POST-TENSIONING APPLICATION AND TECHNOLOGY

Moe Kyaw Aung
Overview

1. Background
2. Basic Design Concept
3. Application and Benefits
4. Components of Post-tensioning System
5. Installation Process
6. Construction of a Flatted Warehouse in Singapore
BACKGROUND
Background

• Post-tensioning is a method of pre-stressing

• Eugène Freyssinet (1879-1962), a French Civil & Structural Engineer was pioneer in development of modern pre-stressed concrete

• Although Freyssinet was not inventor but he did much to develop pre-stressed concrete. Other engineers such as German Engineer Doehring had patented methods for pre-stressing as early as 1888

• 1928: Eugène Freyssinet invented Pre-stressed Concrete using high quality concrete and steel

• 1946: Post-Tensioning gained momentum in Europe
Background

- 1951: 1\textsuperscript{st} Post-tensioned bridge was constructed in US
- 1963: TY Lin introduced “Load Balancing Method”. He is the pioneer of standardizing the use of pre-stressed for practical use
- 1963: Pre-stressed Concrete was incorporated into ACI and subsequently PTI was established in US
- 1970: PT system started popular in Australia and spread to South East Asia
- 1980: Well known European Specialist Contractors established base in Singapore and work around the region. Later some local contractors established themselves as Specialist Contractor in PT Technology
Background

• How’s about the use of PT System in Myanmar?
• We learned Pre-stressed Concrete with ACI Code in YIT
• Use in bridge construction by Myanmar Public Works
• How’s about the use of PT System in Building in Myanmar?
• The technology may be new for application in building construction sector in Myanmar but seeing some European companies started establishing base here
• Looking forward to see using PT System in Building Construction
BASIC DESIGN CONCEPT
Basic Design Concept

Pre-stressed Concrete – Pre-stressing

The classic everyday example of Pre-stressing - Lifting a row of books by pressing the ends together
Basic Design Concept

• Pre-stressed Concrete – Pre-compress the concrete before loading in bending (Flexural tension)
• This compressive stress is introduced into concrete members by using tensioned high tensile strength steel tendon
• How to do Pre-compressing (or) Pre-stressing?
Basic Design Concept

• Pre-tensioning and Post-tensioning

  • Tension the steel before concrete is placed
  • Pre-cast Yard

  • Tension the steel after concrete is hardened
  • Site use
• The result?
• A lower in net tensile stress in concrete and allowing an optimization of structural system having long span and reduced member’s depth
• Control or eliminate tensile stresses in the concrete (cracking) at least up to service load levels.
• Control or eliminate deflection at some specific load level.
• Allow the use of high strength steel and concrete
Full Stressing (No tensile stress)
Post-Tensioned elements can be cast and tensioned in the final location (cast-in-place). They can also be precast.

Pre-Tensioned elements are often precast in a factory and shipped to the site on any profile.
• Design Procedure (Manual calculation)

1. Member sizing based on span-depth ratio
2. Define **Slab System**
• Slab System
  - Flat Plate (span 7-9m), up to IL 7.5KPa
  - Flush soffit and simplify construction
- **Slab System**
  - Flat Slab with Drop Panel (span 13m), up to IL 10KPa
  - Thin slab and improve stiffness, cost saving

<table>
<thead>
<tr>
<th></th>
<th>Imposed Load (kPa)</th>
<th>Span/Depth Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Span</td>
<td>3</td>
<td>38</td>
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<td>5</td>
<td>35</td>
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<td>10</td>
<td>32</td>
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<tr>
<td>End Span</td>
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<td>5</td>
<td>43</td>
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<td>10</td>
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<tr>
<td>Internal Span</td>
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<td>52</td>
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<td>49</td>
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<td>45</td>
</tr>
</tbody>
</table>
• **Slab System**
  - Banded Slab (beam span 8-15m), up to IL 15KPa
  - Longer span, fast construction

