Chapter 3

TRUSS PATTERNS AND TENDON LAYOUTS CONSIDERED FOR ANALYTICAL STUDY

In the present analytical study, effectiveness of strengthening of different truss patterns of bridges, by various internal and external posttensioned tendon layouts is brought out through numerical illustrations. The details of different truss patterns and various internal and external posttensioned tendon layouts considered are presented in this chapter. In deterministic analysis, it is aimed at calculating member forces, deflections and natural frequencies of the trusses before and after posttensioning; whereas in reliability analysis the objective is to estimate the reliability index of each member for different failure modes by various reliability assessment methods (both probability and fuzzy based) and the corresponding probability of failure.

3.1 TRUSS PATTERNS CONSIDERED

Statically determinate and indeterminate bridge trusses of three different patterns namely Warren, Howe and Pratt type are considered for this analytical study. The span of each truss is 48 m with 8 panels, each panel being 6 m and height of the truss is 7.5 m. All the trusses are subjected to a vertical load of 600 kN at each joint along their bottom chord. The truss patterns considered in the present study with their geometry and loads are depicted in Figs. 3.1(a) through 3.1(f).

(a) Determinate Warren Truss
(b) Indeterminate Warren Truss

(c) Determinate Howe Truss

(d) Indeterminate Howe Truss

(e) Determinate Pratt Truss
3.2 POSTTENSIONED TENDON LAYOUTS CONSIDERED

In the present study, each of the trusses shown in Figs. 3.1(a) through 3.1(f) is strengthened by different internal and external posttensioned tendon layouts. An internal tendon layout is one in which the tendons are placed within the truss system; where as an external tendon layout is one in which the tendons are placed outside the truss system.
Fig. 3.2: Determinate Warren Truss Posttensioned With Different Tendon Layouts (Tendon is shown by dotted line)
Determinate Warren truss, posttensioned with different tendon layouts are shown by dotted line in Figs. 3.2 (a) through 3.2(g).

In internal tendon layouts, straight, one-drape and two-drape profiles of tendons are used and connectivity of the tendon is with the existing joints of truss only. Straight tendon is anchored to the truss at joints \( L_0 \) and \( L_8 \) as shown in Fig. 3.2(b), one-drape tendon is anchored to the truss at joints \( U_1 \) and \( U_7 \), passing over a pulley attached at joint \( L_4 \) as shown in Fig. 3.2(c), whereas two-drape tendon layout anchored to the truss at joints \( U_1 \) and \( U_7 \), passing over two pulleys attached at joints \( L_1 \) and \( L_7 \) is as shown in Fig. 3.2(d).

In all the external tendon layouts, only two-drape profiles of tendons are used. Additional joints are created and tendon is passing through these additional joints apart from anchoring the tendon to the existing truss joints at its ends. Vertical member \( L_1 B_1 \) and diagonal member \( L_2 B_1 \) are added to create an additional joint \( B_1 \); whereas vertical member \( L_7 B_7 \) and diagonal member \( L_6 B_7 \) are added and an additional joint \( B_7 \) is created. Tendons are anchored to the truss joints \( L_0 \) and \( L_8 \) and passing over two pulleys attached at additional joints \( B_1 \) and \( B_7 \) as shown in Figs. 3.2(e) to 3.2(g) for different values of the vertical distance between the bottom chord and the tendon (h).

High strength steel tendons are used for posttensioning of the steel trusses. In all the cases the cross sectional area of the tendons is 600 mm\(^2\), the initial posttensioning stress is 1120 N/mm\(^2\) and the corresponding posttensioning force is 672 kN. The value of Young’s Modulus for the tendon is 160 GPa (Belenya, 1977; Troitsky, 1990); whereas Young’s Modulus and yield stress for truss members are taken as 200 GPa and 260 GPa (IS: 800, 1984) respectively.

Figures of each of the remaining five trusses posttensioned with the above tendon layouts have not been shown here, as the tendon layout for them is also same as depicted in Figs. 3.2(a) through Fig. 3.2(g).
Table 3.1: Trusses and Posttensioned Tendon Layouts Considered for Analytical Study

<table>
<thead>
<tr>
<th>Tendon Layout Type</th>
<th>Conventional Truss (Without Tendon)</th>
<th>Internal Straight Tendon</th>
<th>Internal One-Drape Tendon</th>
<th>Internal Two-Drape Tendon</th>
<th>External Two-Drape Tendon with h=2 m</th>
<th>External Two-Drape Tendon with h=4 m</th>
<th>External Two-Drape Tendon with h=6 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Determinate Warren Truss</td>
<td>Case 1</td>
<td>Case 2</td>
<td>Case 3</td>
<td>Case 4</td>
<td>Case 5</td>
<td>Case 6</td>
<td>Case 7</td>
</tr>
<tr>
<td>Indeterminate Warren Truss</td>
<td>Case 8</td>
<td>Case 9</td>
<td>Case 10</td>
<td>Case 11</td>
<td>Case 12</td>
<td>Case 13</td>
<td>Case 14</td>
</tr>
<tr>
<td>Determinate Howe Truss</td>
<td>Case 15</td>
<td>Case 16</td>
<td>Case 17</td>
<td>Case 18</td>
<td>Case 19</td>
<td>Case 20</td>
<td>Case 21</td>
</tr>
<tr>
<td>Indeterminate Howe Truss</td>
<td>Case 22</td>
<td>Case 23</td>
<td>Case 24</td>
<td>Case 25</td>
<td>Case 26</td>
<td>Case 27</td>
<td>Case 28</td>
</tr>
<tr>
<td>Determinate Pratt Truss</td>
<td>Case 29</td>
<td>Case 30</td>
<td>Case 31</td>
<td>Case 32</td>
<td>Case 33</td>
<td>Case 34</td>
<td>Case 35</td>
</tr>
<tr>
<td>Indeterminate Pratt Truss</td>
<td>Case 36</td>
<td>Case 37</td>
<td>Case 38</td>
<td>Case 39</td>
<td>Case 40</td>
<td>Case 41</td>
<td>Case 42</td>
</tr>
</tbody>
</table>

Table 3.1 summarises the total number of cases considered for the present analytical study. In the above Table 3.1, for example Case 28 means Indeterminate Howe Truss posttensioned by external two-drape tendon with $h=6$ m.

### 3.3 DETERMINISTIC ANALYSIS

Stiffness matrices for straight tendon, one-drape tendon and two-drape tendons are formulated using the direct stiffness approach of matrix structural analysis. Computer programs in MATLAB are developed and the trusses are analysed for the member forces, deflections and natural frequencies. Results obtained from computer programs are also checked using ANSYS software.
3.4 RELIABILITY ANALYSIS

In the reliability analysis, performance function in the form of margin of safety, and two failure modes namely yielding and buckling in terms of force are considered. Prior to reliability estimation, sensitivity analysis is carried out to know the contribution of each of the input variables towards the safety of the truss. Then the reliability index for each member of all the trusses before and after posttensioning are estimated using the following probability and fuzzy based methods and the corresponding probability of failure is calculated.

1. First-Order Second-Moment (FOSM) Method
2. Rosenblueth’s Point Estimate Method (RPEM)
3. Advanced First-Order-Second-Moment (AFOSM) Method
4. Fuzzy Point Estimate Method (FPEM)
5. Hybrid analysis

Computer programs using MATLAB are generated for the sensitivity analysis and reliability analysis.