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Son Thuc Ha
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**DESIGN OF CONCRETE DEEP BEAMS WITH OPENINGS
AND CARBON FIBER LAMINATE REPAIR**

**A Thesis
Presented To
The Faculty of the Department of Civil and Environmental Engineering
San Jose State University**

**In Partial Fulfillment
of the Requirements for the Degree
Master of Science**

**by
Son Thuc Ha
August 2002**

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ABSTRACT

DESIGN OF CONCRETE DEEP BEAMS WITH OPENINGS AND REPAIR USING CARBON FIBER LAMINATES

by Son Thuc Ha

This thesis proposes the design of concrete deep beams with openings using a direct design method. There are currently no major design codes that describe the design of concrete deep beams with openings. Twelve concrete deep beams with and without openings were designed using a direct design approach. The beams were then tested to validate the effectiveness of the design method. Also, three selected beams were repaired using carbon fiber laminates and retested for its ultimate load capacity.

This study finds that the proposed method of design is safe, with all the beams meeting their design strengths and having an average ultimate load of 60% greater than the average design load. The repair of deep beams with openings using carbon fiber laminates is effective, repairing each of the three beams to meet their design loads.

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NOTATION

a	Clear shear span, in.
a_u, a_L	Lengths describing opening location for equations 2.3-2.5, in.
A	Area of individual web bar, in. ²
A_s	Area of nonprestressed tension reinforcement, in. ²
A_{sh}	Total horizontal steel area, in. ²
A_{sv}	Total vertical steel area, in. ²
A_x, A_y	Reinforcement areas per unit thickness in the directions x and y respectively, in. ²
b	Breadth (thickness) of beam, in.
b_w	Web width, in.
C_1	Empirical coefficient for equations 2.1 and 2.2
C_2	Empirical coefficient for equations 2.1 and 2.2
D	Over-all depth of beam, in.
d	distance from extreme compression fiber to centroid of longitudinal tension reinforcement, in.
d_b	Bar diameter, in.
E_c	Young's modulus of elasticity for concrete, psi
E_j	Young's modulus of elasticity for carbon fiber, psi
f_c	Concrete compressive strength, negative for compression, psi
f_j	Carbon fiber design stress, psi
f_s	Steel tensile strength, psi

f_c	Concrete compressive strength, psi
f_s	Steel compressive strength, psi
f_t	Cylinder splitting tensile strength of concrete, psi
f_x, f_y	Reinforcement stresses in the directions of x and y respectively, psi
f_y	Steel tensile strength (psi)
$\bar{f}_x, \bar{f}_y$	Reinforcement stresses per unit length, psi/in.
h	Section height, in.
h_o	Height of opening, in.
h_L	Height below opening, in.
H	Horizontal force induced around a web opening, used in equation 2.5, lb
k_1, k_2	Coefficient for defining the position of an opening in equations 2.1 and 2.2
L	Span of beam, in.
ℓ_d	Tensile development length, in.
M	Moment, lb-in.
M_u	Ultimate moment at section, lb-in.
Q_B	Load carried above and below, lb
$(Q_B)_F$	Shear load capacity transmitted below an opening at failure, lb
$(Q_B)_S$	Ultimate shear load that can be transmitted below an opening, lb
Q_T	Load carried above an opening, lb
$(Q_T)_F$	Shear load capacity transmitted above an opening, lb
$(Q_T)_S$	Ultimate shear load that can be transmitted above an opening, lb
Q_u	Ultimate load, lb

t_j	Thickness of carbon fiber, in.
V_c	Nominal concrete shear strength, psi
V_j	Shear strength provided by fiber jacket, lb
V_n	Nominal shear strength, psi
V_u	Ultimate shear strength, psi
x	Clear-shear-span distance, in.
y	Depth at which a typical bar intersects the potential critical diagonal crack, which forms approximately along the line joining the loading and reaction points, used in equations 2.1 and 2.2, in.
α	Angle of intersection between a typical bar and the potential critical diagonal crack for equations 2.1 and 2.2, degrees
α	Reinforcement location factor for equation 4.2
β	Steel Reinforcement coating factor
ε	Strain
ε_j	Carbon fiber design strain
λ	Empirical coefficient for equations 2.1 and 2.2
λ	Lightweight aggregate concrete factor
η	Ratio of ultimate shear load below an opening and the shear load capacity transmitted below an opening
μ	Ratio of ultimate shear load over an opening and the shear load capacity transmitted above an opening
ρ_h	Steel ratio of horizontal reinforcement

ρ_v	Steel ratio of vertical reinforcement
ρ_x, ρ_y	Steel reinforcement ratio in the x and in the y respectively
θ	Orientation of major principal concrete stress to Y axis, degrees
σ_1, σ_2	Principal concrete stresses, psi
$\sigma_x, \sigma_y, \tau_{xy}$	In-plane direct and shear stresses, psi
σ_{xf}, σ_{yf}	In-plane direct stresses summed with concrete compressive strength, psi

Chapter 1 – INTRODUCTION

1.1 General

Deep beams are found in a variety of structures. They are commonly used in tall buildings as transfer girders, transferring loads from one or more columns laterally to other columns. The use of deep beams as transfer girders can provide more open space to the lower stories of the building.

Deep beam action often occurs in walls. For example, where a shear wall is supported on a frame system at the ground floor level or on a pile system. Walls of bunkers, water tanks, and silos often have the deep beam behavior.

In contrast to solid deep beams, there has been little work done with deep beams with openings. Openings in deep beams may be desired for such things as windows and doors, or for the passage of utility lines and ventilation ducts. By allowing openings in deep beams for utilities to pass, there can be a reduction in building story height. The design of concrete deep beams with openings is not yet covered by any major design code of practice. The purpose of this investigation is to provide a direct design method for deep beams with openings.

1.2 Scope

The design method provided in this thesis is based on stress fields obtained by finite element analysis on the basis of elastic theory. The design procedure to reinforce the deep beams uses the calculated stress field of a finite element program. A test

program on twelve beams was carried out to verify the design method. The beams consist of three solid deep beams and nine deep beams with openings varying in design loads, opening locations, the addition of polypropylene fibers in the concrete matrix, and concrete strengths.

After testing the deep beams to their ultimate load capacity, three deep beams with openings were repaired using carbon fiber laminates. The repaired beams were retested for the second time to complete failure to observe the characteristics and effectiveness of the repair method.

1.3 Objectives

The main objective of this study was to propose a direct design method for the design of concrete deep beams with openings and to validate its effectiveness. Another objective of this study was to repair three of the tested beams with openings to observe the gain in strength and beam stiffness after repair.

1.4 Outline

A literature review of previous experimental work completed on concrete deep beams with openings is presented in Chapter 2. Chapter 3 presents the design philosophy for the proposed design method. The proposed design theory is applied to design concrete deep beams with and without openings. The design process and the practical constraints in applying the design approach are dealt with in Chapter 4. A testing program to test the design method is presented in Chapter 5, which also discusses the

method of the repair of the concrete deep beams using carbon fiber laminates. A detailed description of the experiments and analysis of results are presented in Chapters 6. Finally, Chapter 7 concludes the study and presents recommendations for future studies.

Chapter 2 – LITERATURE REVIEW

2.1 Introduction

The stress and strain distribution of beams whose span to depth ratio greater than 2 are well predicted by simple bending theory. The Navier-Bernoulli hypothesis of plane sections remaining plane is reasonable, and the shear distribution across a vertical section is parabolic. When the span to depth ratio is less than 2, the stress distribution across a vertical section is non-linear and the shear distribution is not parabolic. This is because the vertical normal stress, which is neglected in simple bending theory, has a significant influence on the stress distribution. Beams with span to depth ratios of less than 2 are referred to as deep beams. The complexity of the design of concrete deep beams derives from this nonlinear vertical strain profile behavior, which is even further complicated by the addition of an opening in the web of the beam.

There is a large number of studies dealing with the design and analysis of solid deep beams,¹⁻¹⁷ but very limited data reported on deep beams with web openings.¹⁸⁻²⁵ Because of the lack of experimental work, the design of deep beams with openings is not covered by the three major codes of practice, the ACI 318-99 Code,²⁶ the Canadian Code,²⁶ and the United Kingdom Construction Industry Research and Information Association (CIRIA) Guide.²⁸ This chapter will review the major experimental work for the study of concrete deep beams with openings.

2.2 Review of Previous Studies

In 1952, Uhlman²⁹ applied elastic analysis to beams with web openings. Uhlman examined the stresses near rectangular openings in a series of simply supported reinforced concrete girder wall models with openings. Photoelastic analysis was used to determine the design tensile forces. The design tensile forces were determined by finding the increased forces parallel to the original stress direction and the induced force perpendicular to the original stress direction with the introduction of the opening. The typical state of stress for the girder models at the location of the opening for an unperforated girder is shown in Figure 2.1. OX and OY are the original directions of the maximum and minimum principal stresses, respectively. Uhlman found the opening on a perforated stress field produces an increase in magnitude of stress along the edges of the opening which are approximately tangential to the unperforated lines of stress, near corners A and A'. Near corners B and B', a force of opposite sign is induced along the edge of the opening approximately perpendicular to the unperforated lines of stress. Uhlman suggested the reinforcement to be assigned according to the predicted tensile force, but did not give limitations to the size and location of the opening.

The CIRIA followed Uhlman's research and considered the effect of the size and location of the opening. The CIRIA states that an opening that is likely to significantly disturb the stress pattern of the unperforated stress field is not admissible. Likewise, openings that are unlikely to disturb the overall behavior of the stress field are acceptable.

Figure 2.1 Location of opening in an unperforated stress field.

The CIRIA requires the opening to be no greater than 0.2 times the width of the band in which the stress is locally concentrated. The reinforcement is determined by considering the opening surrounded by the four simply supported deep beams subjected to the resolved forces set up within the primary beam. The forces are found by principal stress diagrams.

The CIRIA and Uhlman's study are based on elastic theory, which is valid for reinforced concrete structures before cracking. Once cracking occurs the behavior of the structure predicted by elastic analysis may no longer be valid.

A significant body of work in the study of reinforced concrete deep beams with openings was conducted by Kong and Sharp¹⁸⁻²⁰ at the University of Nottingham in 1979. Kong and Sharp presented a semi-empirical formula to predict the ultimate load carrying capacity of reinforced concrete deep beams with and without openings.

Kong and Sharp completed an extensive test of seventy-two simply supported deep beams with a length of 59 in. (1500 mm), depth of 29.5 in. (750 mm), and width of 4 in. (100 mm). The beams consisted of sixteen normal weight concrete beams and fifty-six lightweight concrete beams. A range of opening sizes and locations were tested along with several different arrangements of web reinforcements. The study by Kong and Sharp revealed the effect of the opening depended on how much the opening interfered with the natural load path that exists between the loading and the supports. When the opening interfered with the natural load path of the beam, the beam strength was reduced. The strength reduction was dependant upon the size and location of the opening.

Kong and Sharp observed three types of failures, which are shown on Figure 2.2. Failure mode 1 occurred when the opening did not interfere with the natural load path of the beam. This is the same failure mode that usually occurs with solid deep beams. Failure modes 2 and 3 occurred when the opening intersected the natural load path of the beam. For these failure modes, a diagonal crack from the inside edge of the support propagated to the farther bottom corner of the opening. Above the opening, a diagonal crack occurred between the outside edge of the load point and the top outside corner of the opening.

Figure 2.2 Failure modes observed by Kong and Sharp

Kong and Sharp found that web reinforcement was effective in controlling crack width and increasing the ultimate shear strength of the beam. Inclined web reinforcement was found to be more effective in increasing the ultimate shear strength of the deep beams. The following are the Kong and Sharp semi-empirical equations for estimating the ultimate shear strength of deep beams.

$$Q_u = C_1 \left[1 - 0.35 \frac{x}{D} \right] f_t b D + C_2 \sum_{\text{for-all-bars}} \left(A \frac{y}{D} \sin^2 \alpha \right) \quad (2.1)$$

$$Q_u = C_1 \left[1 - 0.35 \frac{k_1 x}{k_2 D} \right] f_t b k_2 D + \sum_{\text{for-all-bars}} \left(\lambda C_2 A \frac{y_1}{D} \sin^2 \alpha \right) \quad (2.2)$$

Equation 2.1 is for solid deep beams and for deep beams with openings that do not intersect the natural load path of the beam. Equation 2.2 is for all other deep beams.

- A area of an individual web bar (in.²)
- b breadth (thickness) of beam (in.)
- C₁ empirical coefficient (C₁=1.4 for normal weight concrete and 1.0 for light weight concrete)
- C₂ empirical coefficient (C₂=18,850 psi for plain reinforcement bars and 43500 psi for deformed reinforcement bars)
- D overall depth of beam (in.)
- f_t cylinder splitting tensile strength of concrete (psi)
- k₁,k₂ coefficients defining the position of an opening
- x clear shear-span distance (in.)
- y depth at which a typical bar intersects the potential critical diagonal crack, which forms approximately along the line joining the loading and reaction points (in.)
- α angle of intersection between a typical bar and the potential critical diagonal crack (degrees)
- λ empirical coefficient (λ=1.5 for web bars and λ=1.0 for main longitudinal bars)

Further work on deep beams with openings was conducted by Kubik²⁵ at the University of Cambridge in 1980. Kubik tested eighteen lightweight beams and eight normal weight beams. His normal weight beams were approximately 2 ½ times larger than the beams tested by Kong and Sharp. The beams had dimensions of 157.5 x 71 x 10 in. (4000 x 1800 x 250 mm) with a clear span of 3500 mm. Also, instead of having the flexural steel welded to external steel blocks at the ends like the Kong and Sharp beams, Kubik had 90° bends at the ends of the flexural steel to prevent pullout.

Kubik observed that when the opening interrupted the natural load path of the beam, the beam deformed by the rotation of three major blocks. One block was above the opening, a second block below the opening, and the third block between the opening and the end of the beam. Kubik also observed two failure modes that were not seen by Kong and Sharp. These failure modes are presented in Figure 2.3. These failures occurred at a plane at the top outer corner of the web opening and at the bottom of the beam at either a flexural crack or from the beam soffit. The beam crack patterns observed by Kubik were similar to the crack patterns found by Kong and Sharp except for some splitting cracks in the web of the beam found in Kubik's beams. These new crack types are cracks 7, 8, and 9 in Figure 2.4.

Figure 2.3 Additional failure modes observed by Kubik

Figure 2.4 Crack patterns observed in testing by Kong, Sharp, and Kubik

Kubik also proposed an equation to estimate the strength of deep beams with openings, which only applies when the opening interrupts the natural load path of the deep beam. Kubik's theory on deep beams with openings is based on the deformation of four major blocks of the deep beam as can be seen in Figure 2.5. The beam deformed by the deformation of three blocks, blocks A, B, and C, and the downward displacement of block D.

