place; dry it carefully before storing. If possible, store fiber rope on gratings or in some other manner that will allow circulation of air through the coil. Wire rope should be coiled on a spool for storage and should be properly tagged as to size and length. It should be stored in a dry place to reduce corrosion, and kept away from chemicals and fumes which might attack the metal. Prior to storage, wire rope should always be cleaned and lubricated. If the lubricant film is applied properly and the wire rope is stored in a place protected from the weather, corrosion will be virtually eliminated. Rusting, corrosion of the wires, and deterioration of the fiber core sharply decrease the strength of wire rope.

Section II. CABLE SELECTION

18. Design Considerations

The following factors must be considered in selecting cable size.

a. Horizontal distance between towers or spans.
b. Difference in elevation between towers or slope.
c. Maximum allowable deflection.
d. Length of cable between towers.
e. Weight per foot of cable.
f. Maximum load to be supported.
g. Safety factors. For suspension bridges use 4, for cableways use 3.5.

h. Wind and ice loadings and temperature changes. In most climates these will have a nominal effect and may be disregarded but must be included where extreme conditions occur.

19. Analysis

When a cable is supported at each end and allowed to hang freely under its own weight, it forms a curve which is part of a catenary. Hauling on the ends of the cable will reduce the amount by which it sags. Therefore, the tension in the cable and the amount of sag bear a direct relation. When a load is added to the cable, such as by suspending a trolley from it, either the tension in the cable or the sag, or both, are increased. For purposes of analysis, the computations are simplified by assuming that uniform loading (the weight of the cable) is distributed horizontally and that the cable assumes a parabolic arc. The formulas used are for level spans anchored at both ends. This simplification will produce answers sufficiently accurate for normal work without making the computations laborious. Two conditions may be involved. A uniformly loaded cable, and a uniformly loaded cable (its own weight) with a concentrated load. The first condition applies for suspension bridges or unloaded cableways, and the second for loaded cableways.

a. Uniform Load. In a level span uniformly loaded (its own weight, only) and anchored (fig. 18), the following formulas apply:

\[ y_c = \frac{w_s^2}{8t} \]  
\[ t = \frac{w_s^2}{8y_c} \]  
\[ t' = t \sec \beta \]  
\[ \tan \beta = \frac{4y_c}{s} \]  
\[ L = s \left( 1 + \frac{8}{3} K^2 \right) \]

Where: \( w \) is weight in pounds per foot of cable, \( s \) is span in feet, and \( K \) is the sag ratio \( \frac{y_c}{s} \).

![Figure 18. Symbols for analysis of anchored level span uniformly loaded.](image)
b. Concentrated Load. In a level span uniformly loaded (its own weight) and anchored, with a concentrated load at the center (fig. 19) the following formulas apply:

Center deflection is: \[ y_c = \frac{s(2P + ws)}{8t} \]  
(6)

Horizontal tension is: \[ t = s \frac{(2P + ws)}{8y_c} \]  
(7)

Tension in cable is: \[ t' = t \sec \beta_i \]  
(8)

Cable slope is: \[ \tan \beta_i = \frac{P + ws}{2t} \]  
(9)

Where: \( w \) is weight in pounds per foot of cable, \( s \) is span in feet, and \( P \) is load concentrated at center in pounds.

![Figure 19. Symbols for analysis of anchored level span with concentrated load at center.](image)

20. Field Design

Table II, together with the graphs in appendix III, facilitate field design of expedient cableways and suspension bridges. Table II is used for suspension bridges and unloaded cableways and the graphs for loaded cableways. Examples of their use will be covered in later chapters.

a. Use of Table. Table II, Uniformly Loaded Cable Design Data, is used to determine the tension in a cable for a given span and loading. Column (1) is the sag ratio of deflection \( y_c \) over the span \( s \). Column (2) gives the tension in a cable when a uniform load, \( w \), is suspended on the horizontal span, \( s \). The tension is determined by multiplying the factor in column 2 opposite the appropriate sag ratio by \( ws \). This column is used for suspension bridge design. Column 3 is used to determine the tension in an unloaded cableway. The weight per foot of cable \( w' \), and the span \( s \), are multiplied times the factor opposite the appropriate sag ratio to obtain the tension in the cable. Column 4 is used to determine the length of cable between supports by multiplying the span \( s \), times the factor opposite the appropriate sag ratio.