<table>
<thead>
<tr>
<th></th>
<th>Imposed Load (kPa)</th>
<th>Span/Depth Ratio</th>
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<tr>
<td><strong>Slabs (Ss)</strong></td>
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<td>End Span</td>
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<td>Internal Span</td>
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<td>45</td>
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<tr>
<td><strong>Bond Cems (Lb)</strong></td>
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<tr>
<td>Single Span</td>
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<td>18</td>
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<tr>
<td>End Span</td>
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<td>5</td>
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<td>10</td>
<td>19</td>
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<tr>
<td>Internal Span</td>
<td>3</td>
<td>27</td>
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<td>25</td>
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<td>10</td>
<td>22</td>
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</tbody>
</table>
3. Use **Load Balancing Approach** to determine the pre-stress force for each frame, equivalent frame. Compute average pre-stress force due to balanced load

4. Analyse equivalent frame due to unbalanced load and determine corresponding moment and stress
Load Balancing Approach

• The selection of load to be balanced by post-tensioning tendon is important

• Too high load/ Over-stressing can significantly impact the slab and may incur more cost with pre-stressed solution

• A combination of low level of “balanced load” and addition of reinforcement at peak moment region will prove to be a more economical solutions in most of the applications

• A “good” balance load is typically between 70 and 100 % of the weight of the tributary structural floor system
Slabs cast-in situ with reinforcement and PT strands

PT strands stressed AFTER concreting

Simple Illustration of post-tensioned tendon balancing of vertical load
Freebody Force Concept for Post-Tensioned Concrete
<table>
<thead>
<tr>
<th>Occupancy of building</th>
<th>Partitions and Other Superimposed Dead Load kPa</th>
<th>Live Load kPa</th>
<th>Load to Balance kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car Parks</td>
<td>Nil</td>
<td>2.5</td>
<td>(0.7-0.85)SW</td>
</tr>
<tr>
<td>Shopping Centres</td>
<td>0.0 - 2.0</td>
<td>5.0</td>
<td>(0.85-1.0)SW</td>
</tr>
<tr>
<td>Residential (check transfer carefully)</td>
<td>2.0 - 4.0</td>
<td>1.5</td>
<td>SW + 30% of partition load</td>
</tr>
<tr>
<td>Office Buildings</td>
<td>0.5 - 1.0</td>
<td>3.0</td>
<td>(0.8-0.95)SW</td>
</tr>
<tr>
<td>Storage</td>
<td>Nil</td>
<td>2.4 kPa / m height</td>
<td>SW + 20% LL</td>
</tr>
</tbody>
</table>

Note: SW denotes self weight, LL denotes live load.

**A Guide for Load Balancing under a Range of Building Uses**
5. Superimpose average stresses from post-tensioning force with stresses due to unbalanced load and compare the resulting stresses with allowable stresses

6. Determine minimum non-tensioned reinforcement required

7. Detail tendon and bar layout. Check spacing and cover requirement are satisfied

8. Check ultimate flexural strength requirement

9. Check shear and provide shear reinforcement

10. Compute deflection and compare with deflection limitations
Tendon Profile

- Nominal cover and fire protection requirement
- Parabolic profile (Within $e_{\text{max}}$ & $e_{\text{min}}$)
Post-tensioned Losses

- Short-term losses (Friction in ducts, Wedge set/ Anchorage, Elastic shortening of concrete)
- Long-term losses (Creep of concrete, Shrinkage of concrete, Relaxation of tendon)
- Typically losses in the range of 20-30%
• Available PT Structural System Design Software
  – ADAPT-PT
  – CSI - SAFE
  – Others
  – In-house Spreadsheet Programs
• **Design Procedure (ADAPT-PT)**
  1. Geometry & structural system
  2. Material properties
  3. Loads
  4. Design parameters
  5. Actions due to DL, LL
  6. Post-tensioning
  7. Check for serviceability (According to Codes)
  8. Check for strength (According to Codes)
  9. Check for transfer of pre-stressing
  10. Detailing
Design Procedure - SAFE