Figure 2.5 Kubik's idealization for deformation for deep beams with openings

The moments were calculated at hinges 1-4 for the following equations.

$$Q_T = \frac{M_1(h_o + h_L) + M_2h + M_3h_u}{a_u(h_o + h_L) - h_u(a_L - x_o)} \quad (2.3)$$

$$Q_B = \frac{M_3 + M_4}{a_L} - \frac{h_L}{a_L} \frac{M_1(a_L - x_o) + M_2a + M_3a_u}{a_u(h_o + h_L) - h_u(a_L - x_o)} \quad (2.4)$$

$$H = \frac{M_1(a_L - x_o) + M_2a + M_3a_u}{a_u(h_o + h_L) - h_u(a_L - x_o)} \quad (2.5)$$

Q_T is the load carried above the opening, Q_B is the load carried below the opening, and H is the horizontal force induced around a web opening in the model of Figure 2.5. The ultimate strength of the beam can be found with the hinge moments at failure. However, premature shear failures must be accounted for. From testing results,

hear failures can occur in three regions, above the web opening, in the region between the end of the beam and the web opening, and below the web opening. Let $(Q_T)_F$ be the maximum load above the opening with all the hinge moments at their ultimate values in equation 2.3 and let $(Q_T)_S$ be the ultimate shear load that can be transmitted above the opening, calculated from Kong and Sharp's equation. If the shear capacity over the opening is less than the maximum load by the ultimate hinge moments,

$$(Q_T)_S < (Q_T)_F \quad (2.6)$$

the shear failure will govern the area over the opening. Similarly, this can occur below the opening as well.

$$(Q_B)_S < (Q_B)_F \quad (2.7)$$

Also, suppose that the maximum load is reached simultaneously above and below the opening as seen in Figure 2.6. If shearing failure occurs in the upper load path such that

$$(Q_T)_S / (Q_T)_F = \mu \quad (2.8)$$

then the ultimate load would be the following.

$$Q_u = (Q_T)_S + \mu(Q_B)_F \quad (2.9)$$

Likewise, if premature shearing failure occurs in the lower load path such that

$$(Q_B)_S / (Q_B)_F = \eta \quad (2.10)$$

$$\text{then} \quad Q_u = (Q_B)_S + \eta(Q_T)_F. \quad (2.11)$$

If shearing failure is the controlling failure in both the upper and lower path, equation 2.9 applies when $\mu < \eta$ and equation 2.11 applies when $\eta < \mu$.

Figure 2.6 Assumed increase in load carried by the paths above and below the opening

In 1987, Schlaich, Schafer, and Jennewein³⁰ presented the strut-and-tie method to design concrete structure. The method is based on the truss model, but adapted for concrete structures. It analyzes concrete structures by a system of concrete compressive struts and tensile ties. The struts and ties describe the load resisting mechanisms in the structure. Tensile ties can be steel reinforcing bars or prestressing tendons. A concrete tensile stress field can also be modeled as a tensile tie. The compressive struts are usually concrete regions, but can be combined with axial steel to increase the compressive capacity of the strut. The magnitude of the forces through the compressive struts and tensile ties are controlled by the equilibrium of the system.

The strut and tie method is not a direct method of design since there can be numerous strut and tie orientations to describe the load resistance of a structure. However, the best orientation of the struts and ties will give the least amount of strain in the strut and tie members.

The concrete structure is first divided into two types of regions, B-regions and D-regions. B-regions are the regions of the structure where the Bernoulli hypothesis of plane sections remaining plane is valid and are well defined by beam bending theory. All other regions are considered D-regions. The strain distribution of D-regions is significantly nonlinear. D-regions are usually at concentrated loads, corners, bends, openings, and other discontinuities. Deep beams are oftentimes considered entirely as one D-region.

With B-regions and D-regions defined, the load resistance mechanism of the structure is described using a system of struts and ties. Steel is then proportioned to the struts and ties by maintaining equilibrium of the structure and by staying within the stress limits of the materials.

Chapter 3 – DESIGN PHYLOSOPHY

3.1 Limit States

The ultimate load method is used in the design of the beams in this study. The two considered limit states are the ultimate limit state and the serviceability limit state.

- 1) **Ultimate Limit State** – The ultimate limit state requires that neither the whole structure nor any part of the structure should collapse. Collapse is where the structure is unable to carry any additional load. This can occur either because the structure has become a mechanism or because the structure has become unstable.
- 2) **Serviceability Limit State** – The serviceability limit state requires that the structure should not suffer from excessive deflection, cracking, vibration, etc. at working loads.

The general design procedure is to design the structure to meet ultimate limit states and check the design for the serviceability requirements.

3.2 Limit State Design

3.2.1 Equilibrium Criterion

By the equilibrium criterion, the internal stresses must be in equilibrium with external loads. The internal stresses for reinforced concrete structures are well predicted by elastic theory until cracks form. Although cracking affects the distribution of stresses, it is permissible to base reinforcement on the stress field obtained by elastic analysis, so

long as the structure has sufficient ductility at yielding regions to redistribute stresses to other parts of the structure.

The actual ultimate strength of the structure should at least reach the ultimate design strength because of the underestimated strengths of the materials. The steel reinforcement is designed using its minimum yield strength and strain hardening is neglected. The biaxial compressive strength and tensile strength of concrete are also neglected. These conservative assumptions help ensure the ultimate strength of the structure meets its design load.

3.2.2 The Yield Criterion – Design For In-Plane Forces

Reinforced concrete structures resist forces by concrete alone or by the combination of steel and concrete. The yield criterion is met when the strength at every point in the structure is greater than the applied stresses.

A stress field using elastic analysis for ultimate conditions can be found with finite element analysis. A finite element computer program presents results in the form of direct membrane stresses in the form of two mutually perpendicular directions (i.e., σ_x , σ_y), and an in-plane shear (i.e., τ_{xy}) for each element in the analysis. This thesis employs yield criteria equations modified from Clark's equations.³¹

In order to establish design equations, the following assumptions are made:

- 1) The steel reinforcement can carry only uniaxial stress in their original orientation. The steel is assumed to be elastic-perfectly plastic and to yield at stresses of f_y in tension and f_y' in compression, as can be seen in Figure 3.1.

- 2) The reinforcement is assumed to be positioned symmetrically with respect to the thickness of the section and to be in two orthogonal directions.
- 3) The bar spacing is assumed to be small in comparison with the overall structure so that the reinforcement can be considered in terms of area per unit width.
- 4) The concrete is assumed to have no tensile strength. It is also assumed to exhibit a square yield criterion in plane stress. See Figure 3.2.
- 5) The structure is assumed to fail in the plane of loading and not by buckling of the section.

Figure 3.1 Elastic-perfectly plastic assumption for steel

Figure 3.2 Concrete square yield criterion.

3.2.3 Design Theory

The principal concrete stresses are taken to be σ_1 and σ_2 with the major principal stress σ_1 at θ to the x-axis. Positive stress is taken to be in tension. A typical element showing the sign convention for in-plane direct and shear stresses is shown in Figure 3.3.

Figure 3.3 Typical element with in-plane normal and shear stresses.

The applied stresses are resisted by the combination of concrete and steel. Figure 3.4 shows an element with applied stresses with the stresses resisted by concrete and steel reinforcement placed orthogonally in the horizontal and vertical directions.

The reinforcement is taken in terms of area per unit length in the x and y directions as A_x and A_y , respectively. Their associated stresses are $\bar{f}_x$ and $\bar{f}_y$. The reinforcement ratio is the steel reinforcement area per unit length divided by the thickness.

$$\rho_x = \frac{A_x}{t} \quad (3.1)$$

$$\rho_y = \frac{A_y}{t} \quad (3.2)$$

Figure 3.4 Combination of the resistant stresses

By considering Figure 3.4, the following equations of equilibrium are found by equating the applied stresses.

$$\sigma_x = \sigma_1 \cos^2 \theta + \sigma_2 \sin^2 \theta + \rho_x \bar{f}_x \quad (3.3)$$

$$\sigma_y = \sigma_1 \sin^2 \theta + \sigma_2 \cos^2 \theta + \rho_y \bar{f}_y \quad (3.4)$$

$$\tau_{xy} = (\sigma_1 - \sigma_2) \cos \theta \sin \theta \quad (3.5)$$

The reinforcement in each direction can be in tension, in compression, or there can be no reinforcement. With these three cases, there can be nine possible combinations to consider. Table 3.1 summarizes the nine possible cases. Direct solutions can be found for all the cases except cases A and D where four unknowns are to be determined from three equations. The fourth equation is determined by considering the minimum total amount of reinforcement as follows,

$$\frac{\partial(\rho_x + \rho_y)}{\partial(\tan \theta)} = 0 \quad (3.6)$$

By equations 3.1 through 3.5 and Table 3.1, the solutions for the reinforcement ratios, principal concrete stresses and θ can be found. The solutions are summarized in Table 3.2. The following symbols are introduced in Table 3.2:

$$\sigma_{xf} = \sigma_x + f_c \quad (3.7)$$

$$\sigma_{yf} = \sigma_y + f_c \quad (3.8)$$

$$\beta = \sqrt{1 - \frac{4\tau_{xy}^2}{f_c^2}} \quad (3.9)$$

$$\alpha = \frac{f_c}{2|\tau_{xy}|} \quad (3.10)$$

f_c is the concrete compressive strength with compression as negative.

Table 3.1 Possible Combinations of Reinforcement

Case	Reinforcement Description	Known Values	Method of Solution
A	Both tension	$\bar{f}_x = \bar{f}_y = f_s, \sigma_1 = 0$	Minimization of $(\rho_x + \rho_y)$
B	x tension, no y	$\bar{f}_x = f_s, \rho_y = 0, \sigma_1 = 0$	Direct Solution
C	No x, y tension	$\rho_x = 0, \bar{f}_y = f_s, \sigma_1 = 0$	Direct Solution
D	Both compression	$\bar{f}_x = \bar{f}_y = f'_s, \sigma_2 = f_c$	Minimization of $(\rho_x + \rho_y)$
E	x compression, no y	$\bar{f}_x = f'_s, \rho_y = 0, \sigma_2 = f_c$	Direct Solution
F	No x, y compression	$\rho_x = 0, \bar{f}_y = f'_s, \sigma_2 = f_c$	Direct Solution
G	x tension, y compression	$\bar{f}_x = f_s, \bar{f}_y = f'_s, \sigma_1 = 0, \sigma_2 = f_c$	Direct Solution
H	x compression, y tension	$\bar{f}_x = f'_s, \bar{f}_y = f_s, \sigma_1 = 0, \sigma_2 = f_c$	Direct Solution
I	No reinforcement	$\rho_x = \rho_y = 0$	Direct Solution

Table 3.2 Design Equations for Reinforcement

Case	ρ_x	ρ_y	σ_1	σ_2	$\tan \theta$
A	$\frac{1}{f'_s}(\sigma_x + \tau_{xy})$	$\frac{1}{f'_s}(\sigma_y + \tau_{xy})$	zero	$-2 \tau_{xy} $	$-\frac{\tau_{xy}}{ \tau_{xy} }$
B	$\frac{1}{f'_s}(\sigma_x + \tau_{xy})$	zero	zero	$\frac{\tau_{xy}^2}{\sigma_y + \frac{\tau_{xy}^2}{\sigma_y}}$	$-\frac{\tau_{xy}}{\sigma_y}$
C	zero	$\frac{1}{f'_s} \left(\sigma_y + \frac{\tau_{xy}^2}{\sigma_x} \right)$	zero	$\frac{\tau_{xy}^2}{\sigma_x + \frac{\tau_{xy}^2}{\sigma_x}}$	$-\frac{\sigma_x}{\tau_{xy}}$
D	$\frac{1}{f'_s}(\tau_{xy} - \sigma_x - f_c)$	$\frac{1}{f'_s}(\tau_{xy} - \sigma_y - f_c)$	$f_c + 2 \tau_{xy} $	f_c	$-\frac{\tau_{xy}}{ \tau_{xy} }$
E	$\frac{1}{f'_s} \left(\frac{\tau_{xy}^2}{\sigma_{yf}} - \sigma_{xf} \right)$	zero	$\frac{\tau_{xy}^2}{\sigma_y + \frac{\tau_{xy}^2}{\sigma_{yf}}}$	f_c	$\frac{\sigma_{yf}}{\tau_{xy}}$
F	zero	$\frac{1}{f'_s} \left(\frac{\tau_{xy}^2}{\sigma_{xf}} - \sigma_{yf} \right)$	$\frac{\tau_{xy}^2}{\sigma_x + \frac{\tau_{xy}^2}{\sigma_{xf}}}$	f_c	$\frac{\sigma_{xf}}{\tau_{xy}}$
G	$\frac{1}{f'_s} \left[\sigma_x - \frac{f_c}{2}(1 - \beta) \right]$	$\frac{1}{f'_s} \left[\sigma_y - \frac{f_c}{2}(1 + \beta) \right]$	zero	f_c	$-\frac{1}{\alpha(1 - \beta)}$
H	$\frac{1}{f'_s} \left[\sigma_x - \frac{f_c}{2}(1 + \beta) \right]$	$\frac{1}{f'_s} \left[\sigma_y - \frac{f_c}{2}(1 + \beta) \right]$	zero	f_c	$-\frac{1}{\alpha(1 + \beta)}$
I	zero	zero	$\frac{\sigma_x + \sigma_y + \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}}{2}$	$\frac{\sigma_x + \sigma_y - \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}}{2}$	$\frac{\sigma_x - \sigma_y - \sqrt{(\sigma_x - \sigma_y)^2 + 4\tau_{xy}^2}}{2\tau_{xy}}$

With the nine cases established, it is now necessary to determine which case each particular stress trial follows. This is achieved by considering the relationship among the cases and the limitation of principal concrete stresses. The case boundary equations and a graph of the boundary equations are presented in Table 3.3 and Figure 3.5, respectively. It is also required that $f_c < -2|\tau_{xy}|$ for equation 3.9 to be satisfied.

Table 3.3 Boundary Curves

Curve	Equation
1	$\frac{\sigma_x}{ \tau_{xy} } = +\infty$
2	$\frac{\sigma_x}{ \tau_{xy} } = \frac{1}{2} \left(\frac{f_c}{ \tau_{xy} } + \sqrt{\left(\frac{f_c}{ \tau_{xy} } \right)^2 - 4} \right)$
3	$\frac{\sigma_x}{ \tau_{xy} } = -1$
4	$\frac{\sigma_x}{ \tau_{xy} } = \frac{f_c}{ \tau_{xy} } + 1$
5	$\frac{\sigma_x}{ \tau_{xy} } = \frac{1}{2} \left(\frac{f_c}{ \tau_{xy} } - \sqrt{\left(\frac{f_c}{ \tau_{xy} } \right)^2 - 4} \right)$
6	$\frac{\sigma_x}{ \tau_{xy} } = -\infty$
7	$\frac{\sigma_y}{ \tau_{xy} } = \frac{1}{2} \left(\frac{f_c}{ \tau_{xy} } - \sqrt{\left(\frac{f_c}{ \tau_{xy} } \right)^2 - 4} \right)$
8	$\frac{\sigma_y}{ \tau_{xy} } = -1$
9	$\left(\frac{\sigma_{xf}}{ \tau_{xy} } \right) \left(\frac{\sigma_{yf}}{ \tau_{xy} } \right) = 1$
10	$\left(\frac{\sigma_x}{ \tau_{xy} } \right) \left(\frac{\sigma_y}{ \tau_{xy} } \right) = 1$
11	$\frac{\sigma_x}{ \tau_{xy} } = \frac{f_c}{ \tau_{xy} } + 1$
12	$\frac{\sigma_y}{ \tau_{xy} } = \frac{1}{2} \left(\frac{f_c}{ \tau_{xy} } + \sqrt{\left(\frac{f_c}{ \tau_{xy} } \right)^2 - 4} \right)$

Figure 3.5 Case Boundary Graph

3.2.4 The Mechanism Condition

A structure becomes a mechanism when it is unable to carry any more loads. This is achieved through the formation of hinges or yield zones such as cracks and material yielding.

3.3 Serviceability Limit State

The American Concrete Institute has serviceability requirements for maximum beam deflection and maximum crack width. The ACI maximum crack width is 0.016 inches for interior exposure and 0.013 inches for exterior exposure. The maximum allowable deflection is dependant upon the location and the function of the beam. Table 9.5(b) of ACI 318-99 presents deflection limits, stating that the maximum allowable deflection due to immediate live load is $\frac{1}{360}$ of the span length and the maximum allowable deflection due to dead and live loads is $\frac{1}{180}$ of the span length. The beams will be checked for serviceability at the design loads.

Chapter 4 –PRACTICAL CONSTRAINTS

4.1 Introduction

The proportioning of the steel poses a practical constraint in the design procedure described in section 3.2. Since the theoretically calculated reinforcement ratio varies throughout the structure, it is not possible to provide reinforcement exactly as calculated. Also, local details such as development length and bearing capacity complicate the design procedure even further. This chapter will discuss how these constraints are considered.