<table>
<thead>
<tr>
<th>(1) Sag ratio ( K )</th>
<th>(2) When weight per foot of span is known ( t' = w's ) (factor)</th>
<th>(3) When weight per foot of cable is known ( t' = w's ) (factor)</th>
<th>(4) To get length multiply span by factor ( L = ax ) (factor)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2.60</td>
<td>1.050</td>
<td>1.004</td>
</tr>
<tr>
<td>7</td>
<td>2.14</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>8</td>
<td>1.64</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>9</td>
<td>1.48</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>10</td>
<td>1.35</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>11</td>
<td>1.24</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>12</td>
<td>1.16</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>13</td>
<td>1.08</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>14</td>
<td>1.02</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>15</td>
<td>.97</td>
<td>1.004</td>
<td>1.004</td>
</tr>
<tr>
<td>20</td>
<td>.80</td>
<td>1.004</td>
<td>1.004</td>
</tr>
</tbody>
</table>

b. Use of Graphs. Each graph in appendix III covers a specific slope ratio and sag ratio. Plotted on the graphs are lines indicating acceptable upper limits for track cable and haul rope loading. On a given graph, select the point which has an abscissa equal to the span in feet of the planned cableway. A vertical line through this point will cut the lines of track cable size at ordinates indicating maximum
allowable payload for that size cable. The remaining two graphs are for obtaining ratios of unloaded to loaded sag and tension. If the computation in paragraph 19b is used to determine loaded deflection (sag) at center, the ratios in the graphs can be applied to determine the unloaded or erection sag. If the loaded tension is determined from 19b, the ratios can be applied to determine unloaded or erection tension. This may be needed in order to use a tensiometer to set initial installation tension.

21. Haul Rope

The formulas in paragraph 19b use the symbol P for the load in pounds concentrated on the track cable at the center. Since the haul rope is attached to the carriage, a portion of the weight of the haul rope is included in this load. The tension in the haul rope depends on its weight and sag ratio, the position of the carriage in the span, and the amount of resistance to motion offered by the carriage and payload. Because all of these factors depend on, or affect, the track cable size, the necessity for computation has been eliminated by stipulating on the graphs the haul rope size applicable to a specific track cable.

22. Introduction

Towers for the medium cableway and light aerial tramway M2 are prefabricated and only assembly is required at the site. Single standing trees can usually be used as towers for the casualty evacuation set. For the pioneer light cableway M1, expedient cableways, tramways, and some suspension bridges, towers must be constructed. Terminal tower construction for a cableway, tramway, or toboggan installation is identical. Intermediate towers are constructed for a tramway but are not used for a cableway or a toboggan hauling unit. After the planning of type of installation is completed and a decision has been reached as to number and height of towers, individual tower construction proceeds. At each tower location the type of tower most suited to the location is built.

23. Saddles

For heavy cables or long spans, saddles may be required to protect the timber crossmembers. The saddles may be fabricated from sheet steel or pipe. Several examples are shown in figure 20. The strap shown in (1), figure 20 can easily be fabricated from strap steel. It can be indented to position and steady the cables. A heavier plate and saddle block combination is shown in (2), figure 20. The cable is held in place by only partially driving the nails on either side of the cable. The saddle block and plate can be used on flat timbers to allow for curvature of the cable. (3), Figure 20 illustrates a saddle prefabricated from pipe. It can be used where several cables or a heavier cable is required. Saddles fabricated from ½-inch steel plate are sufficient for cables up to 1½-inch diameter.

24. Tower Erection

Members can be lifted into place by manpower for low towers. When a crossmember is to be lashed to two standing trees at a level too high for it to be erected by lifting it into place, tackle can be
CHAPTER 4
EXPEDITED CABLEWAYS

Section I. DESIGN

40. Requirements

In order to select a cable for a cableway, certain conditions must be known—the payload to be transported, the span, and the maximum allowable deflection. The span and allowable deflection may be determined from a profile as discussed in paragraph 9. From the maximum allowable deflection, the possible sag in the cable may be determined. In selecting a cable, a cable size must first be assumed, and the calculations performed. If the results are unsatisfactory, then a new cable size is assumed and the calculations again performed.

41. Cable Selection by Formula

a. To select a cable size, formulas 7, 8, and 9 (para. 19b) are used.

Example:

A 1,000-pound payload is to be transported across a 500-foot gap. The maximum allowable deflection is 25 feet at the center. In order to use the formulas, a cable size and type must be assumed. From table XVIII, appendix II, select a 6 x 19% -inch diameter improved plow steel (IPS) wire rope. The breaking strength is 10.8 tons and the weight per foot is .40 pounds. Since a payload of 1,090 pounds is desired, a carrier and haul rope weight must be included in the P. In this example, assume 100 pounds. Then \( P = 1,100 \) pounds. To find horizontal tension, apply formula 7:

\[
t = \frac{500(2(1100) + .4(500))}{2(200) + 200}
\]

\[
t = 6,000 \text{ pounds}
\]

To find \( \beta_i \), apply formula 9:

\[
\tan \beta_i = \frac{P + ws}{2t} = \frac{1100 + 200}{2(6000)} = .108
\]

\[
\beta_i = 6^\circ 10'\]