1. Tendon Materials
2. Tendon Properties
3. Tendon Load (Jacking force)
4. Tendon Objects
5. Forces due to Tendons
6. Analysis
   - Strength and Capacity Design
   - Serviceability Design Output
   - Strength Design Output
   - Detailing Output
7. Loss Calculation Parameters
8. Draw Tendons
   - Edit Tendons
   - Auto Tendon Layout
9. Other loads and options
• Use of PT System is still regional
• It requires use high strength materials, specialized equipments, skilled manpower
• Design shall be complied to available Design Codes
  – ACI 318-11
  – EC2 EN 1992-1-1:2004
  – IBC 2012
  – Any other local Codes
APPLICATIONS & BENEFITS
Applications & Benefits

Application of Post-Tensioning System

1) Buildings/ High rise towers
2) Various bridges including cable-strayed and segmental types
3) Underground structures, slab on-grade
4) Water storage tanks, nuclear reactors, silos
5) Offshore structures
6) Ground anchors for retaining structures
7) Load transfer structures
Photos of PT Structures (Credit to PT Specialist)
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Application & Benefits

Why use of PT?

• Longer span (L/D = 28 (RC), 45 (PT))
• Higher load capacity (up to 15 KPa)
• Cheaper
• Faster
• Easier
3. Application & Benefits

![Graph showing relative cost per m² against slab span (m) for Reinforced Concrete and Post-tensioned Concrete, with a break-even point indicated.](image-url)
Why Use PT:

- Reduce the quantity of concrete
- Reduce quantity of Reinforcement
- Simplify reinforcement works

This will lead to:

- Decrease cost of material for slab
- Decrease cost of manpower
- Decrease quantity of columns and foundations
ANALYSIS USING A TYPICAL FLOOR SLAB (BCA Singapore 2012)

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>Conventional Design Non-Prestressed</th>
<th>Prestressed / Precast</th>
<th>Material Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>0.25 m³/m²</td>
<td>0.18 m³/m²</td>
<td>28%</td>
</tr>
<tr>
<td>Reinforcing Steel</td>
<td>18.30 kg/m²</td>
<td>6.20 kg/m²</td>
<td>45%</td>
</tr>
<tr>
<td>Prestressing Steel</td>
<td>-</td>
<td>3.85 kg/m²</td>
<td>45%</td>
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</tbody>
</table>

Flat slabs (one-way-span)
Design for live load = 4 kN/m²
Clear span = 8 m
### Analysis Using a Typical Floor Beam

**Conventional design, non-prestressed**

**Prestressed / precast, beam and slab**

<table>
<thead>
<tr>
<th>Material</th>
<th>Conventional Design Non-Prestressed Type A</th>
<th>Prestressed / Precast Type B</th>
<th>Material Savings from Type A to Type B</th>
<th>Prestressed / Precast Type C</th>
<th>Material Savings from Type B to Type C</th>
<th>Material Savings from Type A to Type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete</td>
<td>0.288 m$^3$/m</td>
<td>0.18 m$^3$/m</td>
<td>37.5%</td>
<td>0.113 m$^3$/m</td>
<td>37.2%</td>
<td>60.8%</td>
</tr>
<tr>
<td>Reinforcing Steel</td>
<td>42.0 kg/m</td>
<td>6.20 kg/m</td>
<td>66%</td>
<td>6.0 kg/m</td>
<td>-</td>
<td>66%</td>
</tr>
<tr>
<td>Prestressing Steel</td>
<td>-</td>
<td>8.47 kg/m</td>
<td>66%</td>
<td>8.47 kg/m</td>
<td>-</td>
<td>66%</td>
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</tbody>
</table>

**Beams, Span = 12 m**

**Clear spacing = 4 m centre to centre**

**Live load = 4 kPa**

*ANALYSIS USING A TYPICAL FLOOR BEAM (BCA Singapore 2012)*
Why use a PT slab???

