

# FORMWORK

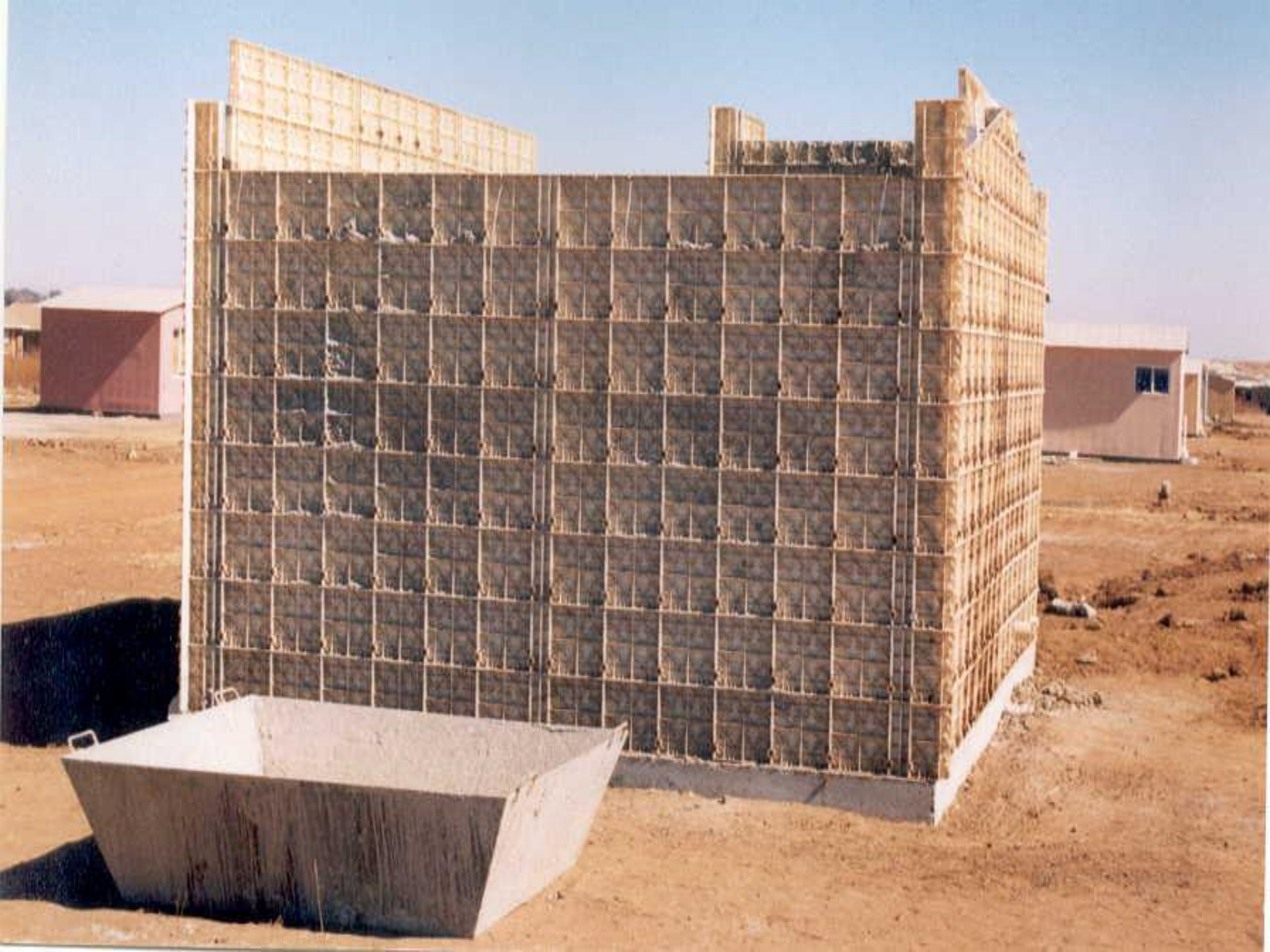
## INTRODUCTION

- Formwork is a mould or open box, like container into which fresh concrete is poured and compacted.
- When the concrete is set, the formwork is removed and a solid mass is produced in the shape of the inner face of the formwork.
- The top of the formwork is normally left open.
- *Falsework is the necessary support system that holds the formwork in the correct position.*

# ***FORMWORK FOR CONCRETE STRUCTURES SHOULD BE***

- 1. Strong enough to resist the pressure or the weight of the fresh concrete plus any constructional live loads.**
- 2. Rigid enough to retain the shape without undue deformation.**
- 3. Economical in terms of the total cost of the forms and the concrete surface finishing when required.**
- 4. Sufficiently watertight to avoid leakage at the joints.**







# **FORMWORK ECONOMY**

**In order to reduce the cost of formwork for concrete structures the following are to be considered:**

- 1. Design the formwork to provide adequate but not excessive strength and rigidity.**
- 2. Fabricate the forms into modular sizes to provide more reuses without refabricating when practical.**
- 3. Prepare working drawings prior to fabricating the forms.**
- 4. Prefabricate form sections on the ground rather than on scaffolding.**

## **FORMWORK ECONOMY (continued)**

- 5. Use the most economical formwork material considering the initial cost and reuses.**
- 6. Use no more nails than are needed to join the forms together safely.**
- 7. Remove the formwork as soon as it is permissible.**
- 8. Clean and oil forms by using releasing agent after each use.**
- 9. When it is permissible install construction joints to reduce the total quantity of form material required and permit the carpenters to work more continuously.**

# **FORMWORK MATERIALS**

**Formwork materials can be classified as:**

- 1. Timber**
- 2. Metals**
- 3. Plastics**



# Timber Formwork



# 1. Timber

## a. Lumber:

Lumber is commonly available material and has excellent strength, weight and cost factor.