To find cable tension, apply formula 8:

\[
t' = t \sec \beta_i
\]

\[
t' = (6000)(1.006)
\]

\[
t' = 6,050 \text{ pounds}
\]

The allowable tension in the cable is the breaking strength divided by the safety factor or—

\[
t \text{ allowable} = \frac{BS}{3.5} = \frac{10.8(2000)}{3.5} = 6,200 \text{ pounds}
\]

The ½ -inch cable is within the allowable tension and therefore can be used. If the allowable tension was less than the tension in the cable, a larger size would be assumed and the computations redone. If the allowable tension was considerably greater, then a smaller size could be assumed.

b. A simplified formula which can be used to determine the safe load on a cable where the sag is 5 percent is—

\[
SL = \frac{BS}{5(SF)} - \frac{DL}{2}
\]

Where:

\( BS = \) Breaking strength of cable

\( SF = \) Safety factor

\( DL = \) Dead load on weight of the cable per foot times the span

\( SL = \) Safe load

The weight of the carrier and haul rope must be subtracted from the safe load to determine the payload.

42. Field Design of Cable With Graphs

To facilitate cable selection using the graphic method, a profile of the centerline similar to figure 42 should be made. In order to determine the allowable sag, formula 10 (para. 19c) is used.

Example:

A payload of 2,000 pounds is to be transported over the 1,000-foot distance shown in figure 42. From the profile, the vertical difference in elevation between towers is 280—80—200 feet. The percent slope is expressed as \( 100 \left( \frac{2}{2} \right) \) or \( 100 \left( \frac{200}{1,000} \right) = 20 \) percent. The elevations most likely to give trouble with the clearance are B and D. Assuming a sag ratio of 5 percent, a tentative sketch of the cableway can be drawn (fig. 43). The deflection at the center \( (y) \) will be 0.05 \( (1,000) = 50 \) feet. Using formula 10, the deflection at B is—

\[
y = \frac{4(50)}{(1,000)^2}[1,000(200) - (200)^2]
\]

\[
y = 32 \text{ feet}
\]

The distance from the horizontal to the chord at B is equal to \( h \left( \frac{x}{s} \right) \) or 200 \( \left( \frac{200}{1,000} \right) = 40 \) feet. Adding the two distances and subtracting the total from the elevation of 280 feet leaves 208 feet, which clears ground B by 98 feet. A similar check at D shows a clearance of 48 feet. Since this is more than is needed at either point, a greater sag can be allowed. Assume a 10-percent sag and recalculate. The
clearance at B is now found to be 9 feet. This is probably insufficient
to clear the carriage, but since the towers will probably be at least
10 feet high, this will provide a total of 19 feet, which is sufficient.
From appendix III, graph number 5 (fig. 153) covering a 10 percent
sag and 20 percent slope, the vertical line for 1,000 feet span cuts the
line for ¾-inch cable at 3,050 pounds payload and the ¼-inch cable
line at 1,825 pounds payload. To use the intended 2,000 pounds
payload, the ¾-inch cable must be used, but the payload can be increased.
If 1,825 pounds is sufficient payload, the ½-inch track cable can be
used. The haul rope must be ¾-inch wire rope in either case.

![Diagram of field profile for example computation](image)

**Figure 42. Field profile for example computation**

![Diagram of tentative sketch of proposed cableway](image)

**Figure 43. Tentative sketch of proposed cableway.**

43. Haul Rope

There are three general methods of using a haul rope (fig. 44). In
a skyline installation, the haul rope leads from the upper terminal to
the carriage. The carriage is hauled up by the haul rope and allowed
to move back down by gravity. If a second haul rope is added from
the carriage to the lower terminal, the haul rope at one tower is paid
out while the other end is used to pull the carriage. In the third

![Diagram of haul rope arrangement](image)

**Figure 44. Diagram of haul rope arrangement.**
method, a continuous haul rope is used. It leads from the upper end of the carriage around a snatch block at the upper tower and back to the lower terminal, where it passes around the drive spool of the power unit and back to the lower end of the carriage. When the power unit is operated, the carriage is moved in the direction of the rope.