- It's faster
  - Reduction in Manpower due to significant reduction in steel fixing
  - Formwork can be struck after stressing normally 3 days after concreting
  - Utilising load balancing leads to reduction in number of back propped floors normally 2 to 3
  - 5 day cycles commonly achieved without double shifts etc.
### Floor to floor

**5 days**

<table>
<thead>
<tr>
<th>Activity</th>
<th>1</th>
<th>2</th>
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<th>13</th>
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<tbody>
<tr>
<td>Installation of formwork</td>
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<td>Installation of bottom reinforcement</td>
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<td>Installation of PT Anchors</td>
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<td>Installation of PT Tendons</td>
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<tr>
<td>Installation of top Reinforcement</td>
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<td>Inspect</td>
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<td>Concreting</td>
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<td>Initial stress (25%)</td>
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<td>Final stress (100%)</td>
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<td>Grout tendons (not on critical path)</td>
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</tbody>
</table>

**Formwork cycle**

**10 days**
Flat Slabs are the preferred option for Residential and Office buildings which are the most common use of Towers

- Why??
  - Easily partitioned
  - Fixing of E and M works is simplified
  - Construction is fast as lends itself to system formwork
  - Concreting steel fixing etc is simplified
  - Improved fire resistance
Post-Tensioning is selected as the construction system of choice to meet these challenging market demands

<table>
<thead>
<tr>
<th>Total PT Tonnage</th>
<th>Market</th>
<th>% of Concrete Buildings PT</th>
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<tbody>
<tr>
<td>65,000</td>
<td>USA</td>
<td>65%</td>
</tr>
<tr>
<td>40,000</td>
<td>Dubai</td>
<td>70%</td>
</tr>
<tr>
<td>14,000</td>
<td>Australia</td>
<td>50%</td>
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<tr>
<td>8,000</td>
<td>UK</td>
<td>15%</td>
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<tr>
<td>4,000</td>
<td>Singapore</td>
<td>60%</td>
</tr>
<tr>
<td>3,000</td>
<td>Thailand</td>
<td>30%</td>
</tr>
</tbody>
</table>

(Representative tonnage and market penetration data for mature markets 2006)
Disadvantage of PT System
- Future modification of structure
- No cracks free
- Grouting/ corrosion of tendon
- Required special skill and equipment
- Cost for Low-rise buildings (20+ storey?)
Components of Post-tensioning System
• In Post-tensioning Technology, there are a few well-know Specialist Contractors in the market
• They have developed and patented their products, design, technology, equipments and other accessories related to PT System
  – Freyssinet PT System
  – VSL Construction System
  – BBR PT System
  – CCL PT System and many more....

• There should not be a mix and match of the components of PT system!!!
Major components

• Wires – Individual drawn wire (7mm)
• Strands - Typically 7 wires wound around to form a strand
• Tendon – A collection of strands in duct (Bonded tendon & Un-bonded tendon)
• Ducts
• Anchors, wedges, pocket former
• Encapsulated
• Supports (chairs and bars)
• Stressing equipment
Forms of Prestressing Steel