4.2 The Application of the Finite Element Program

A finite element analysis was conducted for five different series. Series 1 is a solid deep beam with no opening. Beam series 2 through 5 consist of deep beams with variations in opening locations. A more detailed description of the beams will be described in chapter 5. The finite element mesh of each of the five beam series is shown in Figures 4.1-4.5. 9-node isoperimetric elements were used to model the beams in the finite element analysis. The modulus of elasticity of the finite element analysis is based on the target concrete strengths of the beams. The modulus of elasticity for the beam was determined by equation 4.1.

$$E_c = 57000\sqrt{f_c'} \quad (4.1)$$

The beams were designed with varying concrete strengths f_c' of 7,000 psi, 9,000 psi, and 11,000 psi, designated as A, B, and C, respectively. Table 4.1 lists the design loads for

each beam series and Table 4.2 lists the modulus of elasticity used for the three concrete strengths. The beam design loads are limited by the design requirement of equation 3.9, requiring $\tau_{xy} < 2f_c'$. The elastic stresses are found in the element local coordinate system at the integration points and are extrapolated from the 2 x 2 Gauss integration points of the element to the nodes.

Table 4.1 Design Loads

Beam	Design Load, (kips)
Series 1	175
Series 2	125
Series 3	150
Series 4	70
Series 5	100

Table 4.2 Modulus of Elasticity

Concrete Type	Concrete Compressive Strength, f_c' (psi)	Elastic Modulus, E (ksi)
A	7,000	4,770
B	9,000	5,410
C	11,000	5,980

4.3 Design Consideration For Reinforced Concrete Deep Beams with Opening

4.3.1 Design of Reinforcement

The design method described in section 3.2 was utilized into a computer spreadsheet program. A flow chart of the computer design process is shown in Figure 4.6. The required steel percentages obtained from an elastic analysis of the beams are shown in Figures 4.7-4.11.

It has been found in numerous studies^(9, 18, 32) that as the shear span to depth ratio of the beam decreases, reinforcement perpendicular to the longitudinal axis becomes less effective. At the same time, distributed reinforcement parallel to the longitudinal axis will increase the shear capacity. This correlates with the design results of this study since there is very little steel required in the vertical direction.

It can be observed that the reinforcement ratio varies for each element. In practice, reinforcement ratios cannot vary exactly as required by the theoretical reinforcement ratios. In dealing with this practical constraint, there are two methods of providing steel reinforcement to follow the theoretical reinforcement ratios for the beams. The first option is to place the steel according to the average steel ratio at each level, while the second option is to place the steel to meet the maximum ratio at each level.

The latter method was utilized in this study. The first method is economical, but gives unsafe design because high stressed locations may have inadequate reinforcement. The second method, although less economical, gives a safe design since every location will have the required amount of reinforcement or more.

The calculations for the steel placement of the beams are shown in Figures 4.7-4.11. The steel bar sizes were varied from #3 to #5 bars, to create an efficient design and also to retain as much of a homogeneous and isotropic behavior as possible. Local stress concentrations at the load point and supports were neglected since those locations will be dealt with separately by designing them as short columns, which will be described in section 4.3.4. The local stress concentrations are denoted by the hatched elements in the figures.

Since the steel is placed orthogonally in the horizontal and vertical directions, the maximum required steel percentage was found for each row and each column of the finite element mesh. Steel was provided to satisfy the required steel amounts. Because of the small size of the beams, little reinforcement was required for an individual row or column. For an efficient design, the steel requirements were grouped and the steel was

placed according to the centroid of the steel requirements of the group. It was found that minimum steel was required for the steel in the vertical direction for all the beams designed. Vertical closed stirrups were placed according to the minimum requirements of ACI 318-99 section 11.8.9 stating that for deep flexural members, the vertical shear reinforcement spacing cannot be less than one fifth of the total depth of the member or 18 in. This results in the maximum vertical stirrup spacing of 7.2 in.

4.3.2 Effect of the Variation of Concrete Strength on the Strength of Deep Beams

From Tables 3.1 and 3.2, it can be seen that an increase in concrete compressive strength will have a minor change to the required steel ratio since the concrete compressive strength terms are divided by the steel yield stress. Therefore, increasing the concrete compressive strength will have minimal effect to the reinforcement under the same ultimate load. Previous studies^(9, 13, 18-19, 22, 25) show that concrete strength does have an effect on the ultimate strength of deep beams. Concrete strengths were varied on the beams in this study to observe the effect it has on the ultimate strength of the deep beams. Although the concrete strengths were varied in the range from 7,000 to 11,000 psi, the results for the design for each of the beam series (1,2,3,4, and 5) were identical for each series.

4.3.3 Effect of Polypropylene Fibers on the Strength of Deep Beams

The addition of polypropylene fibers added to the concrete mix can increase the tensile strength and ductility of concrete structures. Plastic fibers were added to beams in

series 1 and 2 at a recommended dosage of 1.5 pounds per cubic yard of concrete, approximately 0.037% by weight. The beams were compared to equivalent beams without fibers to observe their effects on the concrete deep beams. The plastic fibers are not accounted for in the design since it is assumed that the concrete cannot carry any tensile stresses.

4.3.4 Bearing Capacity and Development Length

To avoid premature failure due to the crushing of concrete at the load point and supports, short column design was employed at the bearing locations. The short column design also accounted for the stress concentrations in the finite element analysis. According to ACI 318-99 10.17.1, concrete bearing strength shall not exceed $\phi(0.85f_c' A)$ when the supporting surface is not wider on all sides than the loaded area. The strength reduction factor, ϕ , is 0.85. The remaining load that was beyond the allowable concrete bearing load was resisted axially by steel as short columns. The steel could carry 60,000 psi and the length of the short column is the required length for compression steel development. ACI 318-99 12.3.2 requires the compressive development length to be at least $0.02d_b f_y / \sqrt{f_c'}$, but not less than $0.0003d_b f_y$ or 8 in. The largest bar size used for tensile reinforcement were No. 5 bars ($d_b = 5/8$ in.).

The following formula from ACI 318-99 12.2.2 describes the development length required to acquire full tensile force for a No. 6 bar and smaller. Table 4.3 presents the required tensile development lengths for the bars used in this study.

$$\ell_d = \frac{d_b f_y \alpha \beta \lambda}{25 \sqrt{f_c'}} \quad (4.2)$$

where: ℓ_d = tensile development length (in.)

d_b = bar diameter (in.)

f_y = steel tensile strength (psi)

α = reinforcement location factor

Horizontal reinforcement so placed that more than 12 in. of

Fresh concrete is cast in the member below the

development length = 1.3

β = coating factor

Uncoated reinforcement = 1.0

λ = lightweight aggregate concrete factor

Normal weight concrete = 1.0

Table 4.3 Tensile Development Lengths

Bar No.	Concrete Strength (psi)		
	7,000	9,000	11,000
3	14 in.	13 in.	12 in.
4	19 in.	17 in.	15 in.
5	24 in.	21 in.	19 in.

Figure 4.1 Finite element mesh of beam series I

Figure 4.2 Finite element mesh of beam series 2

Figure 4.3 Finite element mesh of beam series 3

Figure 4.4 Finite element mesh of beam series 4

Figure 4.6 Flow Chart

Figure 4-7 Required steel for beam series I

Figure 4.11 Required steel for beam series 5

Chapter 5 TEST PROGRAM

5.1 Introduction

The main goals of the test program were to observe the behavior of concrete deep beams with openings subjected to in-plane loads and to verify the direct design method proposed in this thesis. The test program also looks into the effects of opening position, concrete strength, and the addition of polypropylene fibers to the ultimate strength of the beams.

The five beam series consists of twelve beams with and without openings. Figure 5.1 describes the beams of this study. All the beams were simply supported and tested using a single, monotonic, central, point loading. The beam deflections at the bottom of the beam at midspan and deflections at the middle of the open span provided by the opening were measured. Steel strains were measured on the longitudinal steel reinforcement at the centerline of the beams. They were measured at the lowest reinforcement bars at the bottom of the beams and at the reinforcement bars immediately above the openings. Figure 5.2 shows the locations of where beam deflections and steel strain measurements were taken. Crack patterns were also traced during the testing of the beams.

Opening Location

Beam Series*	X	Y
1A, 1Af, 1C	None	None
2A, 2Af, 2C	12"	12"
3A, 3B	12"	8"
4A, 4B	12"	17"
5A, 5B	18"	12"

Thickness = 4"

*f denotes beams with plastic fibers

A: 7,000 psi concrete

B: 9,000 psi concrete

C: 11,000 psi concrete

Figure 5.1 Beam Geometry

Figure 5.2 Loading Configuration

5.2 Test Program

5.2.1 Test Specimens

The twelve beams tested consist of 3 solid beams and 8 beams with web openings. Each of the beams has an overall length of 44 inches, a total depth of 36 inches, and a thickness of 4 inches. The openings are 12 x 12 in. square with five variations in location including one without an opening. The opening position is varied with respect to the natural load paths of the beams, as shown in Figure 5.3. The arrows in the Figure 5.3 represent the unobstructed natural load paths of the beams.

The beams were simply supported with a span of 36 inches. 4x4x3/4 in. steel bearing blocks were used at the supports, leaving 32 inches in clear span. The span to depth ratio (L/D) of the beams was 1.0. A 4x6x1 in. long steel bearing plate was used under the load point giving the centrally loaded beams a clear shear-span to depth ratio (x/D) of 0.36 and a shear span to depth ratio (a/D) of 0.5. The variation in concrete strength and the use of plastics fibers is shown in Figure 5.1. Figures 5.4-5.8 describe the steel reinforcement for the five beam series.

5.2.2 Repair Using Carbon Fiber Reinforced Laminates

After testing, three beams were repaired using carbon fiber reinforced laminates and retested. The three beams failed originally by shear failure over the opening of the beams. They were repaired by installing carbon fiber reinforced sheets over the damaged section of the beams above the openings. The fibers were placed on both faces of the beams and were not wrapped around the beam since this would be impractical in practice.

Figure 5.3 Beam Configurations and non-obstructed natural load paths.

Figure 5.5 Reinforcement of beam series 2

Figure 5.6 Reinforcement of beam series 3

Figure 5.7 Reinforcement of beam series 4

Figure 5.8 Reinforcement of beam series 5

5.3 Materials and Instrumentation

5.3.1 Concrete

Portland cement type I/II cement was used for all the concrete mixes. Crushed granite was used for both the coarse and the fine aggregates. The coarse aggregates had a maximum nominal size of 3/8 in. and the fine aggregates had a fineness modulus of 3.02. There were three mix designs for three target 28 day concrete strengths of 7,000 psi, 9,000 psi, and 11,000 psi. The concrete strengths were denoted alphabetically as A, B, and C respectively for the beam notation. The plastic fiber reinforced mixes, was denoted by an "f" in the beam notation.

5.3.2 Reinforcement

Steel reinforcement having a minimum yield stress of 60 ksi was used for the beams. Three samples of the steel reinforcement were tested for yield strength. The coupon samples met the minimum requirement of 60 ksi, yielding at 62 ksi, 64 ksi, and 69 ksi. Polypropylene "Fibermesh" fibers were added to the concrete mix of several

Figure 5.9 "Fibermesh" high performance polymer fibers

beams to observe the effects of fiber reinforced concrete in deep beams. The fibers were added at the recommended proportion of 1.5 pounds per cubic yard of concrete, approximately 0.037% by weight. The polypropylene fibers, shown in Figure 5.9, are mechanically deformed with 3 deformations per 0.39 in. The fibers are 0.035 in. thick and 1.97 in. in length. It has an elastic modulus of 50,000 psi and an ultimate elongation of 15%. Fibers can increase concrete strength and ductility.

5.3.3 Carbon Fiber Reinforced Laminates

Carbon fiber laminate sheets were used to repair three beams in this study. The 0.02-inch thick laminates have resistance in a single direction. The carbon fiber design stress is 36 ksi with a 9 ksi tensile modulus. The fiber ultimate tensile strength is 108 ksi. A two-part epoxy was used to attach the sheets onto the grinded and cleaned surfaces of the deep beams.

The most effective orientation of reinforcement to resist shear is by having the reinforcement resistance perpendicular to the crack propagation and widening. Shear cracks occur in the shear span and propagate towards the load point, so it would be ideal to orient the fibers at a $\pm 45^\circ$ angle to the horizontal. Because of the small area above the opening, there was insufficient development length to lay the fibers at a 45° angle. Instead, the fibers were aligned horizontally and laminate anchors were placed after the first layer of laminate to help with the strength development as seen in Figure 5.10.

Figure 5.10 Carbon fiber laminate and anchors installed onto Beam 2A

Beams 2A and 5A have a depth of 12 inches in the span over the opening. Beam 4B has a depth of 8 inches in the span over the opening. The following is the equation for additional shear strength provided by the fibers.

$$V_j = 2Df_j t_j \quad (5.1)$$

where V_j = Shear strength provided by the fiber jacket (lb)

D = Depth of beam (in.)

f_j = Design stress = $\epsilon_j E_j$ (psi)

ϵ_j = Design strain = 0.004

E_j = Jacket modulus = 9000 psi

t_j = Jacket thickness = 0.02 inches per layer

The small area over the opening was too limiting to repair the beams back to their original strength. Instead, a testing regimen of varying laminate layers was used. Three

layers of the laminate were installed on each face of beam 2A, two layers on beam 5A, and one layer on beam 4B. Theoretically, the laminates provide 51.8 kips, 34.6 kips, and 11.52 kips of additional shear strength to beams 2A, 5A, and 4B, respectively.

5.3.4 Strain Gages

Half-inch long electrical resistance strain gages were attached to the longitudinal reinforcement steel at half span positions. The gages were placed on the lowest reinforcement steel at the bottom, center of the beam and at the immediate longitudinal steel over the opening at the center. Each strain measurement location had two strain gages placed diametrically opposite to each other at the top and the bottom of the bar. See Figure 5.11 below.

Figure 5.11 Strain gages on a No.3 bar before protective coating application.

5.3.5 Casting and Curing

The beams were cast in oiled forms made of plywood. The concrete was placed in the forms by shoveling and compacting using pencil vibrators. A minimum of four, four inch by eight inch cylinders were cast for each of the beams. After construction, the

beams were covered by wet blankets that were kept moist by drip hoses. The cylinders were unmolded 24 hours after pouring and were left to cure at 100% relative humidity in a curing chamber until they were tested for concrete compressive strength on the day of beam testing.

5.3.6 Linear Variable Differential Transformer

Linear Variable Differential Transformers (LVDT) were used to measure the deflection of the beams. LVDTs were placed at midspan, at the center of the span provided by the opening, and at the supports as shown in the Loading Configuration Figure 5.2. The LVDTs at the supports were to account for support settlement.

5.4 Test Setup

The beams were tested using a screw type universal testing machine. The load was applied through a 2 in. diameter, steel, cylindrical roller resting onto a 4x6x1 in. steel bearing block. The support reactions were applied to the beam soffit by a 4x4x1 in. steel blocks that were specially designed for the roller supports to allow rotation. At the concentrated load and supports, steel plates were clamped onto the faces of the beam to provide resistance to Poisson's effect creating bearing failure. A photograph of the test setup is shown in Figure 5.12.

5.5 Testing Procedure

The load was applied monotonically to the beams in 10,000 lb increments up to failure. After each loading increment, the beams were inspected to mark crack patterns. Load, steel strain, and beam deflection were measured at five second intervals during the testing using a computerized data acquisition system. After testing, photographs were taken of the beams to record crack patterns and failure characteristics.

Figure 5.12 Beam testing setup

Chapter 6 – TEST RESULTS

6.1 Introduction

The twelve beams designed using the proposed design method were tested to their ultimate loads. During the testing, crack patterns were observed, and the applied loads and deflections were recorded along with the steel strains at the strain gage locations. Three of the tested beams were selected to be repaired with carbon fiber laminates. The repaired beams were retested to their ultimate loads.