Lumber is classified as:

- **Boards:** 1 to 1.5 inches thick, 2 or more inches width
- **Dimensions:** 2 to 4 inch thick, any width.
- **Timbers:** 5 or more inches thickness, 5 or more inches width

## **b. Plywood**

- **The use of plywood in concrete forming for form facing has improved the quality of finished concrete.**
- **The relatively large sheets of plywood have reduced the cost of building and at the same time have provided smooth surfaces that reduces cost of finishing of concrete surfaces.**
- **Plywood is a manufactured wood product consisting a number of veneer sheets, or plies**
- **Type of plywood can be grouped as exterior and interior. For formwork the exterior plywood is used. Adhesive used to bond the piles in manufacturing of exterior plywood is watertight and gives maximum number of reuses.**

# Metal Formwork





## 2. Metals

- **The initial cost of metal formwork is more than timber formwork but the number of reuses of metal formwork is higher than that of timber.**
- **in long run metal formwork can be economical.**
- **In heavy construction works metal formwork may require a lifting mechanism to handle the formwork panels or props.**

- **Steel sheet formwork has the problem of rusting also. To avoid rusting, in every use the surfaces should be oiled with an appropriate releasing agent.**
- **in metal formwork usage, the metal sheets are prepared as panels of standard sizes. This brings the difficulties of erecting irregular dimensions of formwork.**
- **Steel or aluminum or magnesium is the most widely used metals.**

# Plastic Formwork





# 3. Plastics

- They have impervious surfaces that usually create a smooth finish to the concrete.
- Plastic formwork could be reinforced or un-reinforced.
- Plastic is reinforced by glass fibers.
- Reinforced plastics are specially produced for a specific formwork type.
- Un-reinforced plastics are produced in sheet form with smooth or textured surfaces.
- Plastic formwork is lighter but less durable than metal formwork.

# **FORMWORK TYPES (BY SHAPE)**

**Considering shapes, formwork types can be classified as:**

- **Column Formwork**
- **Beam formwork**
- **Slab Formwork**
- **Wall Formwork**