44. Carriage

a. Requirements. The principal requirement for the carriage is that it should provide a means of supporting a load on sheaves to roll along the track cable. For expedient construction, the payload for which the cableway is designed will dictate the amount of simplification possible. In some cases, for light loads, a single snatch block may be adequate. If the towers are very high, the carriage will probably pass considerably above the loading and unloading points. In such a case it is necessary to rig a tackle and fall line beneath the carriage to raise and lower the load at these positions. If the fall line is secured at the upper terminal (fig. 45), leads to the carriage and over a sheave down to a fall block, and back up over a sheave on the carriage to a power source (hoist unit) at the lower terminal, it provides a simple and convenient method of hoisting and lowering loads. The hoist unit at the terminal is operated to raise or lower the load, but the load will remain in the same relative position beneath the carriage as the carriage moves from terminal to terminal.

b. Blocks. Heavy duty blocks and sheaves are included in the issue sets. For expedient cableways, heavy duty blocks may not be available. Numerous attempts to use standard construction blocks in expedient cableways have been unsuccessful. This is very heavy duty use which tends to wear the blocks excessively. If the sheave is removed and reamed to permit insertion of a bushing of bearing bronze, most of the trouble will be eliminated. In any case, the blocks must be well lubricated. If no grease fitting is on the block,
CHAPTER 5
SUSPENSION BRIDGES

Section I. DESIGN FACTORS

58. Introduction
As previously stated (para. 6), suspension bridges are limited to relatively light loads (personnel or light vehicles). Application of the following information will enable the selection of components, under various conditions, necessary to erect suspension bridges. Bridging for heavier loads requires more careful and complete computations and is beyond the scope of this manual.

59. Recommended Factors
Figure 52 illustrates the location of the various factors used in suspension bridge design.

a. Dip (y) and Sag Ratio \( \frac{y}{s} \). Dip and sag control the strength and stability of the bridge. The sag ratio varies from \( \frac{1}{4} \)th or 5 percent to \( \frac{1}{4} \)th or 16\% percent. If the main cables have a flat curve or low sag ratio, the bridge has more vertical stability, but cable stress is high and strong anchorages are required. If the sag ratio is high, there is less stress on the cable and the anchorages may be placed closer to the towers.

b. Camber (c). Camber allows for deflection of the bridge under load. It is the vertical distance from the top of the floorbeam in the middle of the span to a straight line drawn between the tops of the tower sills. A camber equal to 0.67 percent of the span length normally is used.

c. Cradle (k) and Flare (f). Cradle and flare help steady the bridge. Cradle is the lateral distance from the midpoint of one of the main cables to a straight line drawn between its points of support on the near and far shore towers. It is usually 1.25 percent of the half-span length. Flare is the lateral distance from the cable support on the towers to the cable at the anchorage. Flare is usually 2.5 to 3.5 percent of the horizontal backstay length (fig. 52).
60. Procedure

a. Design of a suspension bridge requires analysis of the following items.

(1) Load to be carried
(2) Panel length
(3) Floorbeams and stringers
(4) Stiffening truss
(5) Dead load
(6) Suspenders
(7) Main cables
(8) Towers
(9) Tower bracing and backstays
(10) Anchorages

b. The load to be carried is used to design a stiffening truss and floor system. The dead and live loads are then used to select suspenders and main cables, towers, and anchorages. The stiffening and floor truss should be designed first, and then the cables, towers, and anchorages selected. The design procedure of a light vehicle bridge will be followed as an example. A 300-foot bridge to carry a 4,000-pound load with a 10-percent sag ratio will be designed.

61. Loads

Loads to be used in designing a suspension bridge can be either a uniform load or a concentrated load. A uniform load condition may be considered, if five or more concentrated loads are carried on the bridge at one time. This simplifies design to a great extent. Impact loads will be considered in cable selection but may be disregarded for timber design. For suspension bridges, an impact load equal to the live load will be used. In designing the floor and siderail system, the dead load and live load are used. The dead load, live load, and impact are used for cable design.

Section II. FLOOR AND TRUSS DESIGN

62. Panel Length

A typical floor and truss section of a bridge is shown in figure 53. The truss helps spread the load over several panels and also stabilizes the bridge. For some very light footbridges, a truss may be omitted
with only a roadway and posts suspended from the main cables. A panel length must be assumed to enable selection of the components. Normally, panel length will be between 10 to 15 feet. A 10-foot panel usually is a practical length. Panels are numbered symmetrically from 0 at the center suspender outward to the towers as shown in figure 54.

63. Stringer Design

a. Table III can be used to select stringers. A uniform loading and an allowable stress of 1,000 psi are used for the table. If a concentrated load is used, half the load values are used. For other than an allowable stress of 1,000 psi, the load is multiplied by the allowable stress over 1,000. Given an available size of stringer, panel span, and load to be carried, the number of stringers required may be determined by dividing the value in column 5 by the span length in feet, multiplying by the allowable stress, and dividing by 1,000.

b. Example. A 4,000-pound concentrated load is to be carried on a 10-foot span by 6- by 6-inch planks, with an allowable bending stress of 2,400 psi, joining down column 1 to 4 x 6 and across to column 5, the allowable load for a 4 x 6 = 12,740 pounds. For a 10-foot span and a concentrated load:

\[
\frac{12740 \times 2400}{1000} = 1530 \text{ pounds per stringer.}
\]

Number of stringers required:

\[
\frac{4000}{1530} = 2.6 \text{ or } 3 \text{ stringers.}
\]

64. Floorbeams and Planks

a. The floorbeams transmit the loads from the stringers to the suspenders. Suspenders cables are wrapped around the floorbeams. The floorbeams are extended beyond the roadway so that knee braces may be used to support the sidetall posts. Table IV gives the size floorbeam to be used with various loads.

b. Floor planks act as the tread and spread the load to the stringers. For personnel 2-inch planking is sufficient. Vehicular loads will require 3-inch planking.