6.2 Presentation of Test Data and Results

6.2.1 Crack Patterns

Figures 6.1-6.12 present photographs of the beams after failure. The numbers beside the cracks represent the load at which the crack was found in units of 10 kips. There were three stages of crack formation.

First Stage: The first cracks to appear were flexural cracks above and below the opening. These cracks appeared quickly at approximately 20% of the ultimate load. The flexural cracks above the opening propagated slowly, limited by the concrete compression caused by the nearby point load. The flexural cracks below the opening propagated quickly, often extending from the bottom of the beam to the bottom of the opening. The region below the opening is mostly in tension, so the crack propagation was less restrictive.

Second Stage: The second series of crack formations were shear cracks. They would first appear from a corner of the opening and incline towards the point load. The shear

Figure 6.1 **Beam 1A after testing, failure by bearing under load point**

Figure 6.2 **Beam 1Af after testing, failure by bearing under load point**

Figure 6.3 **Beam 1C after testing, failure by bearing under load point**

Figure 6.4 **Beam 2A after testing, failure by shear over opening**

Figure 6.5 **Beam 2Af after testing, failure by shear over opening**

Figure 6.6 **Beam 2C after testing, failure by shear over opening**

Figure 6.7 Beam 3A after testing, failure by bearing under load point

Figure 6.8 Beam 3B after testing, failure by bearing under load point

Figure 6.9 **Beam 4A after testing, failure by shear over opening**

Figure 6.10 **Beam 4B after testing, failure by shear over opening**

Figure 6.11 Beam 5A after testing, failure by shear over opening

Figure 6.12 Beam 5B after testing, failure by shear over opening

cracks over the openings began at approximately 40% of the ultimate load. As with all cracks, the closer the crack was to the point load, the smaller the crack width. These shear cracks were often the major failure planes of the beams.

Third Stage: At approximately 50% to 60% of the ultimate load, shear cracks appeared in the inside edge of the support, inclined splitting cracks appeared in the shear span over the opening, and diagonal cracks appeared within the shear span of the beams over the supports. These cracks inclined toward the centerline of the beams. Upon further loading, at approximately 80% of the ultimate load, flexural cracks occasionally occurred on the top of the beams beside the centrally located point load. These small, short cracks had very little influence to the behavior of the beams, and were barely noticeable.

6.2.2 Failure Modes

The beams in this study failed in one of two modes, by shear failure over the opening or by bearing failure under the point load. . In this study, when the opening interrupted the natural load path of the beams, the beams failed by shear over the opening. When the opening did not interrupt the natural load path of the beams, the beams failed in bearing under the point load.

Shear Failure: Beam series 2, 4, and 5 failed by shear over the opening. The shear cracks beginning at the upper corners of the opening combined with the inclined splitting cracks in the shear span over the opening would lead the beams to fail in shear

Bearing Failure: Beam series 1 and 3 failed by bearing under the point load. This failure occurred around the steel bearing block under the point load. Splitting cracks would first

appear and concrete crushing would subsequently occur beneath the load bearing block. Bearing failure is an out-of-plane failure. This failure mode is not considered in the finite element analysis of the beams and is dealt with separately. The short column design and the plates clamped to provide confinement at the load points were applied to resist this out-of-plane failure. Because of this out-of-plane failure, the shear or flexural strength of the beams failing in bearing were never realized for four of the twelve beams. In this study, the beams failed in bearing when the opening did not interrupt the natural load paths of the beams.

6.2.3 Load-Deflection Relationships

Deflections were measured at the midspan at the bottom of the beam and at the top midspan of the opening. The load versus deflection graphs of the beams tested are presented in Figures 6.13-6.21. The beams' stiffness is most dependant on the opening locations. The deflection relative to the load in the span created by the opening increased as the opening was closer to the point load. Conversely, deflections at the bottom of the beam decreased, as the opening location was closer to the point load.

Concrete compressive strength also influenced the stiffness of the beams. Higher concrete compressive strength results in a higher modulus of elasticity, which increases the overall stiffness of the beam.

Table 6.1 presents the deflections of the beams at the design loads and at the ultimate loads. ACI 318-99 section 9.5.2.6 limits the deflection due to immediate live load to 360^{th} of the supported span length. With a span length of 36 inches, the

**Beam Series 1: Load vs. Deflection
(Bottom Center)**

Figure 6.13 Load vs. deflection, Beam Series 1 (Bottom Center)

**Beam Series 2: Load vs. Deflection
(Opening Top Center)**

Figure 6.14 Load vs. deflection, Beam Series 2 (Opening Center)

**Beam Series 2: Load vs. Deflection
(Bottom Center)**

Figure 6.15 Load vs. deflection, Beam Series 2 (Bottom Center)

Beam Series 3: Load vs. Deflection (Opening Top Center)

Figure 6 16 Load vs. Deflection, Beam Series 3 (Opening Center)

**Beam Series 3: Load vs. Deflection
(Bottom Center)**

Figure 6.17 Load vs. Deflection, Beam Series 3 (Bottom Center)

**Beam Series 4: Load vs. Deflection
(Opening Top Center)**

Figure 6.18 Load vs. Deflection, Beam Series 4 (Opening Center)

**Beam Series 4: Load vs. Deflection
(Bottom Center)**

Figure 6.19 Load vs. Deflection, Beam Series 4 (Bottom Center)

**Beam Series 5: Load vs. Deflection
(Opening Center)**

Figure 6.20 Load vs. Deflection, Beam Series 5 (Opening Center)

**Beam Series 5: Load vs. Deflection
(Bottom Center)**

Figure 6.21 Load vs. Deflection, Beam Series 5 (Bottom Center)

Table 6.1 Beam Deflections and First Crack Loads

Beam	Design Load (kips)	Concrete Strength (psi)	First Crack Load (kips)	Deflection at Opening Center (in.)		Deflection at Bottom Center (in.)	
				Design Load	Ultimate Load	Design Load	Ultimate Load
1A	175	7253	70	-	-	0.060	0.105
1Af	175	6689	50	-	-	0.068	0.109
1Cf	175	11025	85	-	-	0.050	0.122
2A	125	7695	30	0.081	0.148	0.048	0.071
2Af	125	7047	48	0.070	0.108	0.034	0.038
2Cf	125	10653	60	0.069	0.159	0.028	0.052
3A	150	6882	40	0.082	0.140	0.058	0.094
3B	150	8851	40	0.063	0.176	0.043	0.125
4A	70	6633	80	0.042	0.080	0.010	0.023
4B	70	8565	50	0.036	0.066	0.009	0.017
5A	100	7088	60	0.040	0.090	0.023	0.051
5B	100	8672	60	0.013	0.032	0.010	0.002

Beam Series 1: Load vs. Steel Strain
(Bottom Center)

Figure 6.22 Load vs. Steel Strain, Beam Series 1 (Bottom Center)

Beam Series 2: Load vs. Steel Strain (Opening Center)

Figure 6.23 Load vs. Steel Strain, Beam Series 2 (Opening Center)

Beam Series 2: Load vs. Steel Strain (Bottom Center)

Figure 6.24 Load vs. Steel Strain, Beam Series 2 (Bottom Center)

**Beam Series 3: Load vs. Steel Strain
(Opening Center)**

Figure 6.25 Load vs. Steel Strain, Beam Series 3 (Opening Center)

**Beam Series 3: Load vs. Steel Strain
(Bottom Center)**

Figure 6.26 Load vs. Steel Strain, Beam Series 3 (Bottom Center)

**Beam 5B: Load vs. Steel Strain
(Opening Center)**

Figure 6.27 Load vs. Steel Strain, Beam 5B (Opening Center)

**Beam 5B: Load vs. Steel Strain
(Bottom Center)**

Figure 6.28 Load vs. Steel Strain, Beam 5B (Bottom Center)

maximum allowable deflection is 0.1 inch. All the beams meet the allowable service deflections at the design loads.

6.2.4 Steel Strain

The steel used in this study had a minimum yield strength of 60ksi, which has a minimum yield strain of 0.0021. Unfortunately, steel data was lost for 3 beams in this study: Beam 4A, Beam 4B, and Beam 5A. The plots of the steel strains are presented in Figures 6.22- 6.28.

A number of the steel strain graphs show signs of steel slippage resulting from poor anchorage, which is indicated by an increased load with no change in strain or negative change in strain. The steel strains correspond to the beams deflections. There strain at the bottom of the beam increased relative to the load as the opening is farther away from the load point.

6.2.5 Effects of Fiber Reinforced Concrete

Four beams in beam series 1 and 2 had polypropylene fibers incorporated into the matrix of the concrete at 1.5 pounds of fiber to a cubic yard of concrete. This is approximately 0.037% by weight, which is a low dosage. The only difference between beams 1A and 1Af, and beams 2A and 2Af is that the “f” beams have plastic fibers incorporated into the matrix of the concrete. The addition of fibers had an insignificant effect on the behavior of the deep beams. From Table 6.2, it can be seen that the introduction of fibers into the beams play little, if any, effect to the ultimate strength of

the beams. There is a significant increase in ultimate strength for beams 1Cf and 2Cf with the fibers, but this increase in ultimate strength is not from the addition of fibers. The increase in ultimate strength is from an increase in the compressive strength of the concrete.

The fibers have little influence on the stiffness of the deep beams due to polypropylene's low strength. Figures 6.29-30 show the load versus deflection graphs of beam series 1 and 2 respectively.

Fiber reinforced concrete can help limit crack propagation and widening. The first crack results of Table 6.1 shows no clear sign of a delayed first crack with the addition of the fibers. Although crack widths were not measured in this study, the fibers did not have a noticeable effect on the cracking of the deep beams. Fibers can add ductility to structures. However the beams' ductility could not be measured since the loading was force controlled.

Table 6.2 Plastic Fiber Results

Beam	f'_c (psi)	Fiber/No Fiber	Ultimate Load (kips)	Failure Mode
1A	7,253	No Fiber	240	Bearing
1Af	6,689	Fiber	250	Bearing
1Cf	11,025	Fiber	290	Bearing

Beam	f'_c (psi)	Fiber/No Fiber	Ultimate Load (kips)	Failure Mode
2A	7,695	No Fiber	185	Shear over opening
2Af	7,047	Fiber	165	Shear over opening
2Cf	10,653	Fiber	230	Shear over opening

Beam Series 1: Load vs. Deflection at Bottom Center

Figure 6.29 Load vs. Deflection, Beam Series 1 (Bottom Center)

Beam 2: Load vs. Deflection Over Opening

Figure 6.30 Load vs. Deflection, Beam Series 2 (Opening Center)

6.2.6 Ultimate Loads

Table 6.3 lists the beams design and failure loads along with their failure modes. A graph of the beams with their corresponding design loads is presented in Figure 6.26. All the beams met their design loads by at least 30% in reserve strength. On average, the beams failed at 60% greater than the design strength.

As discussed in section 4.3.2, the design equations show that an increase in concrete compressive strength does not significantly reduce the required reinforcement for a beam. It is shown in the testing that increasing the concrete strength will increase the beam strength. The beams reserve strength beyond the design load was most dependent upon the concrete strength.

6.2.7 Results of Repair Using Carbon Fiber Laminates

Beams 2A, 4B, and 5A were repaired using carbon fiber laminates and retested to failure. Each of the three repaired beams failed in a different manner. Table 6.4 describes the beams design strength, the original ultimate load before the repair, and the strength of the beams after the carbon fiber repair. Beam 2A had three layers of the carbon fiber laminate applied to each face of the beam. Even though it had the most reinforcement, it did not have the greatest strength recovery. It can be observed from the table that the ratio of repaired strength to the original strength is not simply affected by the number of laminate layers. The carbon fiber reinforcement of Beam 2A failed prematurely as can be seen in Figure 6.32. Beam 2A failed originally at a load of 186 kips and was retested to a load of 140 kips. The beam failed at the same location it failed originally by the

Table 6.3 Deep Beam Testing Summary

Beam	Design Load (kips)	Ultimate Load (kips)	Ultimate/Design	Failure Mode	Concrete Strength (psi)
1A	175	240	137.1%	Bearing failure at load point	7253
1Af	175	249.9	142.8%	Bearing failure at load point	6689
1Cf	175	297.5	170.0%	Bearing failure at load point	11025
2A	125	185.9	148.7%	Shear failure over opening	7695
2Af	125	162.9	130.3%	Shear failure over opening	7047
2Cf	125	228.6	182.9%	Shear failure over opening	10653
3A	150	226.4	150.9%	Bearing failure at load point	6882
3B	150	260	173.3%	Bearing failure at load point	8851
4A	70	104.5	149.3%	Shear failure over opening	6633
4B	70	105.5	150.7%	Shear failure over opening	8565
5A	100	170	170.0%	Shear failure over opening	7088
5B	100	219	219.0%	Shear failure over opening	8672
Average Ultimate Strength / Design Strength:			160.4%

Figure 6.31 Graph of beam testing results

delaminating of the fibers at the major shear crack. The concrete broke out of plane and pulled the laminate away from the face of the concrete, tearing off the face of the concrete.

Table 6.4 Carbon Fiber Repair Results

	Beam 4B 1 Layer	Beam 5A 2 Layers	Beam 2A 3 Layers
Design Strength	70k	100k	125k
Original Strength	106k	170k	186k
Repaired Strength	85k	111k	140k
Repaired/Original	0.8	0.65	0.75

Figure 6.32 Beam 2A repaired and retested

Beam 5A failed originally by shear over the opening at a load of 170 kips. It was repaired with two layers of the carbon fiber on each face of the beam. It was expected that the repaired beam would fail again in the damaged region, but instead Beam 5A failed in shear below the opening from a crack that propagated from the left support as can be seen in Figure 6.33. The fibers were able to sustain the shear load of 111 kips applied to the beam. Although the bottom of the beam was able to resist a larger load applied to the beam originally, the entire mechanics of the beam changed with the addition of the carbon fiber laminates. The region reinforced by the laminate became stiffer than the original area, affecting the behavior of the entire beam. This explains the lower ratio of repaired to original strength.

Figure 6.33 Beam 5A repaired and retested

The last beam repaired and retested was Beam 4B which failed originally by shear over the opening. The beam failed originally at 106 kips and was repaired with a single layer of carbon fiber on each face of the beam over the opening. Like the repaired Beam 2A, the repaired Beam 4B failed at the original major shear crack. But unlike Beam 2A, Beam 4B did not fail prematurely by an out of plane failure. The concrete remained in plane and the beam failed by the tearing of the carbon fiber along the major shear crack over the opening as shown in Figure 6.34. The beam was retested to a load of 85 kips.

Figure 6.34 Beam 4B repaired and retested

Although Beam 4B had only one layer of carbon fiber, it had the best recovery of strength for the three beams repaired. This was due to the out-of-plane failure of Beam 2A and Beam 5A's failure away from the repaired region of the beam.

The number of layers of fiber reinforcement plays a significant role on the behavior of the beam. As the number of laminate layers increased, the stiffness of the beams matched more closely to the original behavior of the beams as can be seen in Figure 6.35. The figure also shows that the carbon fiber provides more ductility after reaching the ultimate load.

Carbon Fiber Beam Repair Load vs. Deflection Over Opening

Figure 6.35 Carbon Fiber Repair, Load vs. Deflections

Chapter 7 – SUMMARY AND CONCLUSION

7.1 Summary

Twelve deep beams with and without openings were designed and constructed using the proposed direct design method. The deep beams were tested to their ultimate loads and performed to meet their design criteria. It was observed that the failure modes were greatly influenced by the geometry of the beams and the ultimate strengths were highly dependent on the concrete compressive strength. The design method was found to be conservative for the beams investigated in this study. The average ultimate strength was 160% of the ultimate design strength.

