SUPERSEDES BRIDGE DESIGN AIDS SECTION 14 DATED OCTOBER 1989

14-3 FIBER REINFORCED POLYMER (FRP) COMPOSITES COLUMN CASING SYSTEMS

Introduction

Several advanced composite column casing systems have been tested and are approved for use in limited situations as explained below. Advanced composite column casing thicknesses, as shown on the Standard Detail Sheet XS7-210, are designed to enhance both the shear capacity and increase the lateral confinement of the plastic hinge zone for bridge columns with poor transverse reinforcement details. E-glass and carbon fiber composites have been appoved for use in limited situations. Materials testing standards and provisional specifications have been devloped for these systems.

Advanced composites systems may be specified as an alternative to steel colum casings if the conditions specified below are satisfied. For situations not meeting these criteria the Office of Earthquake Engineering (OEE) should be consulted for possible exceptions.

1. The displacement ductility demand μ_p is not more than 6 for circular columns and not more than 3 for rectangular columns.
2. For rectangular columns, the longest side dimension is limited to a maximum of 3 feet and the aspect ratio may not be greater than 1.5.
3. For circular columns, the diameter is 6 feet or less.
4. Lap splices are not present in the expected plastic hinge zones.
5. Composites shall not be used for structures with single column bents.
6. The total axial load (dead load + overturning) on the column is not greater than 15% of its axial capacity.
7. The column longitudinal reinforcement ratio is not greater than 2.5%.
8. The bridge does not require flame-sprayed plastic.
9. The columns are prismatic in shape.
10. The extent of the region designated as t_1 shown on the Standard Detail Sheet XS7-210 is not less than $1\text{-}^1/_2$ times the column diameter and includes the portion of the column where reinforcement is 75% (or greater) of the maximum moment.

A “push-over” analysis should not be performed on columns retrofitted with FRP, as this would over estimate the strain of the advanced composite material and the results would not be accurate. In these situations, the engineer should consult with OEE for guidance.

A list of currently approved systems may be obtained from the OEE. Refer to Standard Detail Sheet XS7-210 for design instructions.

Casing Thickness:

The thicknesses shown on Standard Detail Sheet XS7-210 were derived from the following procedure.

Based on laboratory testing, it is necessary to provide a confining stress of 300 psi at a radial dilating strain, f_1 = 0.004 in regions within a plastic hinge zone. For regions outside the plastic hinge zone, the criteria may be reduced to a confining stress of 150 psi at a radial dilating strain of 0.004.

Note: since advanced FRP composite materials do not typically exhibit a yield stress (linear elastic strain to failure) and since the strains are limited to the radial dilating strain, the developed hoop stress (f_h) may be defined as follows:

$$f_h = \alpha_f E_f \varepsilon_j$$

Where:

f_h = Hoop stress developed in the composite jacket (psi)

E_f = Modulus of Elasticity (psi) of the composite jacket material fiber

α_f = Reduction factor for fiber Modulus of Elasticity = 0.90

ε_j = Dilating strain as defined above

From equilibrium of the column jacket:

$$2f_h A_j = f_1 D s$$

Where:

$A_j = t_j s$ = cross sectional area of the jacket (in^2)

f_1 = the concrete confining stress (psi)

D = the column diameter (in.)

t_j = Composite jacket thickness (in.) based on the dry fiber thickness

t_f = layer thickness of dry fiber

s = unit height of jacket (in.)

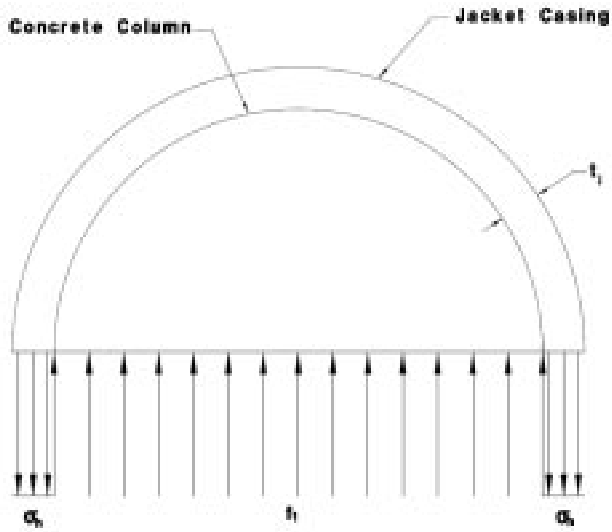

Figure 1

Therefore, solving for composite jacket thickness t_j: $t_j = \dfrac{f_1 D}{2\alpha_f E_f \varepsilon_j}$

The number of layers (N) of the FRP column casing is then:

$N = t_j/t_f$ (Note: round up to the next number of full layers)

Example Calculation:

The required jacket thickness for a 48-inch diameter column inside the plastic hinge zone is as follows:

$$t_j = \frac{f_1 D}{2\alpha_f E_f \varepsilon_j}$$

Where D = 48 in.

E_f = 29,200,000 psi

ε_j = 0.004

f_1 = 300 psi

=> t_j = 0.06849 in.

Therefore, with a dry fiber thickness of 0.0065 in./layer,

The total number of layers = $\dfrac{0.06849 \text{ in.}}{0.0065 \text{ in/layer}}$ = 10.5 layers or 11 layers

References:

1. California Department of Transportation, Standard Detail Sheet XS7-210