65. Sidetalls and Posts

On very light or short footbridges, sidetalls are not necessary. As the span increases and the load to be carried increases, sidetalls must be added to stabilize the bridge. On light footbridges, 2- by 4-inch posts and sidetalls can be used with single sidetalls being sufficient. Heavier vehicular bridges require 3- by 6-inch posts with double sidetalls and toe boards as shown in figure 53 should be used. Posts should be approximately 3 feet 6 inches long for safety and convenience.

<table>
<thead>
<tr>
<th>Nominal size in.</th>
<th>Actual size in.</th>
<th>Area of section</th>
<th>Weight per linear foot w=60 pounds per cable ft.</th>
<th>Maximum safe uniform load based on bending on 1-foot span ft=1,000 psf</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td>(5)</td>
</tr>
<tr>
<td>4 x 6</td>
<td>3 1/4 x 3 1/4</td>
<td>20.4</td>
<td>5.66</td>
<td>12,740</td>
</tr>
<tr>
<td>6 x 6</td>
<td>5 1/4 x 5 1/4</td>
<td>30.3</td>
<td>8.40</td>
<td>18,490</td>
</tr>
<tr>
<td>4 x 8</td>
<td>3 1/4 x 7 1/4</td>
<td>27.2</td>
<td>7.55</td>
<td>22,700</td>
</tr>
<tr>
<td>6 x 8</td>
<td>5 1/4 x 7 1/4</td>
<td>41.3</td>
<td>11.4</td>
<td>34,400</td>
</tr>
<tr>
<td>8 x 8</td>
<td>7 1/4 x 7 1/4</td>
<td>56.3</td>
<td>15.6</td>
<td>46,900</td>
</tr>
<tr>
<td>6 x 10</td>
<td>5 1/4 x 9 1/4</td>
<td>52.3</td>
<td>14.5</td>
<td>55,200</td>
</tr>
<tr>
<td>8 x 10</td>
<td>7 1/4 x 9 1/4</td>
<td>71.3</td>
<td>19.8</td>
<td>75,200</td>
</tr>
<tr>
<td>10 x 10</td>
<td>9 1/4 x 9/4</td>
<td>90.3</td>
<td>25.0</td>
<td>95,300</td>
</tr>
<tr>
<td>6 x 12</td>
<td>5 1/4 x 11 1/4</td>
<td>63.3</td>
<td>17.5</td>
<td>80,000</td>
</tr>
<tr>
<td>8 x 12</td>
<td>7 1/4 x 11 1/4</td>
<td>86.3</td>
<td>23.9</td>
<td>110,200</td>
</tr>
<tr>
<td>10 x 12</td>
<td>9 1/4 x 11 1/4</td>
<td>109.3</td>
<td>30.3</td>
<td>139,600</td>
</tr>
<tr>
<td>12 x 12</td>
<td>11 1/4 x 11 1/4</td>
<td>132.3</td>
<td>36.7</td>
<td>163,000</td>
</tr>
</tbody>
</table>

Table IV. Floorbeam Size for Given Load

<table>
<thead>
<tr>
<th>Load</th>
<th>Floorbeam cross section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foot troops with full pack</td>
<td>4 by 6 inches</td>
</tr>
<tr>
<td>3/4-ton truck with normal load</td>
<td>6 by 6 inches</td>
</tr>
<tr>
<td>3/4-ton weapons carrier with normal load</td>
<td>8 by 8 inches</td>
</tr>
</tbody>
</table>

66. Bracing

There are three types of bracing used on the truss of the suspension bridge (fig. 53). Saw tooth bracing helps to stiffen the truss and spread the load over several panels. For this use, 2- by 6-inch lumber
is satisfactory. Knee bracing is used to hold the posts and floorbeams. The floorbeams must be extended to allow for the knee braces. For knee bracing 2- by 4-inch material can be used. Sway bracing helps to stabilize the bridge laterally. On light bridges, heavy gage wire may be used with rack sticks as shown in figure 55. Heavier bridges require timber sway bracing as shown in figure 58.

67. Dead Load

a. Once the components of the truss and floor system have been selected, the dead load may be determined. The dead load is calculated in pounds per panel. From figure 53, the dead load per panel includes the following:

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 suspenders</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 floorbeam</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 stringers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 toeboards</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 side posts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20 floor planks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 knee braces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 braces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 to 4 sidetalls</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 curbs (if used)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cable clips and bands</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

b. Example (from table III for weight of lumber).

