ATTACHMENT 2

Capacity Procedure

Methodology

The superstructure must have sufficient capacity to resist the longitudinal and transverse seismic overload demands. Sufficient amounts of mild steel and shear reinforcement shall be provided to satisfy both strength and curvature requirements, for either seismic or vehicle overloads.

A stress-strain compatibility analysis[8] is required in order to assess member strength and curvature capacities. The method is similar for both a prestressed or reinforced concrete section. Material relationships are established to allow the monitoring of stresses and strains. The neutral axis location is varied until the force equilibrium condition is satisfied. Equilibrium is reached when either the ultimate concrete, mild steel or prestressing strains are reached (See Figure 5). The corresponding nominal moment capacity and curvature are then determined. This basic methodology is incorporated into the Caltrans CONC[9], PSSEC[10], and xSECTION[11] computer programs. The empirical relationships in BDS[12] Section 9.17 do not accurately reflect prestress member strength or address the issue of bonded tendon ductility, and therefore, shall not be used in assessing member capacity.

Material Models

Caltrans BDS[12] allows the use of any plastic concrete stress distribution model if it can be shown to result in reasonable predictions of ultimate strength.

The most common stress distributions used in strength design are parabolic, trapezoidal, and rectangular. For simplicity, an equivalent rectangular (Whitney) stress block is typically used in design practice to represent the more exact concrete stress distributions. The CONC[9] computer program (based on Load Factor Design methodology) incorporates this practice along with a simple bilinear stress-strain relationship for reinforcing steel and the PCI[4] material model for prestressing steel to assess member nominal strength.

More complex material relationships are used in the PSSEC[10] computer program and are described in the SDC[2] Section 3.2. The user has a choice of unconfined concrete models as well as more detailed reinforcing steel models incorporating the effects of strain hardening. However, unlike the CONC[9] program, a full range of both strength and curvature capacities are addressed in the PSSEC[10] program.

Mild Steel Reinforcing Limits

At locations where additional longitudinal mild steel reinforcement is not required by analysis, it is recommended that as a minimum, an equivalent of #25 @ 300 (maximum bar spacing not to exceed 300) should be placed in the top and bottom slabs at the bent cap. The reinforcement should extend beyond the inflection points (for seismic loads) of the moment demand envelope. This recommendation will increase the ductility of the section and provide improved serviceability, and provide resistance for unanticipated load combinations.

A maximum limit on the amount of prestressing and mild steel reinforcing is proposed[13]. The method provides a direct way of providing minimum ductility (as compared to the current use of the reinforcement index limits in BDS[12] 9.19) by prescribing a maximum value for the neutral axis location when the nominal strength is reached. The section is considered to be "under-reinforced" if $c / d_e \leq 0.42$, where c equals the distance from the extreme compression fiber to the neutral axis, and d_e equals the corresponding effective depth from the extreme compression fiber to the centroid of the tensile force in the tensile reinforcement.

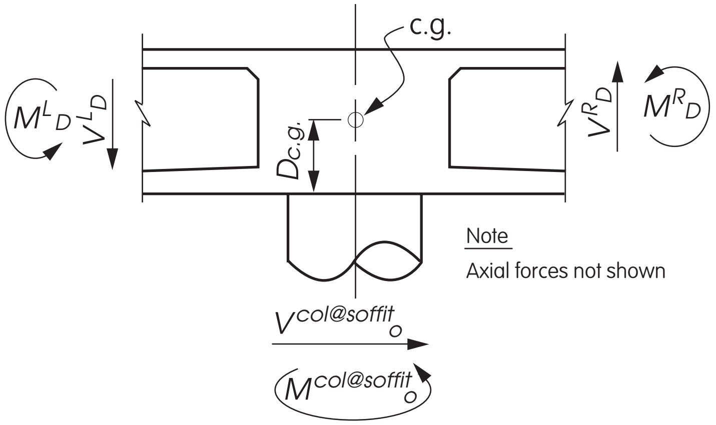
Provisions contained in BDS[12] Section 8 for bar cutoffs, extensions and anchorage lengths, shall be applied to the moment capacity envelope to determine the limits of the mild steel reinforcement.

Splices of the mild steel reinforcement shall meet the "service splice" requirements as defined in MTD[1] 20-9.

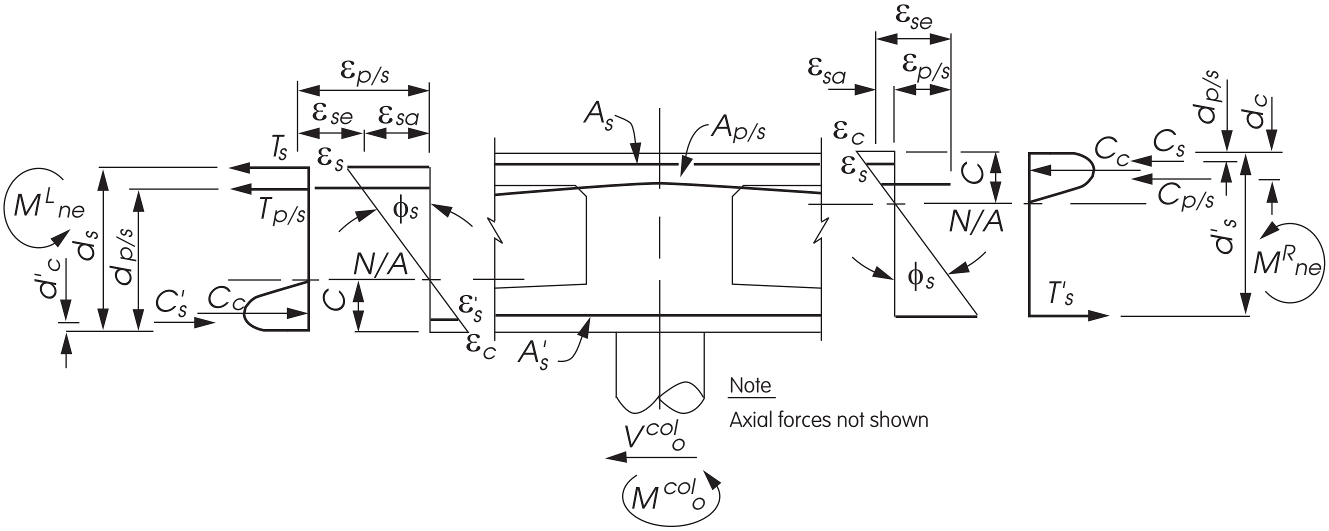
Shear Capacity

The superstructure shall be designed for shear in accordance with BDS[12] 8.16.6. Nominal, rather than expected material properties, shall be used to calculate the shear capacity of the girder and bent cap sections. The intent of this requirement is to provide an additional level of protection from a non-ductile failure mode.

The superstructure joint region should meet the provisions for joint shear as specified in the SDC[2] 7.4.



Superstructure Demand Generated by Column Overstrength Moment



Capacity provided by Superstructure Internal Resistance Force Couple

A_s = Top slab mild steel reinforcement area.

A'_s = Bottom slab mild steel reinforcement area.

$A_{p/s}$= Prestressing steel area

$T_{p/s}$ = Horizontal component of the prestress tendon force.

$\varepsilon_{p/s}$ = Strain in the prestressing steel at ultimate load.

ε_{sa} = The increment of prestressing steel strain as the section passes from the decompression stage to the ultimate load condition.

ε_{se} = Strain in the prestressing steel due to effective prestress force after all losses and decompression of concrete.

ϕ_s = Superstructure section curvature

Figure 5 - Superstructure Demand and Resistance Mechanisms

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