Tendons

Bars
Wire
Strands
Cable
7-wire strand

Mono-strand

Multi-strand
Single strand coupler

Multistrand coupler
<table>
<thead>
<tr>
<th>Diameter</th>
<th>Nominal Diameter (mm)</th>
<th>Nominal Area (mm²)</th>
<th>Nominal Mass (kg/m)</th>
<th>Yield Strength (N/mm²)</th>
<th>Tensile Strength (N/mm²)</th>
<th>Minimum Breaking Load (kN)</th>
<th>Modulus of Elasticity (kN/mm²)</th>
<th>Relaxation^1 (class 2 or low relaxation)</th>
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<tr>
<td>13 mm (0.5&quot;)</td>
<td>12.9</td>
<td>100</td>
<td>0.785</td>
<td>1580</td>
<td>1860</td>
<td>186</td>
<td>195</td>
<td>2.5%</td>
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<tr>
<td>15 mm (0.6&quot;)</td>
<td>12.7</td>
<td>93</td>
<td>0.73</td>
<td>1500</td>
<td>1770</td>
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<td>195</td>
<td>2.5%</td>
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<tr>
<td></td>
<td>12.7</td>
<td>112</td>
<td>0.89</td>
<td>1580</td>
<td>1860</td>
<td>209</td>
<td>195</td>
<td>2.5%</td>
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<tr>
<td></td>
<td>12.7</td>
<td>98.7</td>
<td>0.775</td>
<td>1670</td>
<td>1860</td>
<td>183.7</td>
<td>195</td>
<td>2.5%</td>
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<tr>
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<td>15.7</td>
<td>150</td>
<td>1.18</td>
<td>1500</td>
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<td>15.2</td>
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<td>1.295</td>
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<td>15.2</td>
<td>140</td>
<td>1.10</td>
<td>1670</td>
<td>1860</td>
<td>260.7</td>
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<tr>
<td>Stress Bars</td>
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<tr>
<td>20 mm</td>
<td>BS 4486: 1980</td>
<td>20</td>
<td>314</td>
<td>2.39</td>
<td>835</td>
<td>1030</td>
<td>323</td>
<td>170/205</td>
</tr>
<tr>
<td>25 mm</td>
<td>BS 4486: 1980</td>
<td>25</td>
<td>491</td>
<td>3.9</td>
<td>835</td>
<td>1030</td>
<td>505</td>
<td>170/205</td>
</tr>
<tr>
<td>32 mm</td>
<td>BS 4486: 1980</td>
<td>32</td>
<td>804</td>
<td>6.66</td>
<td>835</td>
<td>1030</td>
<td>828</td>
<td>170/205</td>
</tr>
<tr>
<td>40 mm</td>
<td>BS 4486: 1980</td>
<td>40</td>
<td>1257</td>
<td>10</td>
<td>835</td>
<td>1030</td>
<td>1300</td>
<td>170/205</td>
</tr>
<tr>
<td>50 mm</td>
<td>BS 4486: 1980</td>
<td>50</td>
<td>1963</td>
<td>16.02</td>
<td>835</td>
<td>1030</td>
<td>2022</td>
<td>170/205</td>
</tr>
<tr>
<td>Cold-drawn Wire</td>
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<tr>
<td>7 mm</td>
<td>BS 5896: 1980</td>
<td>7</td>
<td>38.5</td>
<td>302</td>
<td>1300</td>
<td>1570</td>
<td>60.4</td>
<td>205</td>
</tr>
<tr>
<td></td>
<td>BS 5896: 1980</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 mm</td>
<td>BS 5896: 1980</td>
<td>5</td>
<td>19.6</td>
<td>154</td>
<td>1390</td>
<td>1670</td>
<td>64.3</td>
<td>205</td>
</tr>
</tbody>
</table>
# Material Properties

## Prestressing Steel

### Design Aid 11.2.4  Properties and design strengths of prestressing bars

#### Plain Prestressing Bars, $f_{pu} = 145$ ksi

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>$\frac{3}{8}$</th>
<th>$\frac{1}{2}$</th>
<th>1</th>
<th>1¼</th>
<th>1½</th>
<th>1¾</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, sq. in.</td>
<td>0.442</td>
<td>0.601</td>
<td>0.785</td>
<td>0.994</td>
<td>1.227</td>
<td>1.485</td>
</tr>
<tr>
<td>Weight, plf</td>
<td>1.50</td>
<td>2.04</td>
<td>2.67</td>
<td>3.38</td>
<td>4.17</td>
<td>5.05</td>
</tr>
<tr>
<td>0.7 $f_{pu}$ $A_{ps}$, kips</td>
<td>44.9</td>
<td>61.0</td>
<td>79.7</td>
<td>100.9</td>
<td>124.5</td>
<td>150.7</td>
</tr>
<tr>
<td>0.8 $f_{pu}$ $A_{ps}$, kips</td>
<td>51.3</td>
<td>69.7</td>
<td>91.0</td>
<td>115.3</td>
<td>142.3</td>
<td>172.2</td>
</tr>
<tr>
<td>$f_{pu}$ $A_{ps}$, kips</td>
<td>64.1</td>
<td>87.1</td>
<td>113.8</td>
<td>144.1</td>
<td>177.9</td>
<td>215.3</td>
</tr>
</tbody>
</table>