# Column Formwork



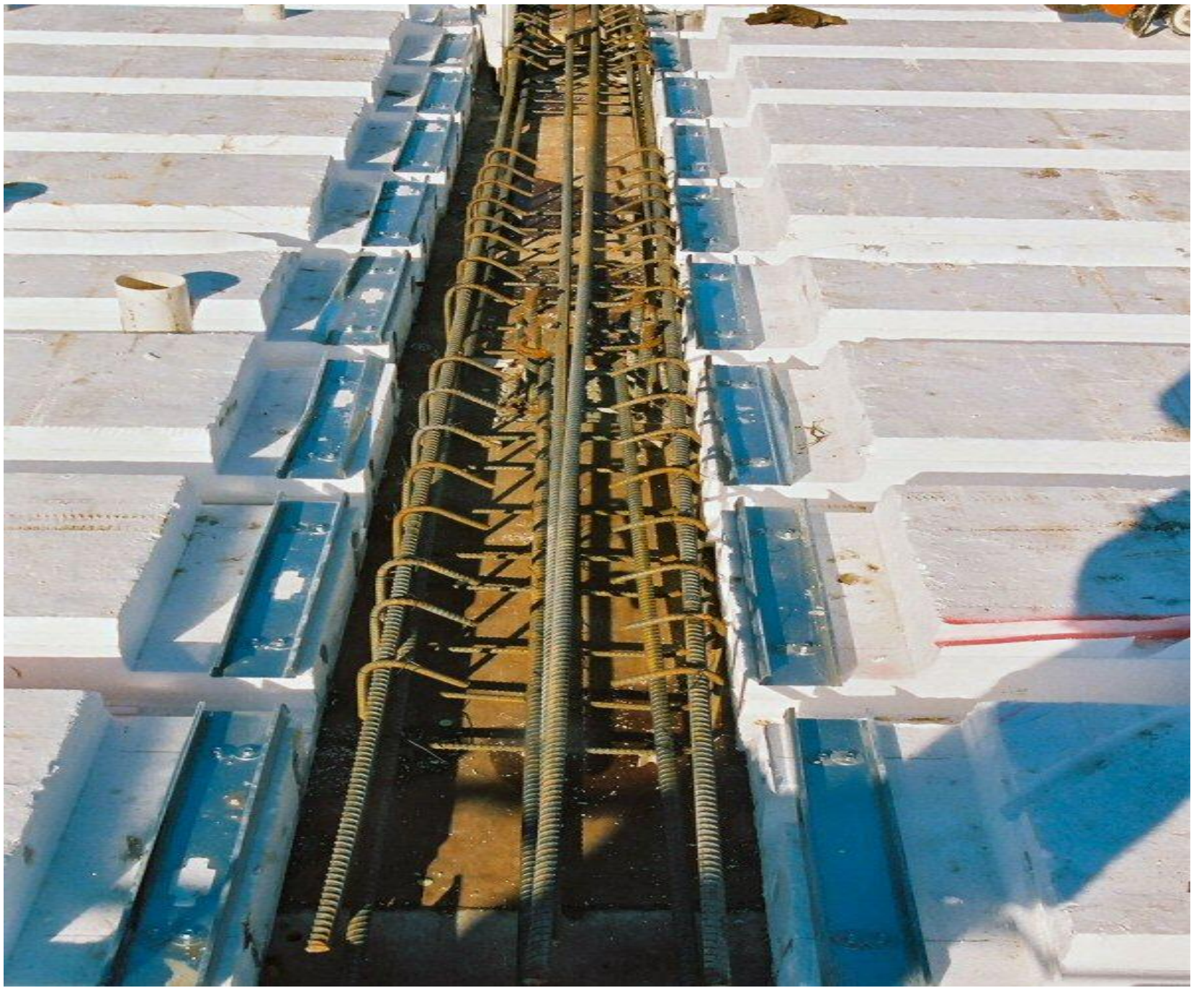


# Column Formwork

- **Column formwork is made usually with either timber or metal panels.**
- **The principle is to create an enclosed box with frames at the exact size of the column and fix it tightly on the kicker left from base or at the last stage of column concreting.**
- **The box is held in position by steel column clamps or bolted yokes and supported by timber studs or props**

# Beam Formwork





# Beam Formwork

- **Beam formwork consists of open through section and because it is not closed at the top requires more supporting framework to restrain the sides.**
- **The supports need to be maintained to the soffit and also provide lateral support to the sides.**
- **In timber this is done by the use of a headtree across the top of a vertical member.**
- **Metal panels are used with corner pieces, but timber headtrees are needed for vertical support.**



# Slab Floor Formwork



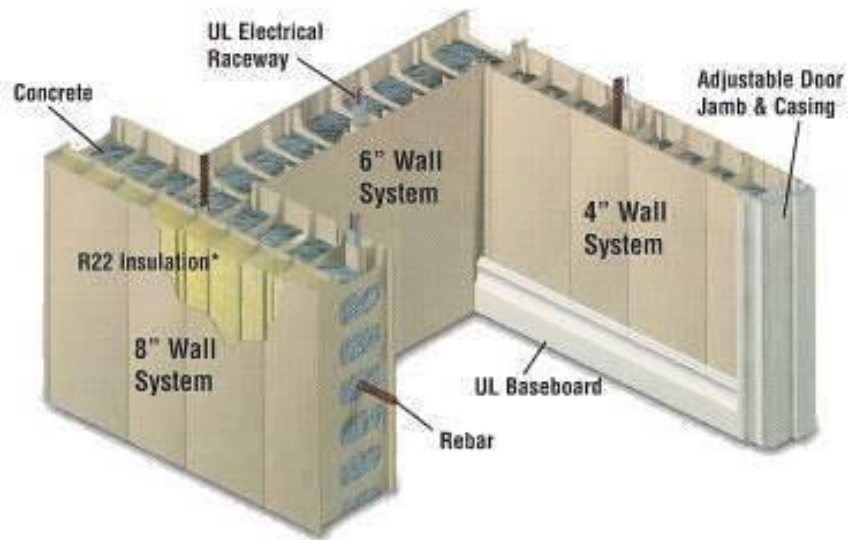


# Slab Formwork

- Floors require a large area of formwork to be provided usually from beam to beam.
- Timber floor formwork consists of timber boards or plywood sheets supported on a framework and resting on a series of timber joists.
- Again timber and metal props can be used for vertical supports.
- Metal panels can be used and bolted or clipped together and held in place by a system of metal beams or a tubular scaffold system.
- Adjustable props need for levelling purposes

# Wall Formwork







# Wall Formwork

- **Wall formwork is simpler than for other concrete units as the actual forces against it are less, most of the load being carried vertically downwards.**
- **The panels at both sides are held in position by ties.**
- **Ties are also used as spacers, arranging wall thickness.**
- **Wall support systems are usually sloping props at satisfactory intervals.**

# ***FORMWORK STRIKING TIMES***

**The time to be allowed before formwork can be removed naturally depends on many factors, such as:**

## **1. The type of concrete mix used (type of cement)**

**Rapid hardening cement mix requires less time, whereas high water cement ratio needs longer time for striking the formwork.**

## **2. The type of structural member being cast**

**Soffit of beams and slabs or sides of beams or columns require different time.**

## **3. Temperature**

**High temperature can cause rapid curing of concrete and formwork can be struck in shorter time than low temperature weather.**



