RS.400.00 per m<sup>2</sup> and Rs.450.00 per m<sup>2</sup>.

Cost for skim coating = Rs. 36050 x 244.00 + 20600 x 269.00  
= Rs. 14,337,600.00

The rates for painting on the walls and on the ceiling are respectively Rs.244.00 per m<sup>2</sup> and Rs.269.00 per m<sup>2</sup>. Here this rate is lower than the rate for skim coating when

semi system (DOCA) formwork is used. When using the Aluminium panel system formwork the concrete surface is smoother than the other situations.

Other costs : Rs. 211,435.56  
Total cost for finishes :Rs.23,690,000.00+14,337,600.00 + 211,435.56  
: **Rs. 38,239,035.56**

#### Cost for waste disposal

The waste generated from this type of formwork negligible. Therefore no cost should be allocated to waste disposal when using Aluminium panel system formworks.

#### Cost for machinery

When using the system formwork in the construction the machinery involvement is as follows (only the machinery involvement for formwork related activities is considered)

- Tower crane : 1 No.  
Monthly rent for the tower crane is 750,000.00 and the cost for installation is 2,500,000.00.  
Total cost = Rs.  $9 \times 38 \times 750,000.00 / (30 \times 9)$   
= Rs. 950,000.00
- Builder hoists : 4 No.  
Monthly rent for a hoist is 350,000.00 and have to use 3 hoists in the project.  
Cost for hoists = Rs.  $3 \times 9 \times 38 \times 350,000.00/30$   
= Rs. 15,960,000.00

Total machinery cost affected by the formwork,

**= Rs. 16,910,000.00**


Other machinery cost = Rs. 24,452,260.00  
The cost for machinery = Rs. 16,910,000.00 + 24,452,260.00  
= **Rs. 41,362,260.00**

Preliminary running cost = Rs. 189,470.57x 40 x 30  
 = **Rs. 227,364,684**

**Cost break-down for semi system (DOCA) formwork**

Duration of the project

Floor cycle = 14 days  
 Excess days for this type = 14 - 9  
 = 5 days  
 Total excess time = 5 x 38  
 = 190 days  
 = 190/30  
 = 6.33 months  
 = 7 months  
 Duration of the project = 40 + 7  
 = **47 months**

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Cost for formworks of the project

Material cost (DOCA system) = Rs. 16,352,621.33  
 Material cost (plywood sheets) = Rs. 4,478,800.00  
 Material cost (other) = Rs. 2,000,000.00  
 Total cost for the materials =Rs.16,352,621.33+4,478,800.00+3,000,000.00  
 = **Rs. 22,831,421.33**  
 Labour = Rs. 10,860,000.00

The labour requirement for this type of formwork is about 30 skilled labours and 20 non-skilled labours per 100m<sup>2</sup>. At the same time supervisory staff requirement is about 1 engineer, 2 assistant engineers, 1 supervisor, 2 assistant supervisors and 8 survey helpers for the whole construction per day.

Total cost for formwork : Rs. 22,831,421.33 + 10,860,000.00  
 : **Rs. 33,691,421.33**

### Cost for finishes

Cost for painting = Rs. 36050 x 400.00 + 20600 x 450.00  
= Rs. 23,690,000.00

The rates for painting on the walls (vertical surfaces) and on the ceiling (horizontal surfaces) are respectively Rs.400.00 per m<sup>2</sup> and Rs.450.00 per m<sup>2</sup>.

Cost for skim coating = Rs. 36050 x 295.00 + 20600 x 315.00  
= Rs. 17,123,750

The rates for skin coating on the walls and on the ceiling are respectively RS.295.00 per m<sup>2</sup> and Rs.315.00 per m<sup>2</sup>. Always the rate for horizontal surfaces is a little higher than the vertical surfaces as the labour cost is a little bit higher there.

Other costs : Rs. 156,945.67

Total cost for finishes :Rs.23,690,000.00+ 17,123,750.00+ 156,945.67

: Rs. 40,940,695.67



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Cost for waste disposal due to formworks used in the site

Hire for the dump truck : Rs. 8500.00/day

No. of loads : 600

Labour involvement : 10 per load

Cost : 600 x (8500.00 + 10 x 850.00)

: Rs. 10,200,000.00

Other cost : Rs. 2,426,000.00

Total cost for waste disposal : Rs. 10,200,000.00 + 2,426,000.00

: Rs. 12,626,000.00

### Cost for machinery

When using the Aluminium panel system formwork in the construction the machinery involvement is as follows (only the machinery involvement for formwork related activities is considered)