#### Plain Prestressing Bars, $f_{pu} = 160$ ksi

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>$\frac{3}{8}$</th>
<th>$\frac{1}{2}$</th>
<th>1</th>
<th>1¼</th>
<th>1½</th>
<th>1¾</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, sq. in.</td>
<td>0.442</td>
<td>0.601</td>
<td>0.785</td>
<td>0.994</td>
<td>1.227</td>
<td>1.485</td>
</tr>
<tr>
<td>Weight, plf</td>
<td>1.50</td>
<td>2.04</td>
<td>2.67</td>
<td>3.38</td>
<td>4.17</td>
<td>5.05</td>
</tr>
<tr>
<td>0.7 $f_{pu}$ $A_{ps}$, kips</td>
<td>49.5</td>
<td>67.3</td>
<td>87.9</td>
<td>111.3</td>
<td>137.4</td>
<td>166.3</td>
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<tr>
<td>0.8 $f_{pu}$ $A_{ps}$, kips</td>
<td>56.6</td>
<td>77.0</td>
<td>105.0</td>
<td>127.2</td>
<td>157.0</td>
<td>190.1</td>
</tr>
<tr>
<td>$f_{pu}$ $A_{ps}$, kips</td>
<td>70.7</td>
<td>96.2</td>
<td>125.6</td>
<td>159.0</td>
<td>196.3</td>
<td>237.6</td>
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</tbody>
</table>

#### Deformed Prestressing Bars

<table>
<thead>
<tr>
<th>Nominal Diameter, in.</th>
<th>$\frac{5}{8}$</th>
<th>1</th>
<th>1¼</th>
<th>1½</th>
<th>1¾</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, sq. in.</td>
<td>0.28</td>
<td>0.85</td>
<td>0.85</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>Weight, plf</td>
<td>0.98</td>
<td>3.01</td>
<td>3.01</td>
<td>4.39</td>
<td>4.39</td>
</tr>
<tr>
<td>Ult. strength, $f_{pu}$, ksi</td>
<td>157</td>
<td>150</td>
<td>160&lt;sup&gt;a&lt;/sup&gt;</td>
<td>150</td>
<td>160&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>0.7 $f_{pu}$ $A_{ps}$, kips</td>
<td>30.5</td>
<td>89.3</td>
<td>95.2</td>
<td>131.3</td>
<td>140.0</td>
</tr>
<tr>
<td>0.8 $f_{pu}$ $A_{ps}$, kips</td>
<td>34.8</td>
<td>102.0</td>
<td>108.8</td>
<td>150.0</td>
<td>160.0</td>
</tr>
<tr>
<td>$f_{pu}$ $A_{ps}$, kips</td>
<td>43.5</td>
<td>127.5</td>
<td>136.0</td>
<td>187.5</td>
<td>200.0</td>
</tr>
</tbody>
</table>

Stress-strain characteristics (all prestressing bars):

For design purposes, following assumptions are satisfactory:

- $E_s = 29,000$ ksi
- $f_y = 0.95 f_{pu}$

<sup>a</sup> Verify availability before specifying.
TENDON SYSTEMS

Unbonded Tendon

Bonded Tendon
Unbonded System
BONDED TENDONS

ADVANTAGES

- Higher flexural capacity
- Good flexural crack distribution
- Good corrosion protection
- Flexibility for later cutting of penetrations
- Easier demolition
Stressing equipment for single strands

Stressing Equipment for multistrand tendons

NOTE: Jack and gauge should be calibrated and remain together

Anchor head and wedges (wedges are usually retained by springs or neoprene bushings inside jack while strands are pulled).
HYDRAULIC JACKS
Installation Process
Typical Installation Process