Three beams were repaired using carbon fiber laminates. This study shows that the carbon fiber repair method is very effective, restoring 80% of the ultimate capacity of the beams using only one layer of repair laminate on each side of the beam. The study shows that the number layers of carbon fiber laminates can affect the stiffness and strength of the deep beams.

7.2 Conclusion

The following conclusions were found based on the results of the testing.

1. The proposed direct design method is a safe and reliable approach for designing concrete deep beams with openings. The average ultimate strength for the beams was 160% of the design strength.
2. The position of the opening is a major factor influencing behavior of the deep beams. When the opening did not interrupt the natural load path of the beam, it

behaved like a solid deep beam. In this study, the beams with openings that interrupted the natural load path of the beam failed by shear failure over the opening.

3. According to the design equations, an increase in concrete strength will not significantly reduce the required steel for the beam design. However, it is clearly seen that higher concrete strengths will result in higher ultimate load capacities.
4. The addition of polypropylene fibers into the concrete mix can increase the beam strength, stiffness, and ductility. This study found that polypropylene fibers at a dosage of 1.5 pounds per cubic yard of concrete (0.037% by weight) have a minimal effect on the beams' cracking, stiffness, and ultimate failure modes.
5. The use of carbon fiber reinforced laminates is an effective method for repairing and strengthening deep beams. The fibers provided more ductility to the beams. The beam's stiffness increased with an increase in carbon fiber laminate layers.

7.3 Suggestions for Future Work

The following are suggestions for future work.

1. Full scale testing should be considered to verify that scale effects do not influence the behavior of the beams.
2. Future studies should include different types of loading and different beam geometries to further test the design method. This includes studies with continuous beams, multiple load points, different beam dimensions, and different opening positions, sizes, and shapes.

3. The design equations may be modified to account for the increased beam strength with increase in concrete strength.
4. The finite element mesh influences the results of the required reinforcement. A study varying the finite element meshes can be conducted to see how it affects the required reinforcement results.
5. A nonlinear analysis can be employed for the finite element evaluation. It can be used to verify the beam's mode of failure and create a more efficient beam design.
6. A more extensive testing program can be applied to the carbon fiber laminate repair study. This may include the use of different fiber types, different fiber orientations, layers, and types of epoxy.

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TESTING DATA

Instrument Numbering

BEAM 1A

#2	#2deflection	#2 actual	#3	#3deflection	#4	#4deflection	3&4 average	#7	#7microstrain	#8	#8microstrain	7&8 average	Load
-8.54	0.000	0.000	8.930	0.000	8.080	0.000	0.000	0.079	0.000	0.074	0.000	0.000	0
-8.43	0.005	0.001	8.980	0.002	8.200	0.005	0.004	0.138	17.520	0.130	16.830	17.175	5
-8.35	0.009	0.003	9.000	0.003	8.270	0.009	0.006	0.198	35.520	0.188	33.810	34.665	10
-8.29	0.011	0.003	9.050	0.005	8.330	0.011	0.008	0.327	74.400	0.303	68.970	71.685	15
-8.24	0.014	0.004	9.070	0.006	8.370	0.013	0.010	0.784	211.470	0.717	193.050	202.260	20
-8.19	0.016	0.004	9.120	0.009	8.410	0.015	0.012	1.152	321.870	1.057	295.050	308.460	25
-8.15	0.018	0.005	9.140	0.009	8.440	0.016	0.013	1.424	403.470	1.306	369.750	386.610	30
-8.11	0.019	0.005	9.170	0.011	8.470	0.017	0.014	1.639	467.970	1.498	427.350	447.660	35
-8.04	0.023	0.007	9.200	0.012	8.500	0.019	0.015	1.873	538.170	1.713	491.850	515.010	40
-7.99	0.025	0.009	9.210	0.013	8.520	0.020	0.016	2.089	602.970	1.924	555.150	579.060	45
-7.95	0.027	0.009	9.230	0.014	8.540	0.021	0.017	2.294	664.470	2.119	613.650	639.060	50
-7.89	0.029	0.012	9.240	0.014	8.560	0.022	0.018	2.518	731.670	2.331	677.250	704.460	55
-7.84	0.032	0.013	9.250	0.014	8.570	0.022	0.018	2.815	820.770	2.616	762.750	791.760	60
-7.8	0.033	0.014	9.270	0.015	8.590	0.023	0.019	3.091	903.570	2.878	841.350	872.460	65
-7.75	0.036	0.016	9.280	0.016	8.600	0.023	0.020	3.291	963.570	3.072	899.550	931.560	70
-7.68	0.039	0.018	9.290	0.016	8.630	0.025	0.020	3.540	1038.270	3.318	973.350	1005.810	75
-7.62	0.041	0.021	9.300	0.017	8.630	0.025	0.021	3.750	1101.270	3.510	1030.950	1066.110	80
-7.58	0.043	0.022	9.310	0.017	8.640	0.025	0.021	3.980	1170.270	3.730	1096.950	1133.610	85
-7.49	0.047	0.025	9.330	0.018	8.680	0.027	0.022	4.560	1344.270	4.250	1252.950	1298.610	90
-7.43	0.050	0.028	9.320	0.018	8.690	0.027	0.022	4.760	1404.270	4.440	1309.950	1357.110	95
-7.36	0.053	0.030	9.330	0.018	8.710	0.028	0.023	5.090	1503.270	4.750	1402.950	1453.110	100
-7.31	0.055	0.032	9.330	0.018	8.730	0.029	0.024	5.300	1566.270	4.950	1462.950	1514.610	105
-7.26	0.058	0.034	9.340	0.018	8.730	0.029	0.024	5.490	1623.270	5.130	1516.950	1570.110	110
-7.21	0.060	0.036	9.340	0.018	8.740	0.030	0.024	5.690	1683.270	5.330	1576.950	1630.110	115
-7.16	0.062	0.038	9.350	0.019	8.740	0.030	0.024	5.910	1749.270	5.540	1639.950	1694.610	120
-7.11	0.064	0.039	9.370	0.020	8.770	0.031	0.025	6.120	1812.270	5.730	1696.950	1754.610	125
-7.06	0.067	0.041	9.380	0.020	8.780	0.031	0.026	6.330	1875.270	5.920	1753.950	1814.610	130
-7.01	0.069	0.043	9.390	0.021	8.780	0.031	0.026	6.540	1938.270	6.120	1813.950	1876.110	135
-6.96	0.071	0.045	9.400	0.021	8.780	0.031	0.026	6.690	1983.270	6.250	1852.950	1918.110	140
-6.89	0.074	0.048	9.400	0.021	8.780	0.031	0.026	6.910	2049.270	6.420	1903.950	1976.610	145
-6.82	0.077	0.051	9.400	0.021	8.790	0.032	0.027	7.390	2183.270	6.740	1999.950	2096.610	150
-6.77	0.080	0.052	9.430	0.023	8.820	0.033	0.028	7.660	2274.270	6.930	2056.950	2165.610	155
-6.72	0.082	0.054	9.440	0.023	8.830	0.034	0.028	7.890	2343.270	7.150	2122.950	2233.110	160
-6.66	0.085	0.056	9.440	0.023	8.830	0.034	0.028	8.120	2412.270	7.350	2182.950	2297.610	165
-6.6	0.087	0.059	9.460	0.024	8.830	0.034	0.029	8.370	2487.270	7.570	2248.950	2368.110	170
-6.55	0.090	0.060	9.470	0.024	8.860	0.035	0.030	8.630	2565.270	7.800	2317.950	2441.610	175
-6.49	0.092	0.063	9.470	0.024	8.860	0.035	0.030	8.920	2652.270	8.040	2389.950	2521.110	180
-6.44	0.095	0.064	9.490	0.025	8.890	0.036	0.031	9.200	2736.270	8.280	2461.950	2599.110	185
-6.38	0.097	0.066	9.510	0.026	8.890	0.036	0.031	9.470	2817.270	8.510	2530.950	2674.110	190
-6.32	0.100	0.069	9.510	0.026	8.890	0.036	0.031	9.750	2901.270	8.760	2605.950	2753.610	195
-6.26	0.103	0.071	9.520	0.027	8.900	0.037	0.032	10.100	3006.270	9.050	2692.950	2849.610	200
-6.19	0.106	0.074	9.510	0.026	8.900	0.037	0.031	10.550	3141.270	9.420	2803.950	2972.610	205
-6.09	0.110	0.078	9.510	0.026	8.940	0.039	0.032	13.600	4056.270	13.360	3985.950	4021.110	210
-6.01	0.114	0.081	9.520	0.027	8.940	0.039	0.033	13.610	4059.270	13.660	4075.950	4067.610	215
-5.93	0.118	0.084	9.520	0.027	8.960	0.039	0.033	13.620	4062.270	13.660	4075.950	4069.110	220
-5.77	0.125	0.092	9.520	0.027	8.960	0.039	0.033	13.620	4062.270	13.660	4075.950	4069.110	225
-5.68	0.129	0.095	9.530	0.027	8.970	0.040	0.033	13.620	4062.270	13.660	4075.950	4069.110	230
-5.59	0.133	0.099	9.540	0.027	8.970	0.040	0.034	13.610	4059.270	13.660	4075.950	4067.610	235
-5.46	0.139	0.105	9.530	0.027	8.970	0.040	0.033	13.620	4062.270	13.670	4078.950	4070.610	240
-5.22	0.149	0.116	9.550	0.028	8.970	0.040	0.034	13.610	4059.270	13.660	4075.950	4067.610	237
-5.21	0.150	0.116	9.540	0.027	8.970	0.040	0.034	13.610	4059.270	13.660	4075.950	4067.610	236
-5.13	0.154	0.120	9.540	0.027	8.970	0.040	0.034	13.610	4059.270	13.670	4078.950	4069.110	226

BEAM 1A1

#2	#2deflection	#3	#3deflection	#4	#4deflection	3&4 average	#2 actual	#7	#7microstrain	#8	#8microstrain	7&8 average	Load
-6.7	0.000	2.083	0.000	7.930	0.000	0.000	0.000	-0.019	0.000	-0.011	0.000	0.000	0
-6.35	0.016	2.229	0.007	8.380	0.019	0.013	0.003	0.052	21.270	0.031	12.600	10.651	5
-6.18	0.023	2.307	0.010	8.610	0.030	0.020	0.003	0.112	39.420	0.066	23.220	19.743	10
-6.08	0.029	2.367	0.013	8.750	0.037	0.025	0.004	0.191	63.090	0.115	37.800	31.603	15
-5.98	0.032	2.391	0.014	8.820	0.040	0.027	0.006	0.292	93.360	0.178	56.550	46.769	20
-5.93	0.035	2.431	0.016	8.850	0.041	0.028	0.006	0.392	123.330	0.242	75.810	61.786	25
-5.88	0.037	2.437	0.016	8.880	0.043	0.029	0.008	0.543	168.630	0.375	115.800	84.503	30
-5.84	0.039	2.440	0.016	8.910	0.044	0.030	0.009	0.682	210.330	0.473	145.200	105.402	35
-5.79	0.041	2.441	0.016	8.920	0.044	0.030	0.011	1.044	318.930	0.980	297.300	159.955	40
-5.73	0.044	2.441	0.016	8.950	0.046	0.031	0.013	1.423	432.630	1.367	413.400	216.999	45
-5.68	0.046	2.442	0.016	8.950	0.046	0.031	0.015	1.621	492.030	1.577	476.400	246.804	50
-5.64	0.048	2.442	0.016	8.960	0.046	0.031	0.017	1.763	534.630	1.710	516.300	268.170	55
-5.61	0.049	2.443	0.016	8.970	0.047	0.031	0.018	1.865	565.230	1.807	545.400	283.519	60
-5.55	0.052	2.441	0.016	8.970	0.047	0.031	0.020	2.034	615.930	1.972	594.900	308.951	65
-5.51	0.054	2.442	0.016	9.000	0.048	0.032	0.022	2.264	684.930	2.164	652.500	343.547	70
-5.42	0.058	2.444	0.016	9.010	0.048	0.032	0.025	2.811	849.030	2.675	805.800	425.853	75
-5.36	0.060	2.446	0.016	9.020	0.049	0.033	0.028	3.127	943.830	2.987	899.400	473.409	80
-5.3	0.063	2.445	0.016	9.030	0.049	0.033	0.030	3.302	996.330	3.160	951.300	499.745	85
-5.25	0.065	2.445	0.016	9.040	0.050	0.033	0.032	3.500	1055.730	3.358	1010.700	529.544	90
-5.14	0.070	2.447	0.016	9.060	0.051	0.034	0.037	3.910	1178.730	3.820	1149.300	591.275	95
-5.1	0.072	2.448	0.016	9.060	0.051	0.034	0.038	4.000	1205.730	3.930	1182.300	604.830	100
-5.05	0.074	2.448	0.016	9.070	0.051	0.034	0.041	4.170	1256.730	4.100	1233.300	630.415	105
-4.98	0.077	2.449	0.016	9.100	0.052	0.034	0.043	4.390	1322.730	4.440	1335.300	663.585	110
-4.94	0.079	2.450	0.017	9.130	0.054	0.035	0.044	4.510	1358.730	4.750	1428.300	681.740	115
-4.89	0.081	2.451	0.017	9.150	0.055	0.036	0.046	4.580	1379.730	4.930	1482.300	692.330	120
-4.84	0.084	2.451	0.017	9.150	0.055	0.036	0.048	4.740	1427.730	5.170	1554.300	716.450	125
-4.79	0.086	2.452	0.017	9.160	0.055	0.036	0.050	4.870	1466.730	5.410	1626.300	736.070	130
-4.74	0.088	2.451	0.017	9.160	0.055	0.036	0.052	4.980	1499.730	5.600	1683.300	752.665	135
-4.7	0.090	2.451	0.017	9.160	0.055	0.036	0.054	5.090	1532.730	5.800	1743.300	769.265	140
-4.66	0.092	2.454	0.017	9.180	0.056	0.036	0.055	5.210	1568.730	6.000	1803.300	787.365	145
-4.62	0.094	2.455	0.017	9.180	0.056	0.036	0.057	5.310	1598.730	6.180	1857.300	802.455	150
-4.56	0.096	2.452	0.017	9.180	0.056	0.036	0.060	5.420	1631.730	6.390	1920.300	819.060	155
-4.52	0.098	2.458	0.017	9.180	0.056	0.036	0.062	5.510	1658.730	6.590	1980.300	832.660	160
-4.47	0.100	2.455	0.017	9.180	0.056	0.036	0.064	5.610	1688.730	6.800	2043.300	847.765	165
-4.43	0.102	2.455	0.017	9.180	0.056	0.036	0.066	5.720	1721.730	7.000	2103.300	864.365	170
-4.38	0.104	2.455	0.017	9.180	0.056	0.036	0.068	5.820	1751.730	7.240	2175.300	879.485	175
-4.28	0.109	2.453	0.017	9.230	0.058	0.037	0.071	6.050	1820.730	7.600	2283.300	914.165	180
-4.23	0.111	2.455	0.017	9.230	0.058	0.038	0.074	6.180	1859.730	7.830	2352.300	933.780	185
-4.18	0.113	2.455	0.017	9.230	0.058	0.038	0.076	6.270	1886.730	8.030	2412.300	947.380	190
-4.14	0.115	2.454	0.017	9.230	0.058	0.037	0.078	6.240	1877.730	8.210	2466.300	942.970	195
-4.09	0.118	2.453	0.017	9.230	0.058	0.037	0.080	6.250	1880.730	8.380	2517.300	944.555	200
-4.04	0.120	2.454	0.017	9.230	0.058	0.037	0.082	6.230	1874.730	8.550	2568.300	941.640	205
-4	0.122	2.456	0.017	9.230	0.058	0.038	0.084	6.190	1862.730	8.770	2634.300	935.750	210
-3.93	0.125	2.455	0.017	9.230	0.058	0.038	0.087	6.270	1886.730	9.320	2799.300	948.025	215
-3.87	0.127	2.455	0.017	9.230	0.058	0.038	0.090	6.280	1889.730	9.740	2925.300	949.735	220
-3.82	0.130	2.454	0.017	9.240	0.059	0.038	0.092	6.280	1889.730	10.540	3165.300	950.135	225
-3.76	0.132	2.456	0.017	9.240	0.059	0.038	0.095	6.770	2036.730	13.340	4005.300	1025.035	230
-3.67	0.136	2.457	0.017	9.230	0.058	0.038	0.099	6.920	2081.730	13.650	4098.300	1047.690	235
-3.61	0.139	2.455	0.017	9.230	0.058	0.038	0.102	6.880	2069.730	11.260	3381.300	1040.495	240
-3.51	0.144	2.455	0.017	9.240	0.059	0.038	0.106	6.780	2039.730	10.920	3279.300	1025.325	245
-3.43	0.147	2.455	0.017	9.240	0.059	0.038	0.109	6.620	1991.730	11.300	3393.300	1001.515	249.5
-3.42	0.148	2.455	0.017	9.230	0.058	0.038	0.110	6.540	1967.730	11.460	3441.300	989.595	240
-3.41	0.148	2.455	0.017	9.240	0.059	0.038	0.110	6.490	1952.730	11.510	3456.300	982.120	235