# ***British Standards Formwork Striking Times***

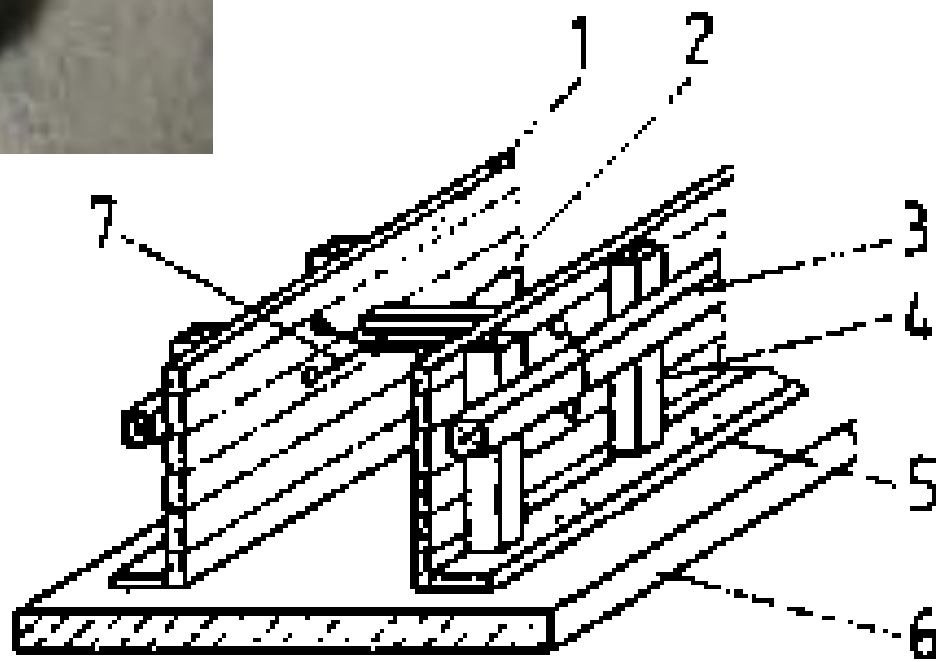
<b>Structural Member formwork</b>	<b>Minimum Striking Times</b>		
	<b>Surface Temperature of Concrete</b>		
	<b>16°C</b>	<b>7°C</b>	<b>2°C</b>
<b>Formwork to columns, beam sides and walls</b>	<b>9 hours</b>	<b>12 hours</b>	<b>1 day</b>
<b>Formwork to slabs (props left in position)</b>	<b>4 days</b>	<b>7 days</b>	<b>11 days</b>
<b>Formwork to beam soffit (props left in position)</b>	<b>8 days</b>	<b>14 days</b>	<b>21 days</b>
<b>Props to slabs</b>	<b>11 days</b>	<b>14 days</b>	<b>21 days</b>
<b>Props to beam soffits</b>	<b>15 days</b>	<b>21 days</b>	<b>30 days</b>

## ***Turkish Standard Formwork Striking Time***

<b>Cement Type</b>	<b>Sides of beams, walls and columns</b>	<b>Slabs</b>	<b>Props of beams and large opening slabs forms</b>
<b>Normal Portland Cement</b>	<b>3 days</b>	<b>8 days</b>	<b>21 days</b>
<b>Rapid hardening Portland Cement</b>	<b>2 days</b>	<b>4 days</b>	<b>8 days</b>