For Bonded Post-tensioning Slab

• Erecting of slab supporting formwork
• Fitting of end formwork and placing of anchorages
• Marking and placing of M&E box-outs, cast-in items
• Placing of bottom and edge reinforcement
• Placing of ducts/ tendon according to drawing
• Supporting of ducts/ tendons with spacer/ bar (or) wire chair according to details
Typical Installation Process

• Placing of top reinforcement, bursting control reinforcement at all live/ dead end anchors
• Concreting of the section of the slab
• Removal of end formwork and forms for stressing block-outs
• Stressing of cables according to stressing program (Elongation check)
• Stripping of slab supporting formwork
• Grouting of cables and concreting of block-outs
5. Installation Process

<table>
<thead>
<tr>
<th>Activity</th>
<th>1</th>
<th>2</th>
<th>3</th>
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<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of formwork</td>
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<tr>
<td>Installation of bottom reinforcement</td>
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<tr>
<td>Installation of PT Anchors</td>
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<tr>
<td>Installation of PT Tendons</td>
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<tr>
<td>Installation of top Reinforcement</td>
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<tr>
<td>Inspect</td>
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<td>Concreting</td>
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<td>Initial stress (25%)</td>
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<tr>
<td>Final stress (100%)</td>
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<tr>
<td>Strip of formwork</td>
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<tr>
<td>Grout tendons (not on critical path)</td>
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</tbody>
</table>

- **Floor to floor**: 5 days
- **Formwork cycle**: 10 days
Multiple Strands: Multistrand
Grouting Equipment
Construction of Flatted Warehouse in Singapore
8 Storey Flatted Warehouse at Paya Lebar Road

• Developer – XXXX Land

• Architect - XXXX Architects

• Structural Consultants: XXXX Engineers

• Contractor – XXXX Construction
  – Post-tensioning Specialist – XXX Singapore
  – Formwork Specialist – XXXX
• Is it a Landmark Building in Singapore?
• No, it’s not. It’s just a simple light industrial building. But we can learn lessons from this project.
• In early 90, demand for warehousing rose significantly. Developer would like to build the warehouse with bigger loading, longer span and higher ceiling. And, the Developer also would like to complete the warehouse in 12 months to capitalize the market

• As per Developer’s intent, the Architect and Engineers worked hard to fulfil the requirement

• The warehouse was designed as PT banded flat slab with drop panel to maximize the capacity, span and ceiling height

• Typical span 8-9m, ceiling height 4-5m, imposed load 7.5-10 KPa
• Contractor also planned necessary manpower and resources to meet the schedule
• Contractor worked under fast-track schedule
• Contractor engaged PT specialist for post-tensioning work
• Basement construction is RC construction
• Contractor also used all possible means to speed up the construction process
  – Table form for slab
  – Slip-forming system for lift shaft
Lessons learnt from this project

• Project completed successfully?
• Schedule met the milestone?
• Advanced technologies useful?
• Application of Technology served purpose?

• Contributing factors
  – First time application of technology (PT, Slip-forming) in company
  – Insufficient detailed/ **advanced planning**
  – Productivity was slow during initial implementation
  – Slow and inefficient co-ordination with M&E trades, CSD
  – Productive solution was not implemented for Finishing trades
  – Similar/ repeated project may benefit from these lessons
  – Frequent changing workforce in industry
  – In a few more years time, company closed down
Closing Notes

• PT System has been in the construction market for more than 6 decades
• It’s not new to construction industry but it’s may be new to the users in Myanmar
• Willingness from local developer to try out PT System for better building with cheaper cost
• Difficulties (or) finding disadvantages in initial use of technology
• Over the time, user may benefit from this application
• Courage to local Main/ General Contractor for application of this technology as part of construction
Attention!!!

It is important to note that pre-stressing requires specialised expertise and a high level of quality control and inspection. Hence, it is important that developers or main contractors engage qualified pre-stressing specialist for the design and construction of pre-stressing operations.
THANK YOU