BEAM 1C7

#2	#2deflection	#3	#3deflection	#4	#4deflection	3&4 average	#2 actual	#7	#7microstrain	#8	#8microstrain	7&8 average	Load
-8.160	0.000	7.950	0.000	8.640	0.000	0.000	0.000	-0.003	0.000	-0.006	0.000	0.000	0
-7.880	0.013	8.390	0.020	8.740	0.004	0.012	0.000	0.011	3.960	0.013	5.670	4.815	5
-7.610	0.025	8.640	0.031	9.030	0.017	0.024	0.000	0.024	8.070	0.034	11.880	9.975	10
-7.370	0.036	8.830	0.040	9.240	0.027	0.033	0.002	0.043	13.680	0.056	18.450	16.065	15
-7.190	0.044	8.930	0.044	9.440	0.036	0.040	0.004	0.062	19.260	0.078	25.050	22.155	20
-7.040	0.050	9.060	0.050	9.620	0.044	0.047	0.003	0.090	27.750	0.108	34.140	30.945	25
-6.920	0.056	9.160	0.055	9.770	0.051	0.053	0.003	0.127	38.880	0.145	45.210	42.045	30
-6.750	0.063	9.230	0.058	10.010	0.061	0.060	0.004	0.194	59.100	0.205	63.120	61.110	35
-6.630	0.069	9.280	0.060	10.150	0.068	0.064	0.005	0.279	84.450	0.274	84.030	84.240	40
-6.540	0.073	9.310	0.061	10.260	0.073	0.067	0.006	0.382	115.410	0.360	109.740	112.575	45
-6.430	0.078	9.350	0.063	10.260	0.073	0.068	0.010	0.562	169.410	0.511	155.040	140.000	50
-6.320	0.083	9.400	0.065	10.260	0.073	0.069	0.014	0.867	260.910	0.776	234.540	180.000	55
-6.220	0.087	9.450	0.068	10.260	0.073	0.070	0.017	1.010	303.810	0.897	270.840	210.000	60
-6.120	0.092	9.520	0.071	10.260	0.073	0.072	0.020	1.102	331.410	0.969	292.440	240.000	65
-5.880	0.103	9.730	0.080	10.260	0.073	0.076	0.026	1.230	369.810	1.061	320.040	280.000	70
-5.750	0.109	9.790	0.083	10.260	0.073	0.078	0.031	1.378	414.210	0.653	197.640	305.925	75
-5.630	0.114	9.820	0.084	10.260	0.073	0.078	0.035	1.647	494.910	0.735	222.240	358.575	80
-5.480	0.121	9.840	0.085	10.260	0.073	0.079	0.042	1.868	561.210	0.769	232.440	396.825	85
-5.350	0.127	9.890	0.087	10.260	0.073	0.080	0.046	2.023	607.710	0.787	237.840	422.775	90
-5.240	0.131	9.900	0.088	10.260	0.073	0.080	0.051	2.239	672.510	0.792	239.340	455.925	95
-5.120	0.137	9.940	0.090	10.260	0.073	0.081	0.056	2.451	736.110	0.810	244.740	490.425	100
-5.030	0.141	10.000	0.092	10.260	0.073	0.083	0.058	2.637	791.910	0.804	242.940	517.425	105
-4.880	0.148	10.000	0.092	10.260	0.073	0.083	0.065	2.734	821.010	0.240	73.830	550.000	110
-4.770	0.153	10.050	0.095	10.260	0.073	0.084	0.069	2.846	854.610	0.209	64.320	570.000	115
-4.640	0.158	10.070	0.096	10.260	0.073	0.084	0.074	2.903	871.710	0.172	53.340	590.000	120
-4.550	0.163	10.110	0.097	10.260	0.073	0.085	0.078	3.007	902.910	0.185	57.270	605.000	125
-4.530	0.163	10.120	0.098	10.260	0.073	0.085	0.077	3.007	902.910	0.184	56.910	620.000	130
-4.530	0.163	10.110	0.097	10.260	0.073	0.085	0.078	2.997	899.910	0.175	54.090	650.000	135
-4.480	0.166	10.120	0.098	10.260	0.073	0.085	0.078	2.986	899.610	0.174	53.970	675.000	140
-4.220	0.177	10.200	0.101	10.260	0.073	0.087	0.080	3.075	923.310	0.186	57.390	685.000	145
-4.130	0.181	10.230	0.103	10.260	0.073	0.088	0.094	3.389	1017.510	0.205	63.150	710.000	150
-4.100	0.183	10.290	0.105	10.260	0.073	0.089	0.094	3.450	1035.810	0.201	61.890	725.000	155
-4.050	0.185	10.290	0.105	10.260	0.073	0.089	0.096	3.430	1029.810	0.185	57.240	750.000	160
-3.920	0.191	10.360	0.109	10.260	0.073	0.091	0.100	3.510	1053.810	0.190	58.710	765.000	165
-3.730	0.199	10.430	0.112	10.260	0.073	0.092	0.107	3.620	1086.810	0.187	57.750	790.000	170
-3.540	0.208	10.470	0.114	10.260	0.073	0.093	0.115	3.800	1140.810	0.200	61.740	805.000	175
-3.490	0.210	10.480	0.114	10.260	0.073	0.093	0.117	4.190	1257.810	0.229	70.380	820.000	180
-3.450	0.212	10.480	0.114	10.260	0.073	0.093	0.119	4.230	1269.810	0.232	71.190	850.000	185
-3.430	0.213	10.470	0.114	10.260	0.073	0.093	0.120	4.170	1251.810	0.210	64.590	875.000	190
-3.270	0.220	10.570	0.118	10.260	0.073	0.095	0.125	4.170	1251.810	0.205	63.240	885.000	195
-3.180	0.224	10.620	0.120	10.260	0.073	0.095	0.128	4.340	1302.810	0.224	69.030	920.000	200
-3.014	0.232	10.690	0.123	10.260	0.073	0.096	0.134	4.480	1344.810	0.247	75.840	950.000	205
-2.935	0.235	10.720	0.125	10.260	0.073	0.098	0.137	4.640	1392.810	0.247	75.750	970.000	210
-2.844	0.239	10.740	0.126	10.260	0.073	0.099	0.140	4.730	1419.810	0.253	77.670	990.000	215
-2.774	0.243	10.750	0.126	10.260	0.073	0.099	0.143	4.770	1431.810	0.240	73.770	1005.000	220
-2.675	0.247	10.760	0.127	10.260	0.073	0.099	0.147	4.840	1452.810	0.263	80.610	1025.000	225
-2.562	0.252	10.790	0.128	10.260	0.073	0.100	0.152	4.720	1416.810	0.244	74.880	1050.000	230
-2.247	0.266	10.850	0.131	10.260	0.073	0.102	0.165	4.620	1386.810	0.305	93.180	1065.000	235
-2.238	0.267	10.840	0.130	10.260	0.073	0.101	0.165	7.480	2244.810	0.459	139.440	1085.000	240
-1.977	0.278	10.940	0.135	10.260	0.073	0.104	0.175	7.210	2163.810	0.419	127.440	1100.000	245
-1.969	0.279	10.940	0.135	10.260	0.073	0.104	0.175	7.810	2343.810	0.359	109.440	1150.000	250
-1.887	0.282	10.960	0.136	10.260	0.073	0.104	0.178	7.740	2322.810	0.344	104.940	1170.000	255
-1.886	0.282	10.960	0.136	10.260	0.073	0.104	0.178	7.120	2136.810	0.141	44.070	1205.000	260
-1.708	0.291	10.950	0.135	10.260	0.073	0.104	0.187	7.120	2136.810	0.139	43.350	1240.000	265
-1.701	0.291	10.950	0.135	10.260	0.073	0.104	0.187	8.290	2487.810	0.132	41.370	1300.000	270
-1.511	0.299	10.950	0.135	10.260	0.073	0.104	0.187	8.240	2472.810	0.124	38.790	1360.000	275
-1.504	0.300	10.960	0.136	10.260	0.073	0.104	0.195	9.540	2862.810	0.110	34.590	1390.000	280
-1.500	0.300	10.960	0.136	10.260	0.073	0.104	0.196	9.380	2814.810	0.080	25.860	1420.335	285
-1.302	0.309	10.950	0.135	10.260	0.073	0.104	0.198	9.260	2778.810	0.066	21.390	1500.000	290
-1.285	0.310	10.960	0.136	10.260	0.073	0.104	0.205	10.610	3183.810	-0.040	-10.380	1586.715	295
-1.280	0.310	10.950	0.135	10.260	0.073	0.104	0.205	10.470	3141.810	-0.060	-16.200	1562.805	297.5
						0.104	0.206	10.280	3084.810	-0.075	-20.850	1531.980	285

1	#1	#1 actual	2	#2	#2 actual	3	#3	4	#4	3&4 average	5	#5	6	#6	5&6 average	7	#7	8	#8	7&8 average	Load
-7.930	0.000	0.000	-7.870	0.000	0.000	8.180	0.000	8.140	0.000	0.000	0.005	0.000	0.005	0.000	0.000	0.007	0.000	0.003	0.000	0.000	0
-7.770	0.007	0.002	-7.710	0.007	0.002	8.390	0.008	8.160	0.001	0.005	0.084	23.610	0.111	31.770	27.690	0.065	17.280	0.059	16.890	50.000	5
-7.680	0.011	0.004	-7.620	0.011	0.004	8.470	0.013	8.170	0.001	0.007	0.151	43.680	0.203	58.340	51.510	0.114	32.250	0.108	31.560	125.000	10
-7.600	0.015	0.008	-7.570	0.014	0.005	8.520	0.015	8.190	0.002	0.008	0.228	66.900	0.300	68.580	77.745	0.173	48.820	0.164	48.300	170.000	15
-7.520	0.018	0.008	-7.510	0.018	0.008	8.530	0.015	8.240	0.004	0.010	0.330	87.580	0.424	125.730	111.660	0.279	81.660	0.266	78.990	250.000	20
-7.450	0.021	0.010	-7.460	0.018	0.007	8.570	0.017	8.270	0.006	0.011	0.431	127.770	0.545	162.030	144.900	0.485	143.430	0.486	144.960	340.000	25
-7.340	0.026	0.013	-7.360	0.023	0.010	8.620	0.019	8.300	0.007	0.013	0.833	248.370	1.081	322.830	285.600	1.368	408.630	1.548	483.880	438.245	30
-7.250	0.030	0.017	-7.290	0.026	0.013	8.620	0.019	8.310	0.006	0.014	1.087	324.570	1.419	424.230	374.400	1.616	482.730	1.883	564.080	523.395	35
-7.180	0.033	0.019	-7.240	0.028	0.014	8.640	0.020	8.340	0.008	0.015	1.282	383.070	1.685	504.030	443.560	1.718	513.330	2.012	602.780	554.045	40
-7.080	0.038	0.023	-7.170	0.032	0.018	8.670	0.022	8.340	0.008	0.015	1.508	450.270	1.988	584.330	522.300	1.823	574.830	2.255	675.880	625.245	45
-6.980	0.042	0.027	-7.100	0.035	0.018	8.670	0.022	8.350	0.008	0.016	1.722	515.070	2.288	678.830	587.000	2.300	687.930	2.571	770.480	728.195	50
-6.880	0.047	0.030	-7.040	0.037	0.021	8.710	0.023	8.360	0.010	0.017	1.832	548.070	2.383	713.430	630.750	2.553	783.830	2.787	835.280	798.545	55
-6.790	0.051	0.034	-6.980	0.040	0.024	8.750	0.023	8.360	0.010	0.016	2.019	604.170	2.621	784.830	684.500	2.781	832.230	2.982	883.760	862.885	60
-6.710	0.054	0.036	-6.910	0.043	0.027	8.710	0.023	8.360	0.010	0.017	2.118	633.870	2.755	825.030	728.450	3.029	908.830	3.181	953.460	930.045	65
-6.590	0.060	0.042	-6.860	0.045	0.028	8.750	0.025	8.360	0.010	0.018	2.288	684.870	2.933	878.430	781.850	3.241	970.230	3.377	1012.280	981.245	70
-6.510	0.063	0.046	-6.820	0.047	0.030	8.750	0.025	8.360	0.010	0.018	2.457	735.570	3.135	938.030	837.300	3.540	1058.930	3.580	1067.180	1063.545	75
-6.430	0.067	0.049	-6.770	0.050	0.032	8.760	0.026	8.360	0.010	0.018	2.628	788.870	3.352	1004.130	886.500	3.750	1122.930	3.740	1121.180	1122.045	80
-6.350	0.070	0.053	-6.730	0.051	0.034	8.760	0.026	8.360	0.010	0.018	2.823	845.370	3.580	1072.530	958.850	3.940	1178.930	3.830	1178.180	1178.045	85
-6.250	0.075	0.057	-6.660	0.054	0.036	8.760	0.026	8.360	0.010	0.018	3.082	928.070	3.820	1174.530	1050.300	4.220	1263.930	4.130	1234.180	1251.045	90
-6.180	0.078	0.058	-6.640	0.055	0.037	8.800	0.027	8.360	0.010	0.019	3.257	975.570	4.140	1240.530	1108.050	4.380	1314.930	4.270	1280.180	1297.545	95
-6.090	0.082	0.063	-6.580	0.056	0.039	8.800	0.027	8.360	0.010	0.019	3.460	1036.470	4.420	1324.530	1180.500	4.600	1377.930	4.480	1337.180	1357.545	100
-6.010	0.085	0.068	-6.540	0.060	0.041	8.830	0.029	8.360	0.010	0.019	3.630	1087.470	4.660	1386.530	1242.000	4.780	1434.930	4.620	1385.180	1410.045	105
-5.920	0.089	0.070	-6.480	0.062	0.043	8.840	0.029	8.360	0.010	0.020	3.820	1144.470	4.920	1474.530	1308.500	5.000	1487.930	4.810	1442.180	1470.045	110
-5.840	0.093	0.073	-6.450	0.064	0.044	8.880	0.030	8.360	0.010	0.020	3.980	1192.470	5.150	1543.530	1388.000	5.180	1551.930	4.970	1480.180	1521.045	115
-5.750	0.097	0.077	-6.380	0.067	0.047	8.880	0.030	8.360	0.010	0.020	4.170	1248.470	5.420	1624.530	1437.000	5.380	1614.930	5.180	1547.180	1581.045	120
-5.650	0.101	0.081	-6.330	0.069	0.048	8.870	0.031	8.380	0.011	0.021	4.360	1308.470	5.710	1711.530	1508.000	5.620	1683.930	5.380	1607.180	1645.545	125
-5.560	0.105	0.084	-6.280	0.071	0.050	8.880	0.031	8.380	0.011	0.021	4.520	1354.470	5.950	1783.530	1588.000	5.810	1740.930	5.530	1658.180	1696.545	130
-5.480	0.109	0.088	-6.250	0.073	0.052	8.880	0.031	8.400	0.012	0.021	4.680	1402.470	6.180	1852.530	1627.500	6.000	1797.930	5.710	1712.180	1735.045	135
-5.370	0.114	0.092	-6.180	0.076	0.054	8.880	0.031	8.420	0.013	0.022	4.870	1458.470	6.480	1942.530	1701.000	6.250	1872.930	5.930	1778.180	1825.545	140
-5.280	0.118	0.096	-6.130	0.078	0.056	8.880	0.031	8.440	0.013	0.022	5.050	1513.470	6.770	2029.530	1771.500	6.470	1938.930	6.120	1835.180	1887.045	145
-5.190	0.122	0.099	-6.080	0.081	0.058	8.880	0.031	8.470	0.015	0.023	5.220	1564.470	7.050	2113.530	1838.000	6.670	1988.930	6.300	1889.180	1944.045	150
-5.090	0.126	0.102	-6.040	0.082	0.058	8.910	0.032	8.490	0.016	0.024	5.380	1615.470	7.340	2200.530	1908.000	6.880	2061.930	6.480	1943.180	2002.545	155
-4.990	0.131	0.108	-5.980	0.085	0.060	8.910	0.032	8.520	0.017	0.025	5.580	1675.470	7.670	2289.530	1987.500	7.100	2127.930	6.680	2003.180	2065.545	160
-4.880	0.136	0.111	-5.930	0.087	0.062	8.920	0.033	8.530	0.017	0.025	5.770	1729.470	8.000	2388.530	2064.000	7.310	2180.930	6.870	2090.180	2125.545	165
-4.770	0.141	0.115	-5.880	0.090	0.064	8.920	0.033	8.550	0.018	0.026	5.870	1788.470	8.380	2512.530	2151.000	7.530	2258.930	7.040	2111.180	2184.045	170
-4.620	0.147	0.121	-5.800	0.093	0.067	8.940	0.034	8.570	0.018	0.026	6.340	1900.470	8.950	2683.530	2292.000	7.820	2343.930	7.300	2189.180	2266.545	175
-4.500	0.153	0.128	-5.750	0.095	0.069	8.940	0.034	8.570	0.019	0.027	6.530	1957.470	9.270	2778.530	2368.500	8.030	2408.930	7.480	2243.180	2325.045	180
-4.210	0.166	0.138	-5.690	0.098	0.071	8.930	0.033	8.620	0.022	0.027	6.830	1987.470	9.710	2911.530	2448.500	8.290	2484.930	7.680	2308.180	2385.545	185
-3.980	0.176	0.148	-5.680	0.099	0.071	8.930	0.033	8.630	0.022	0.028	6.510	1951.470	9.750	2923.530	2437.500	8.380	2511.930	7.760	2327.180	2419.545	185.8
-3.900	0.179	0.151	-5.670	0.099	0.071	8.950	0.034	8.630	0.022	0.028	6.450	1933.470	9.730	2917.530	2425.500	8.360	2511.930	7.760	2327.180	2419.545	185
-3.790	0.184	0.158	-5.670	0.099	0.071	8.940	0.034	8.640	0.022	0.028	6.360	1908.470	9.670	2896.530	2403.000	8.350	2502.930	7.730	2318.180	2410.545	184
-3.760	0.186	0.157	-5.670	0.099	0.071	8.940	0.034	8.640	0.022	0.028	6.310	1891.470	9.640	2890.530	2381.000	8.340	2499.930	7.710	2312.180	2408.045	182
-3.700	0.188	0.160	-5.660	0.100	0.071	8.940	0.034	8.640	0.022	0.028	6.260	1876.470	9.620	2884.530	2360.500	8.320	2493.930	7.700	2309.180	2401.545	180