# ***FORMWORK TIES***

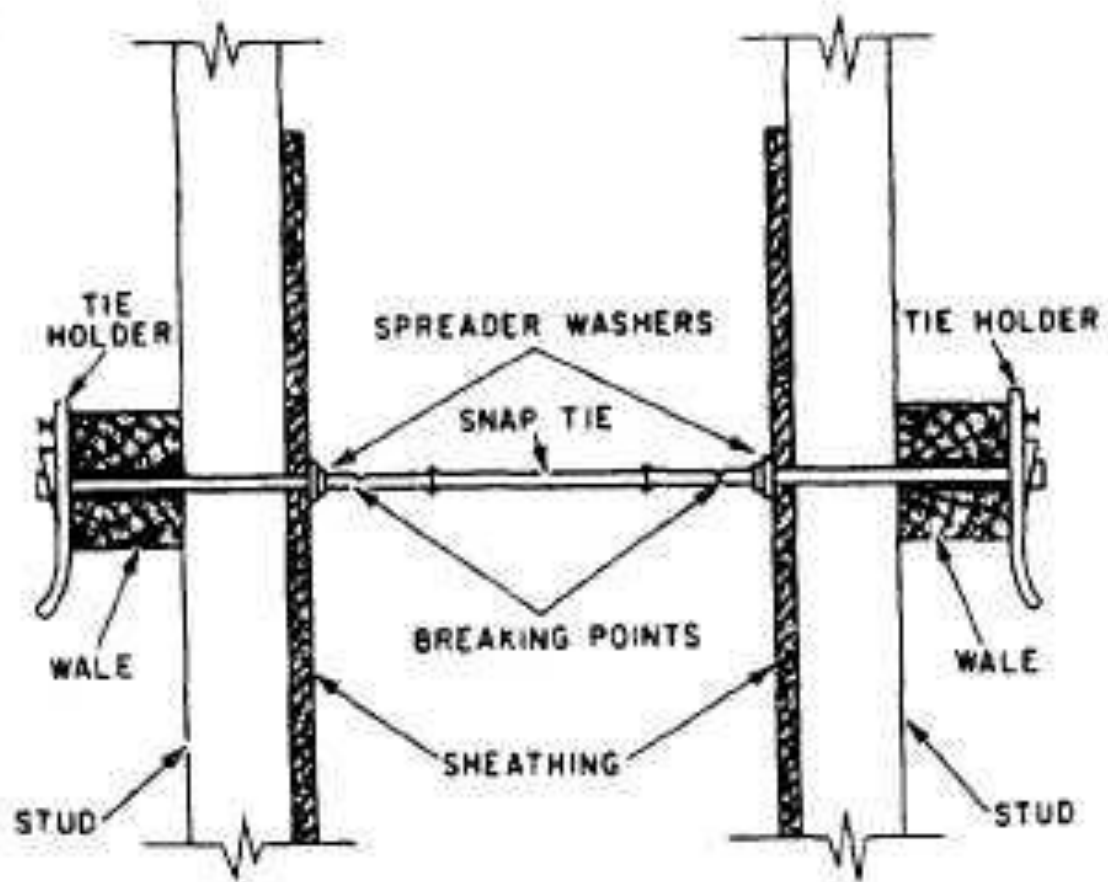
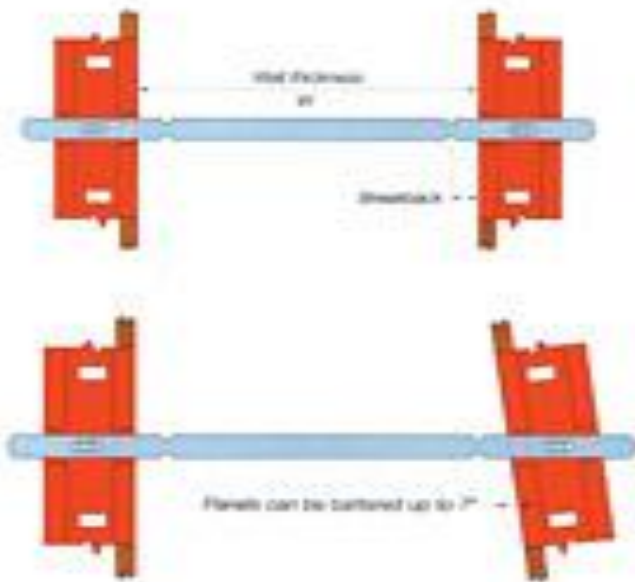
- **When concrete is placed in wall formwork, the pressure exerted by the fresh concrete tends to force the opposite sides of the formwork apart.**
- **Normal economic solution to this problem is to collect the force exerted by the concrete firstly onto the face material, generally plywood, and then to the walling to distribute the force into soldiers on either side of the formwork.**
- **The soldiers are prevented from moving apart by use of steel rods called tie rods passing through the concrete to connect the two soldiers together.**
- **Tie systems are in two categories: non-recoverable ties *and recoverable ties.***



# Non-recoverable ties

## 1. Snap ties

- The principal of snap ties is that it is cast into the wall and has normal wedge connection at each end for fixing to the formwork.
- Once the wall is concreted and the formwork is ready for removal the snap tie is then physically over-stressed and the ends "snap" generally inside the concrete.
- The snap tie arrangement also acts as a spacer to the formwork so that ordering the right length of snap tie automatically gives the correct wall thickness.
- Essentially these ties are used in building works on strip and re-erect type of formwork.