- Tower crane : 1 No.  
Monthly rent for the tower crane is 750,000.00 and the cost for installation is 2,500,000.00.  
Total cost = Rs. 14 x 38 x 750,000.00/30  
= Rs. 13,300,000.00

- Builder hoists : 4 No.  
Monthly rent for a hoist is Rs.350,000.00 and have to use 3 hoists in the project.  
Cost for hoists =4 x 14 x 38 x 350,000.00/30



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Total machinery cost affected by the formwork

**= Rs. 38,126,666.67**

Other machinery cost = Rs. 19,129,147.67

The cost for machinery = Rs. 38,126,666.67+ 19,129,147.67  
**= Rs. 57,255,814.34**

Preliminary running cost : Rs. 189,470.57 x 47 x 30  
**: Rs. 267,153,503.7**

Total project cost : **Rs. 1,926,560,299.00**

### Cost break-down for modern conventional type formwork

#### Duration of the project

Floor cycle	= 22 days
Excess time taken to this type of formwork	= 22 – 9
	= 13 days
Total excess time	= 13 x 38
	= 494 days
	= 280/30
	= 16.46 months
	= 17 months
Duration of the project	= 40 + 17
	= <b><u>57 months</u></b>

#### Formwork cost of the project

Material cost = Rs. 17,700,000.00

Labour = Rs. 10,100,000.00

The labour requirement for this type of formwork is about 50 skilled labours and 80 non-skilled labours per 100m<sup>2</sup>. At the same time supervisory staff requirement is about 3 engineers, 8 assistant engineers, 8 supervisors, 12 assistant supervisor, 16 survey helpers for the whole construction per day.

Total cost for the formwork = Rs. 17,700,000 + 10,100,000  
= **Rs. 27,800,000.00**

#### Cost for finishes

Cost for plastering = Rs. 36050.00 x 600 + 20600 x 650.00  
= Rs. 35,020,000

The rates per plastering on the walls and on the ceiling are respectively Rs.600.00 per m<sup>2</sup> and Rs.650.00 per m<sup>2</sup>. The rate for plastering of horizontal surfaces is a little higher than the plastering of vertical surfaces as the labour involvement is a little higher there.

Cost for painting = Rs. 36050 x 450.00 + 20600 x 500.00  
 = Rs. 26,522,500

The rates per painting on the walls and on the ceiling are respectively Rs.450.00 per m<sup>2</sup> and Rs.500.00 per m<sup>2</sup>. Paining on the plaster is a little more than the painting on the concrete.

Other costs :Rs. 1,215,436.27  
 Total cost for finishes :Rs. 35,0230,000.00 +26,522,500.00 + 1,215,436.27  
**:Rs. 62,757,936.27**

Cost for waste disposal due to formworks used in the site

The waste generated from this type of formwork is mainly plywood, kickers, joists, bracings...etc. Ply wood can be re-used only about for 4 times. So there will be lot of waste generated in the site and have to dispose them properly. It will add a cost to the total project cost. According to the estimates done,

Hire for the dump truck : Rs. 8500.00/day  
 No. of loads : 1000  
 Labour involvement : 10 per load  
 Cost : 1000 x (8500.00 + 10 x 850.00)  
 : Rs. 17,000,000.00  
 Other cost : Rs. 2,455,000.00  
 Total cost for waste disposal : Rs. 17,000,000.00 + 2,455,000.00  
**: Rs.19,455,000.00**

Cost for machinery

When using the conventional type formwork in the construction the machinery involvement is as follows (only the machinery involvement for formwork related activities are considered)

- Tower crane : 1 No.  
 Monthly rent for the tower carne is 750,000.00 and the cost for installation is 2,500,000.00.



Total cost = Rs. 22 x 38 x 750,000.00/30  
= Rs. 20,900,000.00

- Builder hoists : 5 No.  
Monthly rent for a hoist is 310,000.00 and has to use 3 hoists in the project.  
Cost for hoists = 3 x 22 x 38 x 350,000.00/30  
= Rs. 29,260,000.00

Total machinery cost affected by the formwork

**= Rs. 50,160,000.00**

Other machinery cost = Rs. 42,238,800.00

The total cost for machinery = Rs. 50,160,000.00+ 42,238,800.00

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Preliminary running cost = Rs. 189,470.57 x 57 x 30  
: **Rs. 323,994,674.70**

Total project cost : **Rs. 2,027,523,841.00**



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