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 suspenders</td>
<td>10 ft @ .40 lb/ft</td>
<td>8 lb</td>
</tr>
<tr>
<td>1 floorbeam</td>
<td>6 x 6 x 10 ft @ 8.40 lb/ft</td>
<td>84 lb</td>
</tr>
<tr>
<td>20 deck planks</td>
<td>3 x 6 x 5 ft 10 in. @ 4.10 lb/ft</td>
<td>479 lb</td>
</tr>
<tr>
<td>3 stringers</td>
<td>4 x 6 x 11 ft @ 5.66 lb/ft</td>
<td>186 lb</td>
</tr>
<tr>
<td>4 toeboards</td>
<td>2 x 6 x 10 ft @ 2.54 lb/ft</td>
<td>102 lb</td>
</tr>
<tr>
<td>2 side posts</td>
<td>2 x 6 x 3 ft 10 in. @ 2.04 lb/ft</td>
<td>19 lb</td>
</tr>
<tr>
<td>2 knee braces</td>
<td>2 x 4 x 4 ft 1 in. @ 1.64 lb/ft</td>
<td>13 lb</td>
</tr>
<tr>
<td>4 braces</td>
<td>2 x 6 x 5 ft 8 in. @ 2.54 lb/ft</td>
<td>58 lb</td>
</tr>
<tr>
<td>4 sidetalls</td>
<td>2 x 6 x 10 ft @ 2.54 lb/ft</td>
<td>102 lb</td>
</tr>
<tr>
<td>2 curbs</td>
<td>4 x 4 x 10 ft @ 3.65 lb/ft</td>
<td>73 lb</td>
</tr>
<tr>
<td>clips</td>
<td>10 lb</td>
<td></td>
</tr>
</tbody>
</table>

\[
\text{Total load} = 1,134 \text{ pounds}
\]

<table>
<thead>
<tr>
<th>Load per suspender</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Dead load</td>
<td>1,134 pounds</td>
</tr>
<tr>
<td>Live load</td>
<td>4,000 pounds</td>
</tr>
<tr>
<td>Impact load</td>
<td>4,000 pounds</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load per suspender</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total load</td>
<td>9,134 pounds</td>
</tr>
</tbody>
</table>

70
From table XVIII, appendix II, for 1\(\frac{1}{8}\)-inch diameter improved plow steel 6 x 19 wire rope, the breaking strength is 16.6 tons.

The allowable then is \(\frac{(16.6)(2,000)}{5} = 6,640\) pounds

The next smaller size rope will not carry the required load; therefore, 1\(\frac{1}{8}\)-inch wire rope must be used.

70. Suspenders Length

a. In order to determine the effective length, or distance from main cable to floorbeam, of suspenders, the following formula is used:

\[
h = L + \left(\frac{n}{N}\right)^2 (C_0 + y)
\]

Where:
- \(h\) = effective suspender length
- \(L\) = effective length of center suspender
- \(n\) = panel point of suspender
- \(N\) = panel point of tower
- \(C_0\) = camber of the bridge in ft
- \(y\) = dip or sag of main cable in ft

b. Example. For panel point No. 5:

\[
\begin{align*}
L & = 2.5 \text{ feet} \\
n & = 5 \\
N & = 15 \\
C & = 2 \text{ feet} \\
y & = 30 \text{ feet}
\end{align*}
\]

\[
h = 2.5 + \left(\frac{5}{15}\right)^2 (2+30) = 6.05 \text{ ft}
\]

The cut length should include sufficient length to wrap around the floorbeams and form a loop to attach the suspenders to the main cable. An additional 5 to 6 feet added to the effective length is sufficient. The loop must have a thimble included to prevent shearing of the suspender cable.

71. Main Cable Design With Uniform Load

a. The main cables are designed using the formulas in paragraph 19 or table II. A uniform loading can be determined by dividing the load by the span.

b. Example. A bridge with a 300-foot span is to carry five 4,000-pound vehicles spaced evenly across the bridge. The uniform load is—

\[
w = \frac{(5)(4000)}{300} = 66.7 \text{ pounds/foot.}
\]

Using the live load and impact load to be carried, plus the dead load of the bridge as the total uniform load, a cable size is assumed and the calculations performed using formulas from paragraph 19a. A live load of 66.7 pounds, impact of 66.7 pounds, and a dead load of 113.4 pounds per foot, gives a total load of 255 pounds, per foot. Assuming a 10 percent sag ratio for a 300-foot bridge, the sag \((y)\) will be 30 feet. A 1\(\frac{1}{8}\)-inch diameter improved plow steel wire rope will be assumed. That weight per foot from table XVIII, appendix II, is 2.03 pounds per foot.