BEAM 2A1

1	01	01 actual	2	02	02 actual	3	03	4	04	364 average	5	05	6	06	667 average	7	07	8	08	768 average	Load
-8.270	0.000	0.000	-8.180	0.000	0.000	3.250	0.000	4.020	0.000	0.000	-0.007	0.000	-0.003	0.000	0.000	-0.007	0.000	-0.008	0.000	0.000	0
-7.940	0.015	0.008	-7.940	0.011	0.002	3.320	0.003	4.340	0.014	0.008	0.033	12.180	0.071	22.140	17.160	0.038	13.500	0.020	8.290	125.000	5
-7.750	0.023	0.009	-7.770	0.018	0.004	3.420	0.008	4.480	0.021	0.014	0.080	20.290	0.116	35.670	79.000	0.073	23.850	0.040	14.250	250.000	10
-7.590	0.030	0.011	-7.830	0.025	0.008	3.540	0.013	4.600	0.026	0.020	0.081	29.310	0.164	50.010	110.000	0.111	35.340	0.081	20.700	325.000	15
-7.450	0.036	0.012	-7.510	0.030	0.008	3.680	0.018	4.700	0.030	0.024	0.117	37.320	0.203	61.770	180.000	0.143	44.850	0.079	26.010	425.000	20
-7.290	0.044	0.013	-7.360	0.037	0.008	3.770	0.023	4.860	0.038	0.031	0.162	50.880	0.268	81.120	250.000	0.205	63.540	0.116	37.770	550.000	25
-7.170	0.049	0.015	-7.270	0.041	0.007	3.830	0.028	4.960	0.042	0.034	0.280	86.100	0.424	127.960	387.000	0.267	282.110	0.207	184.410	650.000	30
-7.000	0.057	0.020	-7.100	0.049	0.012	3.830	0.028	5.080	0.048	0.037	0.882	289.760	1.258	378.450	324.106	2.914	678.210	2.104	633.510	754.880	35
-6.890	0.061	0.023	-7.020	0.052	0.014	3.820	0.028	5.170	0.052	0.038	1.089	328.860	1.585	470.250	389.566	3.235	872.510	2.343	705.210	838.860	40
-6.740	0.068	0.026	-6.900	0.058	0.016	3.830	0.028	5.310	0.058	0.042	1.264	381.360	2.008	602.550	481.866	3.250	977.010	2.389	719.010	848.010	45
-6.630	0.073	0.028	-6.830	0.061	0.016	3.830	0.028	5.430	0.063	0.045	1.416	428.980	2.301	681.050	558.005	3.400	1022.010	2.500	752.310	887.180	50
-6.500	0.079	0.033	-6.780	0.064	0.018	3.830	0.028	5.500	0.068	0.046	1.890	566.180	2.882	865.350	715.755	3.600	1082.010	2.676	805.110	943.580	55
-6.410	0.083	0.034	-6.720	0.066	0.017	3.840	0.027	5.580	0.070	0.048	2.081	628.460	3.181	949.050	787.755	3.780	1138.010	2.831	851.610	986.310	60
-6.310	0.087	0.037	-6.680	0.068	0.018	3.840	0.027	5.660	0.074	0.050	2.282	680.760	3.440	1032.750	856.755	4.040	1214.010	3.029	911.010	1082.510	65
-6.240	0.090	0.039	-6.610	0.071	0.019	3.840	0.027	5.730	0.077	0.052	2.350	707.180	3.580	1077.750	882.455	4.200	1282.010	3.156	948.110	1106.580	70
-6.080	0.097	0.043	-6.460	0.077	0.024	3.840	0.027	5.830	0.081	0.054	2.628	788.960	4.070	1221.750	1005.855	4.290	1289.010	3.248	977.010	1133.010	75
-6.000	0.101	0.046	-6.400	0.080	0.025	3.840	0.027	5.920	0.085	0.055	2.758	829.960	4.300	1280.750	1088.155	4.430	1331.010	3.355	1008.810	1169.910	80
-5.940	0.104	0.048	-6.340	0.083	0.027	3.840	0.027	6.020	0.088	0.056	2.890	868.180	4.510	1353.750	1111.455	4.580	1378.010	3.460	1040.310	1208.180	85
-5.860	0.106	0.051	-6.280	0.086	0.028	3.840	0.027	6.030	0.090	0.057	3.085	927.880	4.810	1443.750	1185.705	4.820	1448.010	3.650	1067.310	1272.860	90
-5.760	0.112	0.053	-6.210	0.089	0.029	3.840	0.027	6.070	0.092	0.058	3.219	987.880	5.020	1508.750	1237.305	5.000	1502.010	3.780	1138.310	1320.860	95
-5.680	0.115	0.056	-6.130	0.090	0.030	3.840	0.027	6.070	0.092	0.059	3.404	1023.360	5.310	1593.750	1308.586	5.230	1571.010	3.970	1183.310	1382.180	100
-5.600	0.116	0.057	-6.200	0.088	0.030	3.840	0.027	6.070	0.092	0.059	3.450	1037.180	5.390	1617.750	1327.485	5.280	1598.010	4.010	1205.310	1385.880	105
-5.520	0.122	0.062	-6.130	0.082	0.032	3.840	0.027	6.130	0.095	0.061	3.780	1130.180	6.020	1806.750	1468.456	5.650	1687.010	4.290	1289.310	1483.180	110
-5.460	0.125	0.064	-6.100	0.084	0.032	3.850	0.027	6.150	0.095	0.061	3.950	1187.180	6.290	1887.750	1537.455	5.870	1783.010	4.460	1360.310	1551.880	115
-5.370	0.129	0.067	-6.070	0.086	0.033	3.850	0.027	6.180	0.097	0.062	4.180	1256.180	6.820	1986.750	1621.455	6.130	1841.010	4.650	1457.310	1618.180	120
-5.290	0.133	0.070	-6.030	0.087	0.034	3.850	0.027	6.210	0.098	0.063	4.430	1331.180	6.860	2086.750	1709.855	6.380	1916.010	4.850	1547.310	1686.880	125
-5.210	0.136	0.073	-5.980	0.089	0.036	3.850	0.027	6.220	0.099	0.063	4.680	1408.180	7.320	2186.750	1801.455	6.820	1988.010	5.020	1598.310	1748.180	130
-5.130	0.140	0.076	-5.950	0.100	0.037	3.850	0.027	6.240	0.100	0.063	4.870	1463.180	7.580	2277.750	1870.455	6.830	2051.010	5.200	1582.310	1808.880	135
-5.050	0.143	0.080	-5.820	0.102	0.038	3.850	0.027	6.280	0.100	0.064	5.080	1528.180	7.880	2367.750	1946.955	7.080	2128.010	5.420	1628.310	1878.880	140
-4.980	0.147	0.083	-5.910	0.102	0.038	3.850	0.027	6.280	0.101	0.064	5.230	1571.180	8.130	2438.750	2005.455	7.320	2198.010	5.560	1670.310	1934.180	145
-4.860	0.152	0.087	-5.900	0.103	0.038	3.850	0.027	6.300	0.102	0.065	5.380	1610.180	8.330	2496.750	2054.955	7.610	2285.010	5.710	1715.310	2000.180	150
-4.750	0.157	0.092	-5.870	0.104	0.039	3.850	0.027	6.300	0.102	0.065	5.380	1610.180	8.380	2514.750	2086.966	7.760	2330.010	5.810	1745.310	2037.880	155
-4.680	0.168	0.103	-5.860	0.104	0.039	3.850	0.027	6.340	0.104	0.066	5.330	1601.180	8.110	2433.750	2017.455	7.880	2368.010	5.860	1760.310	2064.880	160
-4.580	0.173	0.108	-5.870	0.104	0.038	3.850	0.027	6.340	0.104	0.066	5.100	1532.180	7.840	2352.750	1942.455	7.770	2333.010	5.760	1730.310	2031.880	162.9
-4.290	0.177	0.111	-5.870	0.104	0.038	3.850	0.027	6.350	0.104	0.066	5.200	1562.180	8.180	2454.750	1920.000	7.880	2366.010	5.850	1757.310	2061.880	155

