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gauge pressure but not the tension of the strand in the product. The stress limits for strand still apply in this case, and, if stress cannot be held below the limit, friction points must be removed from the setup.

5.3.13 Final Tensioning of Straight Strands

For single strand tensioning, after application of the initial force and establishment of reference marks for measuring elongation, the full strand force shall be applied. Strand force shall be determined in accordance with Article 5.2.2 for every strand. An exception is the case of a completely open bed with no bulkheads or other possible sources of friction. In such instances, strand force shall be checked on the first and last strands tensioned and at least 10% of the remaining strands.

For multiple-strand tensioning, following application of initial force and seating of each strand on the anchorage header, reference marks shall be established for measuring elongation and seating. Reference marks for seating shall be made by marking a straight line across the strands in each row and along the face of the anchorage. For uniform application of force to strands, the face of anchorage at final load shall be in a plane parallel to its position under initial force. Parallel movement shall be verified by measurement of movement on opposite sides of the anchorage and a check of its plumb position before and after application of the final force.

The final force on the strand shall not exceed 80% of the specified tensile strength of the strand after seating.

C5.3.13 Final Tensioning of Straight Strands

Straight strands are the most straightforward tensioning setup. Care is required to be sure a valid starting point is established by pulling to initial force for elongation measurement and that all appropriate corrections are made in the setup calculations.

Since elongation is measured by travel of the anchorage, a reference mark is usually made at the face of the anchorage on each side of the bed.

5.3.14 Final Tensioning of Harped Strands

Harped pretensioning strands may be finally tensioned by either of the following:

1. Partial tensioning and subsequent strains.
In this method, the strands are tensioned in a straight position or on a partially harped trajectory, to a pre-determined intermediate force value between initial and final force. The final force is induced by strains resulting from lifting or depressing strands at all other points of change in strand alignment. Final position and force shall be offset symmetrically about the center of the setup to distribute friction evenly. Force and elongation shall be measured as specified in Article 5.2.2 for

C5.3.14 Final Tensioning of Harped Strands

1. Partial tensioning and subsequent strains.
This method requires a carefully predetermined layout of members on the bed and definite positions of lifting and hold-down devices in order to compute the changes in the length of the strand caused by placing strand into the final harped position. This method can be used with either single strand or multiple strand tensioning.

The strand over most of the bed length will be tensioned to the intermediate value in either a low

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the intermediate force value. Suitable force measurements at each anchorage at each end of the bed shall verify calculated strand forces within 5%. This verification shall be made prior to first casting for any new design or new strand pattern, or with new bed equipment; thereafter, periodic checks are recommended.

2. Final tensioning in harped position.
In this method, the strands are tensioned to final value in the harped position for the full length of the bed. The strands shall pass over devices, which effectively minimize friction at all deflection points. Force and elongation shall be measured as specified in Article 5.2.2.

When final tensioning is done by jacking strands from one end of the bed, even when that tensioning is within tolerance, force shall be measured on at least two strands at the far end. This force shall not be below the theoretical values by more than 5%. If the theoretical elongation has not been attained at one end of the bed when the force, as indicated by pressure gauge or load cell, is exceeded by 5%, the strand shall be jacked from the other end of the bed to the theoretical elongation. If this requires an overstress as indicated by the gauge in excess of 5% overload, the number of deflection points on the bed shall be reduced until the elongation can be attained with not more than 5% overload or the hardware shall be improved to reduce friction. Remaining deflection points shall then be achieved as outlined in Article 5.3.14(1).

If elongation is not obtained within 5% tolerance when theoretical force has been applied, the force may be temporarily increased to overcome friction. Provisions shall be made to reduce the force on the strand to within 5% of the theoretical force, not to exceed 80% of the specified tensile strength of the strand, at final seating.

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position or a high position. When tensioned in the low position, the strand is held down at low points within the member and lifted between members. When tensioned in a high position, the strand is held up between members and forced down at points within the member.
To distribute friction and any restraint at lifting and hold-down devices, the ideal method is to lift or depress simultaneously at all points on the bed. If this is impractical, the lifting or depressing shall commence at the point nearest the center of the bed, and then progress alternately at points equidistant from the center to the ends of the bed.

2. Final tensioning in the harped position.
Support and hold-down devices should be of sufficient rigidity and have adequate support so that the position of strand will remain substantially unchanged under the induced forces in this method.

Procedures should be established to minimize friction at both high and low control points of the strand. The use of pin and roller assemblies generally provides the best method of reducing friction at hold-up and hold-down points. Extra caution should be observed in tensioning harped strands to avoid undue exposure to safety risks of the personnel involved.

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5.3.15 Equal Distribution of Force in Harped Strands

Distribution of force in strands throughout the length of a bed can be determined by measuring elongation of a predetermined length of strand in each member. This procedure shall be employed for the initial setup of a newly installed bed if the bed differs substantially from other beds at the plant or if harping hardware or procedures differ from those normally used.

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C5.3.15 Equal Distribution of Force in Harped Strands

Friction at each of the deflecting devices resists some of the force exerted in tensioning harped strands. The force applied to the strand is therefore decreased at each successive point of deflection away from the source of jacking. For this reason, this procedure is to be used when a new casting facility is first installed if it differs substantially from those already in use. For example, a new bridge beam bed to make Type IV beams should be evaluated when first set-up if it is the first of its kind at the plant. If the plant has already been manufacturing Type III beams with the same or similar harping hardware and procedures, the new bed can be considered additional capacity of similar products and not substantially different. Force distribution should be checked when tensioning procedures change. An example is when strands were previously tensioned straight and subsequently harped and the procedure changes to tensioning in the final fully harped position.

This procedure is not intended to apply to regular, routine changes in form configuration or product layout within the bed.

Measurements of strand elongation at locations within the element are difficult to perform. Form, reinforcing, and equipment restrict access. Evaluation of a measuring tape or bar cannot be considered reliable if read closer than to the nearest one eighth of an inch. The tolerance between measured and calculated elongation should be 5% rounded up to the nearest 1/8 in. For example, if the desired elongation of a 20-ft section of strand is 1-1/2 in., then the acceptable range of measurements should be from 1-3/8 in. to 1-5/8 in. (±1/8 in.). This is because 5% of 1-1/2 in. is 0.075 in. Rounding up to the nearest eighth results in a value of 1/8 in. Measuring bars or tapes should be maintained at or near the temperature of the strand to eliminate thermal differences in measurements. It must be noted that this procedure has significant inherent safety risks due to the necessity of having to work in direct contact with tensioned and harped strand. Therefore, it should be accomplished only when considered necessary as required above. Great care must be exercised and appropriate safeguards applied.