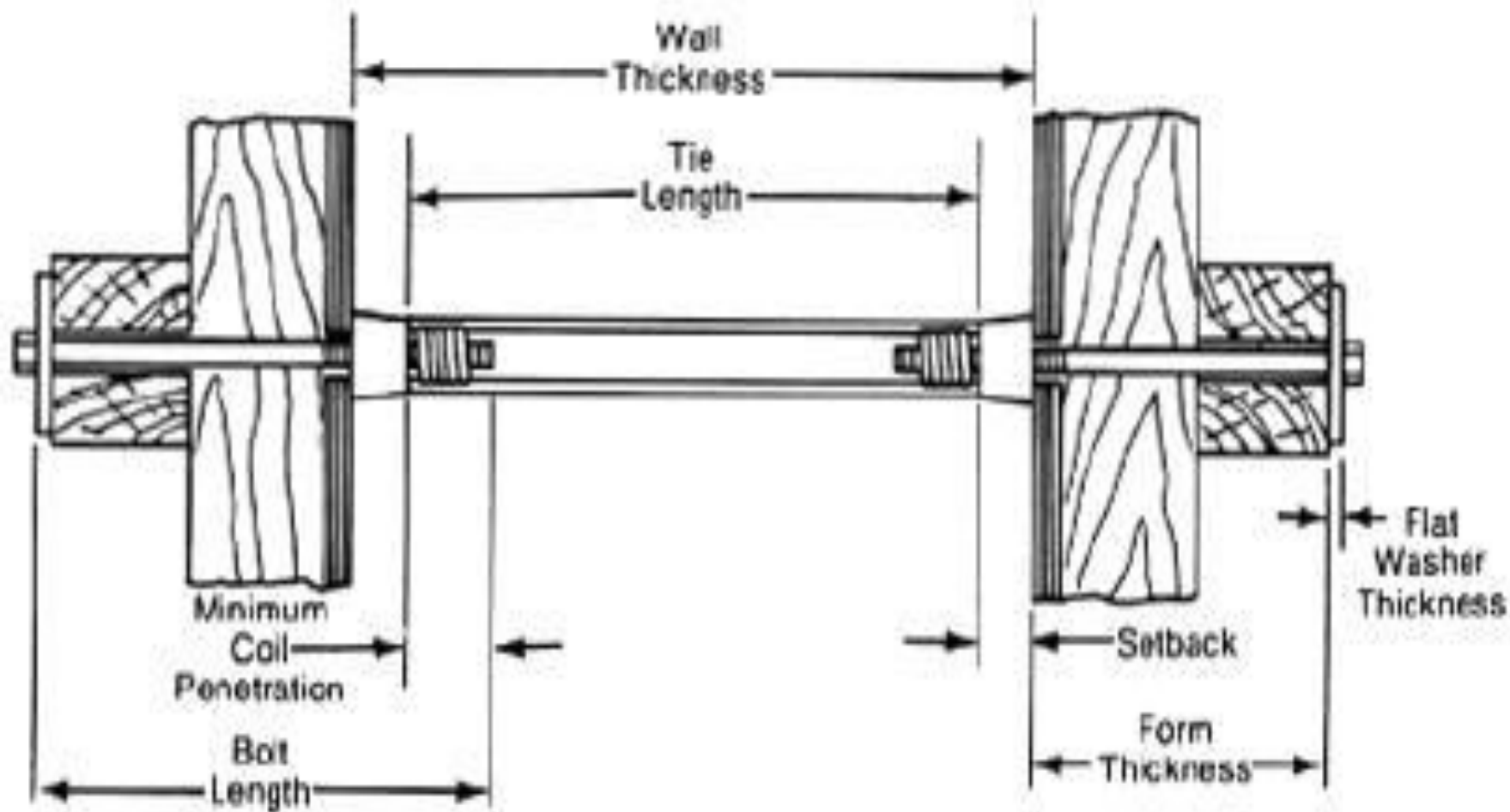
## **2. Mild Steel Ties**

- **Mild steel tie rod systems usually comprise an expendable section of mild steel all thread rod.**
- **On each end of the tie rod there is a tapered rubber cone which gives the cover to the expendable tie.**
- **After formwork is positioned bolts are used through the formwork into the rubber cone.**
- **The system acts as a spacer tie and as with the snap tie the correct length of tie automatically gives the correct wall thickness.**
- **The rubber cones are removable after the formwork is struck and the large holes that they make are more easily made good with 2 mortar.**

### ***3. Coil Ties***

- ✓ **The coil tie system is very similar in principle to the mild steel tie.**
- ✓ **The expendable section of tie comprises two coils of wire.**
- ✓ **A simple re-useable plastic cone is usually screwed onto the ends of the coil to form a cover to the tie rod after striking.**
- ✓ **The big advantage of this system is the coarse rope thread of the tie bolt which screws into the coils, which makes connection much faster than that of the finer.**





## ***4. High Tensile Ties***

- **The H.T. ties rod system comprises a tie rod which is left in the concrete and is connected to a re-useable she-bolt.**
- **The big advantage of the H.T. tie system is that the entire she-bolt, tie rod and other she-bolt is passed through both faces of formwork after the forms have been erected.**
- **Large waler plates are then fitted to the ends of the she-bolts to transfer the high loads into the soldiers or wailings.**

- **The she-bolt normally has a taper in the concrete end to allow easy removal once the concrete has gained strength.**
- **To prevent the tie rod rotating in the green concrete there is usually either a crimp or a deformation in the rod.**
- **The H.T. tie system does not act as a spacer to the wall and separate provision needs to be made for obtaining the correct thickness of wall such as a kicker at the base and a spacer at the top of the form.**

## **2. Recoverable Ties**

*After concrete is placed the ties are removed and a hole is left behind of it. It is not good in water retaining structures.*

*Types of recoverable ties are as follows.*

### **1.Through Ties**

- The bar generally of 15 mm nominal diameter is passed right through the wall and uses an expendable plastic tube with cones at each end as a spacer through the wall.
- The cone is knocked out from one side of the wall after the formwork is removed.
- The larger hole left in the wall by the cone needs filling either with a pre-cast concrete cone or a filler of some sort.