Total load = live load + impact load + dead load + main cable weight

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Live load</td>
<td>66.7</td>
</tr>
<tr>
<td>Impact load</td>
<td>66.7</td>
</tr>
<tr>
<td>Dead load</td>
<td>113.4</td>
</tr>
<tr>
<td>Main cable weight</td>
<td>2.03</td>
</tr>
<tr>
<td>Total load</td>
<td>254.9</td>
</tr>
</tbody>
</table>

Use 255 pounds per foot.

1. From formula 2, paragraph 19a, horizontal tension is—

\[
t = \frac{(255)(300)^2}{8(30)} = \frac{22,950,000}{240} = 95,600
\]

From formula 4, paragraph 19a,

\[
\tan \beta = \frac{4(30)}{300} = .4, \beta = 21^\circ 50'
\]

\[
\sec \beta = 1.077
\]

From formula 3, paragraph 19a, tension in the cables is—

\[
t^2 = (95,600) (1.077) = 103,000
\]

The breaking strength of 1\(\frac{1}{8}\)-inch IPS wire rope is 106,000 pounds. If four cables are to be used, the allowable tension with a safety factor of 4 is \(\frac{(4)(106,000)}{4} = 106,000\) pounds for 4 cables, or \(\frac{106,000}{4} = 26,500\) for one cable. The tension in the cables will be \(\frac{103,000}{4} = 25,750\) pounds per cable or within the allowable tension for 1\(\frac{1}{8}\)-inch IPS wire rope. The length of cable between supports will be from formula 5

\[
L = 300(1 + \frac{8}{3})(.1)^5 = 300(1 + .026)
\]

\[
L = 309 \text{ feet.}
\]

2. Using table II, for a 10 percent sag ratio in column 1; from column 2 for cable tension, the factor 1.35 is determined; from column 4 for cable length, the factor is 1.026. The tension and length are—

\[
t = (255)(300)(1.35) = 103,000\text{ pounds}
\]

\[
L = (300)(1.026) = 309 \text{ feet}
\]
72. Backstays

The portion of the main cable behind the towers or the backstay must be checked to insure that the maximum allowable tension of the cable is not exceeded. The tension in the backstay may be determined by multiplying formula 2 by the secant of the angle of the backstay with the horizontal. To have the equal tension in the cable on both sides of the tower the backstay angle (fig. 53) with the horizontal should be—

\[ \sec \alpha = \sqrt{1 + 16k^2} \]

Where \( k \) is the sag ratio \( \frac{Y}{s} \)

73. Tower Dimensions

a. Chapter 3 covered the various types of towers which can be used for suspension bridges. The tower height is determined by taking the sag ratio \( \frac{Y}{s} \), plus the percentage of camber \( c \) times the span, and adding the effective length of the center suspender.

b. Example. A 300-foot span, 10 percent sag ratio, .67 percent camber, and an effective length center suspender of 2½ feet.

\[
\text{Tower height} = 300(0.10 + 0.0067) + 2.5
\]

\[
= 300(0.1067) + 2.5
\]

\[
= 32.1 + 2.5 = 34.6 \text{ feet}
\]

This is the distance from the top of the sill to the main cable. The width of the tower is determined by the load to be carried with a minimum of 4 feet for personnel.

74. Post Size

a. The post size of the towers is determined by the vertical reactions of the main cables. For simplicity, a 12- by 12-inch post will carry loads up to 2½-ton truck. If, however, the minimum size that can be used must be determined, table V and table XVII, appendix II may be used. From table XVII, appendix II, the maximum vertical reaction for a particular sag ratio, slope and tieback can be determined. Using this value, a post size may be determined from table V.

b. Example: For two 1½-inch cable, 10 percent sag, 0 percent slope, 1 to 2 tieback, and a 34.6-foot high tower, what size post can be used? From table XVII, appendix II, the load for two 1½-inch cable, 10 percent sag, 0 percent slope, 1 to 2 tieback is 19,400 pounds for each cable or 38,800 for two cables. First a post size must be assumed and the \( \frac{1}{d} \) length in inches must be determined and the actual area in square inches. Assume a 10-by 10-inch post of a material with an \( E \) (modulus of elasticity) of 1,600,000.

\[
\frac{1}{d} = \frac{(34.6)(12)}{10} = 41.6
\]

Area = 90.3 square inches.

From table V, for \( \frac{1}{d} = 45 \) and \( E = 1,600,000 \), the allowable stress is 356 pounds per square inch.

(356)(90.3) = 32,100 which is insufficient.

Assuming a 10- by 12-inch timber can be used, the \( \frac{1}{d} \) will be the same, but the area will be 109.3. Therefore, for a 10- by 12-inch timber (356)(109.3) = 38,900 which is sufficient.

