Until the late 1970s, most prestressing strand was stress-relieved. Today, low-relaxation strand is almost universally used. Low-relaxation strand as specified in ASTM A416/A416M differs from stress-relieved strand in two respects: first, it meets more restrictive relaxation loss requirements, and second, the minimum yield strength at an extension of 1% is 90% of the specified minimum tensile strength, compared to 85% for stress-relieved strand. The load tables in Chapter 7 of this design manual are based on low-relaxation strand.

Architectural precast concrete is sometimes prestressed. Prestressing tendons can be either pretensioned or post-tensioned depending on the facilities available at the plant.

Prestressing wire or bars are occasionally used as primary reinforcement in precast elements. The properties of prestressing strand, wire and bars are given in Chapter 8 of this design manual.

Deformed reinforcing bars and wires

Hot-rolled deformed reinforcing bars are required to meet one or more of the following standards: CSA G30.18 or ASTM A82, A184, A185, A496, A497, A704 or A775. These specifications cover both weldable steel and regular steel. Bars are usually specified to have a minimum yield strength of 400 MPa (Grade 400R and 400W). Grade 300R bars may be available only in sizes 10M and 15M. Grade 500R and 500W steel are also available. The maximum yield strength of 400W and 500W bars is limited to 525 MPa and 625 MPa, respectively, to ensure ductile behaviour. The W in the grade designation indicates a weldable bar with controlled chemistry and a maximum carbon equivalent of 0.55%.

Some precast plants use weldable steel (400W) for all reinforcement. Advantages are a reduction in inventory and the possibility of errors. Another advantage is that bar ends can be used for welded connections instead of being scrapped. See CSA W186 for the welding of reinforcing bars.

For a reinforcing bar to develop its full strength in concrete, a minimum length of embedment or a hook is required. Information on bar sizes, bend and hook dimensions and development lengths are given in reference [13] and Figs. 8.2.6 to 8.2.10.

Deformed wire can be used in small, thin members when reinforcement smaller than 10 M bars is used to meet concrete cover and/or small bend radii requirements. Deformed wires should conform to ASTM A497 – see Figures 8.2.11 and 8.2.14.

Welded wire reinforcement

Welded wire reinforcement is prefabricated reinforcement consisting of parallel cold-drawn wires welded together in square or rectangular grids. Each wire intersection is electrically resistance-welded by a continuous automatic welder. Pressure and heat fuse the intersecting wires together and fix all wires in their proper position.

Smooth wires, deformed wires or a combination of both can be used in welded wire reinforcement. Wire sizes are denoted by their area in mm^2 prefixed with the letters MW for smooth wire or MD for deformed wire. Welded wire reinforcement styles are designated by the spacing and wire sizes as shown in Figures 8.2.11 to 8.2.14. For one way welded wire reinforcement, the area of the smaller wires shall not be less than 40% of the area of the larger wires.

Smooth wire reinforcement bonds to concrete by the mechanical anchorage at each welded wire intersection. Deformed wire reinforcement utilizes wire indentations plus welded intersections for bond and anchorage. Many plants have equipment for bending welded wire reinforcement into various shapes such as U-shaped stirrups, four-sided cages, etc. Designers are cautioned to ensure that welded wire reinforcement meets the ductility requirements of CSA A23.1 when used as shear reinforcement.

Protection of reinforcement

Reinforcement is protected from corrosion by embedment in concrete. A protective iron oxide film forms on the surface of bars, wires and tendons as a result of the high alkalinity of the cement paste. As long as the alkalinity is maintained, this film is effective in preventing corrosion.

Example 4.17 *Column Connection; Baseplate and Anchor Bolt Design*

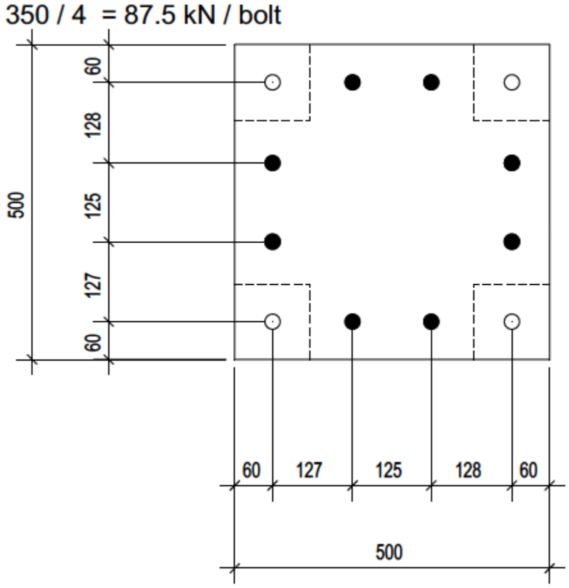
Given:
500 mm square column anchored with threaded rod anchor bolts. The column is assumed pinned at the base; no tension requirements other than structural integrity (CSA A23.3 16.5.2.4)

$f'_{c\ (column)} = 35$ MPa
$f_{y\ (baseplate)} = 300$ MPa

Problem:
Determine anchor bolts size and baseplate size.