## ***2. Taper Ties***

- **The variation of the through tie without a sleeve requirement is to have a machined bar which tapers from one end to the other end.**
- **This is passed through the formwork.**
- **The tie is removed by tapping it through the wall after use.**

### ***3. Anchor Ties***

- **Cast in hook bolts, anchors, loops and fixings to form bedded in ties are generally known as anchor ties.**
- **They are often designed to take both tensile and shear loading and will be used for single face climbing formwork.**
- **The loading often depends on the strength of the concrete in which they are embedded**

## **3.1 Loops**

**Generally loops are used with coil ties**

## **3.2 'L' Bolts**

- **The use of 'L' bolts cast into the concrete can form satisfactory anchors.**
- **The type of connection to the formwork will be similar to the tie system generally used.**
- **The failure of "L' bolts is either due to the shearing of a cone of concrete from behind the 'L' shape or alternatively by the bar straightening and pulling out of the wall.**
- **The minimum concrete strength for this being 14 N per mm<sup>2</sup>.**

## ***3.3 Tail Anchors***

- **The tail anchor normally is a H.T. tie with a bend in the end which is cast into the concrete and connected to formwork with a she-bolt as given above.**
- **The tail anchor gives a much deeper connection of the tie force into the wall and can only be used on thick walls.**
- **Typical loads for a 1/2" tail anchor are 60 kN again with minimum concrete strength of 114 N per mm<sup>2</sup>.**



## 3.4. Anchor Screws

- **The anchor screw is a type of machined cone threaded cone which is inserted into concrete and with a special type of extractor can be withdrawn after use.**
- **They are used for handling large pre-cast units and rely upon tensile forces in the concrete for their load capacity.**
- **The anchor screw is coated with a grease, which allows the screw to be removed after use.**

## ***3.5. Resin Anchors***

- **A new development in providing fixing into walls for climbing formwork is to use resin anchors.**
- **These comprise a hole drilled previously and then filled with a resin capsule which is then broken and mixed inside the hole.**
- **This resin sets and leaves a projecting bar from the existing concrete. It is then possible to connect onto this bar with a coupling, any form of tie rod provided the threads are compatible.**
- **Very often the resin anchors are stronger than the steel. As with all types of anchors the concrete strength is to be checked.**

## ***3.6. Hanger Ties***

- **Where soffit formwork is suspended from beams by hanger ties a load factor of at least 3 should be used.**
- **The hanger ties should fit as tightly as possible on the top flange of the beam so that the eccentricity caused by bending is reduced to a minimum.**

# ***Design of Wall and Column***

- 1. The Maximum Lateral pressure against the sheathing is determined from the appropriate equation.**
- 2. If the sheathing thickness has been specified, the maximum allowable span for the sheathing based on bending, shear and deflection is the maximum stud spacing**
- 3. If the stud spacing is fixed, calculate the required thickness of sheathing**
- 4. Calculate the maximum allowable stud span “Wale Spacing” based on stud size and design load, again considering bending, shear and deflection.**

## ***Design of Wall and Column (continued)***

- 5. If the stud span has already been determined, calculate the required size of the stud.**
- 6. Determine the maximum allowable spacing of wale supports “Tie Spacing” based on wale size and load. . If the tie spacing has been pre selected, determine the minimum wale size.**
- 8. Check the tie’s ability to carry the load imposed by wale and tie spacing the load {W} on each tie is calculated as the design load {KPa}\*the spacing {m}\*wale spacing {m}.**

***Note: If the load exceeds the strength, a stronger tie must be used or the spacing must be reduced.***

## ***Design of Wall and Column (continued)***

- 9. Check bearing stresses “compression perpendicular to the grain” where the studs rest on Wales and where tie ends bear on Wales.**

***Note: Maximum bearing stress must not exceed the allowable compression stress perpendicular to the grain or crushing will result.***

- 10. Design lateral bracing to resist any expected lateral loads, such as wind loads.**

## Design Loads

-For all columns and walls with a vertical rate of placement (2.1 m/h) or less

$$P = 7.2 + \frac{785 R}{T + 18}$$

where : P = lateral pressure (KPa)

R = Rate of placement (m/hr)

T = Temperature (°C)

H = Height (m)

Accept a maximum of 143.6 KPa for columns and 95.8 KPa for walls or whichever is less.

**- For walls with a vertical rate of placement of 2.1 to 3 m/hr**

$$P = 7.2 + \frac{1154}{T + 18} + \frac{244R}{T + 18}$$

Accept a maximum pressure = 95.8 KPa or whichever is less.



-For walls with a vertical rate of placement greater than 10 ft/hr

$$P = 150 \times h$$

- When forms are vibrated externally, the design load found with above formulas 1 and 2 will be multiplied by 2.

- When concrete is pumped into vertical forms from the bottom, for both columns and walls equation 3 should always be used.

## For Floors [elevated slab]

### Loads :

#### i. Dead loads :

- Concrete weight
- Reinforcement weight
- Formwork weight

#### ii. Live loads :

- Equipment weight
- Workers weight
- Construction material weight

## ACI Recommendations:

### Live load

50 lb/ft<sup>2</sup>

75 lb/ft<sup>2</sup> [in placement powered buggies are used]

### Minimum Total Design load

100 lb/ft<sup>2</sup>

125 lb/ft<sup>2</sup> [if powered buggies are used in placement]

Design the formwork for the slab D 102 shown in the plan below. Concrete will be placed by and buggies, Unit weight of concrete are 2403 kg/m<sup>3</sup>.

Sheathing will be plyform structure I 1 in (25.4 mm) with face grain parallel supports.

All lumber will be Eastern Spruce. Joist will be nominal 2\*4 in (50\*100 mm).