A 10- by 12-inch post can be used. Bracing of the towers should be 2-inch lumber. Saddles and saddle blocks as covered in paragraph 23 and figure 20 should be placed on top of the posts to protect them from the cables.

| Table V. Working Stress for Timber Columns Compression Parallel to Grain* |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                |                |                |                |                |                |                |                |
| \( E \)        | 15 or less     | 20              | 25              | 30              | 35              | 40              | 45              |
| 1,000,000      | 1,800          | 1,125           | 720             | 500             | 368             | 282             | 222             | 180             |
| 1,100,000      | 1,800          | 1,230           | 790             | 550             | 404             | 309             | 245             | 196             |
| 1,200,000      | 1,800          | 1,350           | 862             | 600             | 441             | 337             | 267             | 216             |
| 1,300,000      | 1,800          | 1,460           | 930             | 650             | 479             | 366             | 290             | 234             |
| 1,400,000      | 1,800          | 1,575           | 1,010           | 700             | 515             | 396             | 311             | 252             |
| 1,500,000      | 1,800          | 1,675           | 1,080           | 750             | 550             | 422             | 333             | 270             |
| 1,600,000      | 1,800          | 1,760           | 1,150           | 800             | 588             | 450             | 358             | 298             |
| 1,700,000      | 1,800          | 1,840           | 1,220           | 850             | 624             | 479             | 378             | 305             |
| 1,800,000      | 1,800          | 1,900           | 1,295           | 900             | 660             | 507             | 400             | 324             |
| 1,900,000      | 1,800          | 1,960           | 1,370           | 950             | 696             | 534             | 422             | 342             |
| 2,000,000      | 1,800          | 1,960           | 1,440           | 1,000           | 735             | 562             | 444             | 360             |

* Based on \( \frac{F}{A} = \frac{45 E}{(L/d)^2} \)

75. Anchorages

Types of anchorages were covered in chapter 3. The tension that must be withstood by the anchorages are the same as the backstay tension as determined in paragraph 72. A deadman type of installation for the main cables is usually the most satisfactory. If the back guy is anchored to the same deadman, the pull must also be included in determining the holding power required. More detailed coverage on anchorages is contained in TM 5–725.
Section IV. CONSTRUCTION PROCEDURE

76. Site Layout

The site for the bridge must have sufficient area available for assembly of the towers and hangers. Normally, stadia distances provide sufficient accuracy. The distance between towers must be divisible by 20 if 10-foot panels are to be used. The tower sites must be checked to insure that the towers will be perpendicular to the centerline of the bridges. The distances to the deadmen should be measured and marked.

77. Erection Cableway

To facilitate suspension bridge construction, a cableway should be erected within 100 feet of the site of the bridge. The cableway is used to transport personnel and materials across the gap in order to allow construction of the bridge from both banks simultaneously. Once the materials and personnel are across and the main cables erected, the cableway may be dismantled and the wire rope used as guy lines if needed.

78. Erection of Towers

After the sites for the towers have been marked, the area for the sills must be leveled. If footings are needed, the cleared foundation area must be large enough to accommodate them. As the sills are being prepared, the towers are assembled and the deadmen prepared. The towers are erected and braced with side and back braces. Methods for erecting heavy towers can be found in chapter 3.

79. Placing Main Cable

When the towers are erected and deadmen in position, the main cables are placed. A lead line is attached to the main cable and carried across the gap by the cableway. If the main cables are on reels, these are placed behind the towers and the cable guided over the near tower and pulled across to the far tower. The cables are then passed around the deadmen and temporarily clipped in place. A ratchet chain hoist is used to set the cable to the proper sag as covered in paragraph 51. When the cable is properly set, the clips are set and tightened.

80. Assembling Hangers

The floorbeams, posts, knee braces, and suspender cables are assembled together to form hangers (fig. 57). After the posts, braces, and floorbeams are assembled, the suspender cables are wrapped once around the floorbeams and then clipped. The floorbeam should be notched to avoid sharp bends in the cables. The effective length of the suspender is then measured and a thimble installed on the cable and the cable clipped. The effective length is the length when the cable is taut and should be rechecked when the bridge is complete.

81. Erection Scaffold

An erection scaffold is used to place the hangers (fig. 58). Hangers are placed simultaneously from both sides of the bridge. The assembled hangers are given to two men on the erection scaffold who fasten the suspenders to the main cable and then slide them to the proper location (fig. 59). The clips are not tightened until the stringers are set (para. 80).

82. Placing Stringers

When the first hanger is positioned, the stringers are then placed and nailed to the sill and floorbeams (fig. 60). The suspenders are made vertical and the cable clips tightened. The next hanger is brought forward and the procedures repeated with the stringers nailed to the floorbeams. Cleats are nailed to the underside of the stringers to keep them in place on the floorbeams.