Solution:
Anchor bolts: structural integrity

$T_r \geq 1.4\ Ag = 1.4\ (500 \times 500) / 1000$
$= 350$ kN
$350 / 4 = 87.5$ kN / bolt



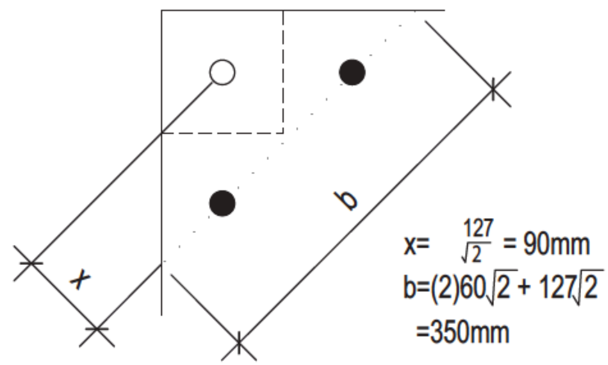
Try 24 mm ASTM A36 bolts

$T_r = \phi_{ar} A_n F_u$
$= 0.67\ [\pi/4\ (24 - 0.938x3)^2]\ 400 / 1000$
$= 94.5$ kN > 87.5 OK

Check anchor pullout strength in footing.

Baseplate:

Check one bolt in tension:



$t = \sqrt{(T_f 4x/ \phi\, sfyb)}$
$= \sqrt{[(87.5 \times 10^3 \times 4 \times 90)/(0.9 \times 300 \times 350)]}$
$= 18.25$ mm

Use plate 500 x 500 x 19 mm

Check plate anchors into precast column.

4.16 WELDING

4.16.1 Welding of Steel Plates

The welding of steel plates is governed by CSA Standard S16. Typically precast connections are welded using fillet welds. See Figure 4.16.1 for capacities. See CISC [6] for more information.

4.16.2 Welding of Reinforcing Bars

Welding of reinforcement is a practical method of developing force transfer in many connections. Typical reinforcing bar welds are shown in Figure 4.16.2.

The welding of reinforcing bars is governed by W186.

Fillet weld size (mm)	Factored resistance V_r (kN/mm)
5	0.78
6	0.93
8	1.24
10	1.55
12	1.87
14	2.18
16	2.49

Note: E49xx electrode
S16 Clause 13.13.2.2
$V_r = 0.67\phi_w A_w X_u (1.0 + 0.5\sin^{1.5}\theta)$
$\phi_w = 0.67$
A_w = effective throat area of weld
X_u = ultimate strength as rated by the electrode classification number
$(1.0 + 0.5\sin^{1.5}\theta)$ has been conservatively taken as equal to 1

Figure 4.16.1 *Factored shear resistance of equal leg fillet welds for each mm of weld length*

Weldability of a bar is a function of its carbon equivalent. Carbon equivalents should be limited to:

0.55% for 20M and smaller bars,
0.45% for 25M and larger bars

Carbon equivalent, C.E., is calculated using:

$$C.E. = \%C + \frac{\%Mn}{6} + \frac{\%Ni}{20} + \frac{\%Cr}{10}$$

Rebar should not be welded when mill reports are not available or when the chemical composition of the bars is not known.

Common considerations in the design and detailing of welded bar connections are:

1. Welding should not be performed within 50 mm or two bar diameters of a bent portion of a bar, whichever is greater, and
2. Allowance should be made for the thermal expansion of steel to avoid concrete spalling or cracking when welding bars to structural shapes that are embedded in concrete.

When item 2 is a concern, adequate confinement reinforcement should be provided in the immediate area or a compressible material should be placed around the steel plate to allow for expansion.

The size of fillet welds for full capacity of a reinforcing bar welded to a plate is shown in Figure 4.16.3. The required length of a flare bevel groove weld, to develop the full strength of the reinforcing bar, is shown in Figure 4.16.4. Reference should be made to W186 for further background information on the design and detailing of welded bar connections.