Stringer will be nominal 3\*4 in (75\*100 mm).

Formwork weighs 0.26 KN/m<sup>2</sup>. Commercial 14.5 KN shore capacity will be used. Poker vibrator will be used to compact concrete.

Live Load = 2.40 KN/m<sup>2</sup>

Maximum allowable deflection is limited to L/240.

Assume all members are continuous over three or more spans.

## Step 1:

Load per meter square:

Concrete	= ( 1 x 0.15 x 9.8 x 2403 ) / 1000	= 3.53
Formwork		= 0.26
Live Load		= 2.40
Total		= 6.19 KN/m <sup>2</sup>

***Design Load = 6.19 KN/m<sup>2</sup>***

## **Step 2:**

### ***Sheathing Design***

Consider a uniformly loaded strip of sheathing 1 m wide placed parallel to the joists;

$$W = (1\text{m}^2/\text{m}) \times (6.19 \text{ KN}/\text{m}^2) = 6.19 \text{ KN}/\text{m}$$

$$L \text{ bending} = 3.16 \left( \frac{FbKs}{W} \right)^{1/2} = 3.16 \left( \frac{622 * 10^3}{6.19} \right)^{1/2} = 1001.69\text{mm}$$

$$L \text{ shear} = 1.67 \left( \frac{FsIb/Q}{W} \right) + 2d = 1.67 \left( \frac{10.39 \times 10^3}{6.19} \right) + 2(25.4) = 2853.92\text{mm}$$

$$L \text{ deflection} = \frac{84.7}{1000} \left( \frac{EI}{w} \right)^{1/3} = \frac{84.7}{1000} \left( \frac{4533 \times 10^9}{6.19} \right)^{1/3} = 763.45\text{mm}$$

***Deflection governs the design. Maximum allowable span of sheathing 763.45 mm***

$$\text{No of spans} = \frac{5700}{763.45} = 7.466 \quad \text{Take 8 spans}$$

$$\text{Span length} = \frac{5700}{8} = 712.5 \text{ mm}$$



## **Step 3:**

### **Joist Design**

$$W = \frac{712.5}{1000} \times 6.19 = 4.41 \text{ KN/m}$$

$$L \text{ bending} = \frac{100}{1000} \left( \frac{FbS}{W} \right)^{1/2} = \frac{100}{1000} \left( \frac{7240 \times 0.5019 \times 10^5}{4.41} \right)^{1/2} = 907.74 \text{ mm}$$

$$L \text{ shear} = \frac{1.11}{1000} \left( \frac{FvA}{W} \right) + 2d = \frac{1.11}{1000} \left( \frac{965 \times 3.387 \times 10^3}{4.41} \right) + 2(89) = 1000.67 \text{ mm}$$

$$L \text{ deflection} = \frac{84.7}{1000} \left( \frac{EI}{W} \right)^{1/3} = \frac{84.7}{1000} \left( \frac{8.3 \times 10^6 \times 2.231 \times 10^6}{4.41} \right)^{1/3} = 1366.45 \text{ mm}$$

***Bending governs the design.***

***Maximum allowable span of joist is 907.74 mm***

$$\text{No of spans} = \frac{3700}{907.74} = 4.1 \quad \text{Take 5 spans}$$

$$\text{Span Length} = \frac{3700}{5} = 740 \text{ mm}$$

## **Step 4:**

### **Stringer Design**

$$W = \frac{740}{1000} \times 1 \times 6.19 = 4.58 \text{ KN/m}$$

$$L_{\text{bending}} = \frac{100}{1000} \left( \frac{FbS}{W} \right)^{1/2} = \frac{100}{1000} \left( \frac{7240 \times 0.836 \times 10^5}{4.58} \right)^{1/2} = 1149.86 \text{ mm}$$

$$L_{\text{shear}} = \frac{1.11}{1000} \left( \frac{FvA}{W} \right) + 2d = \frac{1.11}{1000} \left( \frac{965 \times 5.645 \times 10^3}{4.58} \right) + 2(89) = 1498.23 \text{ mm}$$

$$L_{\text{deflection}} = \frac{84.7}{1000} \left( \frac{EI}{W} \right)^{1/3} = \frac{84.7}{1000} \left( \frac{8.3 \times 10^6 \times 3.718 \times 10^6}{4.58} \right)^{1/3} = 1599.77 \text{ mm}$$

***Bending governs the design,***

***Maximum allowable stringer span is 1149.86 mm***

$$\text{No of spans} = \frac{5700}{1149.86} = 4.957 \quad \text{Take 5 spans}$$

$$\text{Span Length} = \frac{5700}{5} = 1140 \text{ mm}$$

## Step 5:

$$\text{Bearing area} = 38 \times 64 = 2432 \text{ mm}^2$$

$$P = 6.19 \times \frac{712.5}{1000} \times \frac{740}{1000} = 3.263 \text{ KN}$$

$$\text{Bearing Stress} = \frac{3.263}{2432 \times 10^{-6}} = 1341.69 \text{ KN} / \text{m}^2 \leq 1758 \text{ KN} / \text{m}^2 \quad \mathbf{OK}$$