1	01	01 actual	2	02	02 actual	3	03	4	04	3&4 average	5	05	6	06	5&6 average	7	07	8	08	7&8 average	9	Load
-6.670	0.000	0.000	-7.900	0.000	0.000	9.630	0.000	-7.680	0.000	0.000	0.282	0.000	0.170	0.000	0.000	0.008	0.000	-0.003	0.000	0.000	1.528	0
-6.580	0.004	0.003	-7.540	0.003	0.002	9.650	0.001	-7.670	0.000	0.001	0.315	0.080	0.182	0.080	0.886	0.014	1.530	0.001	1.440	1.485	1.740	4.22
-6.510	0.007	0.005	-7.480	0.005	0.003	9.680	0.003	-7.640	0.002	0.002	0.361	23.850	0.172	0.720	12.286	0.023	4.350	0.010	3.980	4.170	2.020	9.82
-6.480	0.008	0.006	-7.440	0.007	0.004	9.720	0.004	-7.660	0.002	0.003	0.368	36.250	0.138	-10.350	23.000	0.027	5.580	0.013	4.850	5.285	2.251	14.44
-6.410	0.012	0.008	-7.410	0.008	0.006	9.750	0.005	-7.570	0.005	0.006	0.434	46.750	0.075	-28.440	40.000	0.038	8.280	0.020	6.870	7.575	2.531	20.04
-6.330	0.015	0.008	-7.370	0.010	0.007	9.780	0.007	-7.560	0.008	0.008	0.478	58.250	0.043	-38.040	55.000	0.044	10.530	0.022	7.740	9.135	2.807	25.58
-6.190	0.021	0.012	-7.320	0.013	0.008	9.780	0.007	-7.410	0.012	0.008	0.748	138.850	0.207	10.950	75.450	-1.022	-308.120	-0.728	-217.880	22.450	3.040	30.22
-6.110	0.025	0.014	-7.320	0.013	0.008	9.800	0.008	-7.370	0.014	0.011	0.845	188.050	0.474	91.200	145.125	-1.230	-371.520	-0.883	-268.880	24.330	3.293	35.28
-6.010	0.028	0.018	-7.310	0.013	0.008	9.800	0.008	-7.340	0.015	0.011	1.081	238.850	0.835	138.500	189.675	-1.482	-447.120	-1.038	-310.380	25.830	3.510	39.82
-7.950	0.032	0.018	-7.300	0.014	0.011	9.820	0.008	-7.240	0.020	0.014	1.164	284.750	0.875	151.500	206.125	-1.572	-474.120	-1.086	-327.780	27.880	3.770	44.82
-7.770	0.040	0.024	-7.170	0.019	0.013	9.810	0.008	-7.180	0.023	0.016	1.338	316.850	0.788	168.700	252.825	-0.180	-58.580	0.313	84.880	32.600	4.020	49.82
-7.720	0.042	0.028	-7.140	0.021	0.013	9.820	0.008	-7.140	0.023	0.016	1.408	337.850	0.831	188.300	288.125	-0.122	-38.030	0.378	113.830	37.385	4.270	54.82
-7.520	0.051	0.034	-7.080	0.024	0.014	9.780	0.007	-7.050	0.028	0.017	1.477	358.850	0.788	188.700	273.675	0.008	-0.180	0.485	148.520	74.870	4.520	58.82
-7.440	0.055	0.037	-7.030	0.028	0.018	9.770	0.008	-7.040	0.028	0.017	1.548	380.250	0.828	187.700	288.875	0.067	14.480	0.550	168.020	80.340	4.780	65.22
-7.380	0.058	0.041	-7.020	0.027	0.018	9.770	0.008	-7.040	0.028	0.017	1.684	414.750	0.804	220.200	317.475	0.141	38.720	0.837	182.120	115.820	5.020	68.82
-7.320	0.060	0.042	-7.000	0.027	0.018	9.780	0.007	-7.010	0.030	0.018	1.728	433.850	0.848	232.800	333.375	0.184	52.740	0.880	208.020	130.380	5.280	74.82
-7.180	0.068	0.047	-6.840	0.034	0.019	9.770	0.008	-7.000	0.030	0.018	1.881	512.850	1.141	281.300	402.075	0.423	124.380	0.885	288.520	188.850	5.520	78.82
-7.150	0.068	0.048	-6.780	0.036	0.022	9.770	0.008	-7.000	0.030	0.018	2.048	528.850	1.185	304.500	417.225	0.488	137.880	0.940	283.020	210.450	5.750	84.42
-7.050	0.072	0.054	-6.720	0.040	0.021	9.780	0.008	-7.000	0.030	0.018	2.280	583.550	1.431	378.300	485.825	0.821	273.780	1.125	338.520	308.150	6.520	99.82
-7.010	0.074	0.055	-6.680	0.041	0.023	9.770	0.008	-7.000	0.030	0.018	2.377	628.850	1.558	416.700	522.875	0.862	288.080	1.181	348.320	317.700	7.020	108.82
-6.930	0.077	0.058	-6.680	0.042	0.024	9.780	0.008	-7.000	0.030	0.018	2.531	674.850	1.747	473.100	573.875	0.962	318.480	1.257	378.120	348.300	7.280	115.22
-6.870	0.080	0.062	-6.630	0.044	0.025	9.770	0.008	-6.980	0.030	0.018	2.630	704.550	1.854	506.200	604.875	1.070	335.280	1.314	386.520	365.250	7.510	118.82
-6.780	0.085	0.064	-6.550	0.047	0.028	9.780	0.008	-6.880	0.036	0.021	2.507	687.850	2.038	580.400	614.025	1.128	355.280	1.387	420.120	380.750	7.770	124.82
-6.730	0.088	0.065	-6.520	0.048	0.027	9.770	0.008	-6.780	0.040	0.023	2.478	718.860	2.213	612.800	685.825	1.213	381.380	1.452	438.620	424.350	8.020	129.82
-6.640	0.090	0.067	-6.480	0.050	0.027	9.770	0.008	-6.780	0.040	0.024	2.750	740.560	2.282	633.800	687.075	1.362	412.080	1.562	466.620	483.800	8.280	135.82
-6.590	0.093	0.069	-6.450	0.052	0.028	9.780	0.008	-6.750	0.042	0.024	2.828	784.250	2.408	651.000	707.825	1.608	478.280	1.513	454.820	467.100	8.510	138.82
-6.480	0.097	0.074	-6.340	0.057	0.033	9.780	0.008	-6.680	0.048	0.028	2.804	788.750	2.408	671.400	726.075	1.689	498.180	1.645	484.520	517.350	8.780	145.22
-6.430	0.100	0.076	-6.280	0.058	0.033	9.780	0.008	-6.650	0.048	0.028	2.828	793.850	2.487	688.100	748.025	1.740	518.480	1.581	478.320	486.800	9.050	150.42
-6.340	0.104	0.078	-6.250	0.061	0.035	9.770	0.008	-6.620	0.048	0.027	3.007	817.850	2.573	720.800	788.275	1.888	563.880	1.988	507.420	535.850	9.280	154.82
-6.280	0.108	0.080	-6.210	0.063	0.038	9.770	0.008	-6.610	0.048	0.027	2.862	813.150	2.850	744.000	778.575	1.953	583.380	1.732	520.820	552.000	9.530	160.82
-6.170	0.111	0.084	-6.180	0.064	0.038	9.770	0.008	-6.610	0.048	0.027	3.041	827.850	2.884	757.200	878.875	2.127	635.580	1.803	541.820	584.750	9.770	164.82
-6.130	0.113	0.086	-6.180	0.064	0.038	9.770	0.008	-6.610	0.048	0.027	2.878	718.350	2.308	641.400	678.875	2.188	658.280	1.938	582.720	602.400	10.040	170.22
-6.070	0.120	0.093	-6.130	0.066	0.039	9.770	0.008	-6.550	0.051	0.028	2.681	722.850	2.287	638.100	688.475	2.482	742.080	1.938	582.720	602.400	10.270	174.82
-6.040	0.121	0.094	-6.100	0.068	0.040	9.770	0.008	-6.550	0.051	0.028	2.581	688.850	2.188	608.400	648.125	2.548	781.280	1.978	584.720	614.450	10.550	180.42
-5.810	0.127	0.098	-6.080	0.068	0.041	9.770	0.008	-6.470	0.054	0.029	2.608	687.250	2.228	616.800	657.075	2.585	775.880	1.873	582.820	684.450	11.030	180.82
-5.780	0.123	0.100	-6.040	0.070	0.041	9.780	0.008	-6.510	0.052	0.030	2.484	680.750	2.187	608.100	634.425	2.725	814.880	2.043	613.820	714.450	11.280	184.82
-5.640	0.135	0.106	-6.000	0.072	0.042	9.770	0.008	-6.440	0.058	0.031	2.389	635.250	2.267	629.100	632.175	2.685	802.880	1.977	584.120	688.550	11.540	200.22
-5.500	0.141	0.110	-5.920	0.078	0.045	9.830	0.014	-6.440	0.058	0.036	2.421	841.850	2.308	641.400	841.825	2.737	818.580	1.987	600.120	708.350	11.780	205.82
-5.370	0.147	0.112	-5.800	0.077	0.047	9.830	0.014	-6.440	0.058	0.036	2.124	562.750	2.221	615.300	584.025	2.850	792.480	1.853	586.820	674.700	12.060	210.42
-5.180	0.156	0.125	-5.700	0.088	0.049	9.880	0.018	-6.380	0.058	0.038	2.083	543.450	2.188	605.400	574.425	2.880	785.480	1.812	544.820	670.050	12.280	215.82
-5.130	0.158	0.132	-5.610	0.090	0.049	10.050	0.019	-6.310	0.081	0.040	2.087	535.850	2.188	598.700	567.675	2.867	787.580	1.772	532.820	665.100	12.520	219.82
-5.080	0.160	0.141	-5.580	0.081	0.051	10.080	0.019	-6.280	0.082	0.041	2.028	523.350	2.148	593.400	558.375	2.856	784.280	1.701	511.320	652.800	12.770	224.82
-5.020	0.162	0.150	-5.580	0.082	0.051	10.080	0.019	-6.280	0.082	0.041	1.848	489.850	2.111	582.300	541.125	2.801	777.780	1.607	483.120	630.450	12.960	228
-4.880	0.164	0.158	-5.540	0.083	0.052	10.080	0.019	-6.280	0.083	0.041	1.948	488.750	2.108	580.800	533.775	2.578	770.280	1.555	467.520	618.800	13.200	228
-4.830	0.166	0.164	-5.540	0.083	0.052	10.080	0.019	-6.280	0.083	0.041	0.738	137.250	0.585	127.500	132.375	1.470	438.480	0.737	222.120	330.300	0.000	223
-6.930	0.077	0.188	-6.680	0.041	0.017	9.680	0.002	-6.630	0.047	0.025												

1	01	01 actual	2	02	02 actual	3	03	4	04	3A4 average	5	05	6	06	5A6 average	7	07	8	08	7A8 average	Lead
-7.310	0.000	0.000	-7.640	0.000	0.000	5.110	0.000	4.510	0.000	0.000	0.000	0.000	-0.001	0.000	0.000	-0.001	0.000	-0.005	0.000	7A8 average	Lead
-6.940	0.016	0.004	-7.300	0.015	0.003	5.480	0.017	4.680	0.008	0.012	0.056	16.620	0.074	22.290	19.006	0.061	16.600	0.054	17.700	0.000	0
-6.820	0.022	0.005	-7.190	0.020	0.004	5.620	0.023	4.740	0.010	0.017	0.107	31.960	0.137	41.340	36.880	0.121	36.480	0.108	34.200	18.150	5
-6.710	0.027	0.008	-7.110	0.024	0.006	5.680	0.026	4.770	0.012	0.019	0.187	48.960	0.213	64.200	57.080	0.182	57.900	0.177	54.720	35.360	10
-6.640	0.030	0.009	-7.040	0.027	0.008	5.730	0.028	4.810	0.013	0.021	0.226	68.280	0.291	87.360	77.820	0.280	80.910	0.250	76.530	58.310	15
-6.570	0.033	0.011	-6.960	0.030	0.007	5.790	0.031	4.820	0.014	0.022	0.311	93.330	0.384	118.410	105.870	0.380	117.180	0.368	111.330	78.720	20
-6.510	0.036	0.012	-6.930	0.032	0.008	5.820	0.032	4.860	0.016	0.024	0.422	126.630	0.540	162.210	144.420	0.572	171.790	0.547	165.630	114.255	25
-6.420	0.040	0.015	-6.830	0.036	0.012	5.840	0.033	4.880	0.017	0.025	0.513	273.930	1.208	362.010	317.970	1.501	450.480	1.837	552.630	163.705	30
-6.340	0.043	0.017	-6.770	0.039	0.013	5.880	0.035	4.900	0.017	0.026	1.205	361.530	1.554	468.410	413.970	1.774	532.360	2.198	680.930	501.565	35
-6.270	0.046	0.019	-6.730	0.041	0.014	5.900	0.036	4.930	0.019	0.027	1.421	426.330	1.788	538.910	483.120	1.984	588.380	2.475	744.030	586.855	40
-6.210	0.048	0.021	-6.680	0.043	0.016	5.910	0.036	4.930	0.019	0.027	1.606	481.830	2.003	601.110	541.470	2.171	651.480	2.694	809.730	671.205	45
-6.130	0.053	0.025	-6.610	0.046	0.018	5.910	0.036	4.950	0.020	0.028	1.836	550.830	2.264	679.410	615.120	2.363	715.080	2.948	885.930	730.605	50
-6.070	0.055	0.027	-6.570	0.048	0.020	5.910	0.036	4.970	0.021	0.028	1.989	588.730	2.441	732.510	664.620	2.563	768.080	3.144	944.730	800.505	55
-5.980	0.058	0.030	-6.480	0.052	0.023	5.910	0.036	5.000	0.022	0.029	2.301	690.330	2.812	843.810	767.070	2.872	801.780	3.160	948.530	856.405	60
-5.930	0.061	0.032	-6.450	0.054	0.024	5.910	0.036	5.020	0.023	0.029	2.368	710.430	2.874	882.410	788.420	2.971	838.280	3.286	981.330	875.655	65
-5.850	0.065	0.035	-6.400	0.056	0.026	5.920	0.037	5.040	0.024	0.030	2.411	723.330	2.912	873.810	788.570	2.971	881.480	3.450	1036.530	908.805	70
-5.780	0.068	0.038	-6.330	0.059	0.029	5.910	0.036	5.060	0.025	0.030	2.543	762.930	3.055	916.710	838.620	3.086	928.980	3.580	1075.530	964.005	75
-5.670	0.073	0.042	-6.260	0.062	0.031	5.910	0.036	5.080	0.026	0.031	2.679	804.930	3.211	963.510	883.620	3.246	973.980	3.730	1120.530	1002.255	80
-5.600	0.076	0.045	-6.220	0.064	0.032	5.920	0.037	5.100	0.026	0.031	2.782	834.930	3.338	1001.610	918.120	3.488	1021.980	3.800	1171.530	1047.255	85
-5.520	0.080	0.048	-6.160	0.067	0.035	5.910	0.036	5.120	0.027	0.032	2.876	862.930	3.570	1071.210	962.020	3.610	1063.180	4.120	1237.530	1086.755	90
-5.450	0.083	0.051	-6.110	0.069	0.037	5.910	0.036	5.120	0.027	0.032	3.186	958.930	3.840	1152.210	1066.520	3.750	1125.180	4.280	1278.530	1180.355	95
-5.380	0.086	0.054	-6.080	0.071	0.039	5.910	0.036	5.130	0.028	0.032	3.342	1002.930	4.030	1208.210	1106.820	3.910	1173.180	4.430	1330.530	1251.805	100
-5.320	0.088	0.057	-6.010	0.073	0.041	5.910	0.036	5.130	0.028	0.032	3.480	1044.930	4.208	1260.210	1182.120	4.080	1224.180	4.600	1381.530	1302.805	105
-5.250	0.092	0.059	-5.980	0.076	0.043	5.920	0.037	5.150	0.029	0.033	3.610	1083.930	4.370	1311.210	1197.120	4.250	1275.180	4.770	1432.530	1353.805	110
-5.170	0.095	0.063	-5.910	0.078	0.046	5.920	0.037	5.150	0.029	0.033	3.770	1131.930	4.570	1371.210	1251.120	4.480	1344.180	4.940	1483.530	1404.805	115
-5.080	0.099	0.066	-5.860	0.080	0.047	5.920	0.037	5.160	0.029	0.033	3.910	1173.930	4.760	1428.210	1306.620	4.680	1388.180	5.100	1531.530	1454.805	120
-5.020	0.102	0.068	-5.810	0.082	0.050	5.920	0.037	5.160	0.029	0.033	4.050	1215.930	4.940	1482.210	1348.620	4.850	1455.180	5.280	1585.530	1505.805	125
-4.950	0.105	0.072	-5.760	0.085	0.052	5.920	0.037	5.160	0.029	0.033	4.180	1254.930	5.130	1538.210	1386.620	5.030	1508.180	5.460	1638.530	1574.355	130
-4.880	0.108	0.075	-5.720	0.086	0.053	5.930	0.037	5.170	0.030	0.033	4.310	1283.930	5.320	1586.210	1444.620	5.220	1568.180	5.630	1680.530	1628.355	135
-4.810	0.111	0.078	-5.670	0.088	0.056	5.920	0.037	5.170	0.030	0.033	4.450	1335.930	5.510	1653.210	1484.120	5.400	1620.180	5.810	1744.530	1682.355	140
-4.730	0.115	0.082	-5.610	0.091	0.058	5.920	0.037	5.180	0.030	0.033	4.600	1380.930	5.720	1716.210	1548.120	5.600	1680.180	6.000	1801.530	1740.855	145
-4.650	0.118	0.085	-5.550	0.094	0.061	5.920	0.037	5.180	0.030	0.033	4.750	1425.930	5.940	1782.210	1603.620	5.810	1743.180	6.210	1864.530	1803.855	150
-4.580	0.121	0.087	-5.500	0.096	0.062	5.920	0.037	5.220	0.032	0.034	4.870	1461.930	6.130	1838.210	1650.120	6.000	1800.180	6.400	1921.530	1860.855	155
-4.480	0.125	0.091	-5.440	0.099	0.065	5.920	0.037	5.220	0.032	0.034	4.920	1478.930	6.220	1886.210	1671.120	6.240	1872.180	6.630	1980.530	1931.355	160
-4.420	0.129	0.094	-5.390	0.104	0.068	5.930	0.037	5.220	0.032	0.034	5.060	1518.930	6.420	1926.210	1722.120	6.450	1935.180	6.840	2053.530	1984.355	165
-4.350	0.132	0.097	-5.340	0.104	0.069	5.930	0.037	5.220	0.032	0.034	5.200	1560.930	6.640	1982.210	1776.120	6.640	1982.180	7.030	2110.530	2051.355	170
-4.270	0.135	0.101	-5.290	0.106	0.071	5.940	0.037	5.220	0.032	0.034	5.350	1605.930	6.880	2058.210	1831.620	6.840	2052.180	7.230	2170.530	2111.355	175
-4.180	0.138	0.104	-5.230	0.108	0.074	5.940	0.037	5.220	0.032	0.035	5.440	1632.930	7.160	2148.210	1880.120	7.100	2130.180	7.470	2242.530	2186.355	180
-4.110	0.142	0.106	-5.170	0.111	0.077	5.940	0.037	5.220	0.032	0.035	5.680	1688.930	7.380	2214.210	1956.120	7.380	2208.180	7.720	2317.530	2262.855	185
-4.010	0.147	0.112	-5.100	0.114	0.080	5.940	0.037	5.220	0.032	0.035	5.730	1719.930	7.500	2250.210	1984.620	7.880	2298.180	8.030	2410.530	2354.355	190
-3.920	0.151	0.116	-5.020	0.118	0.084	5.930	0.037	5.220	0.032	0.034	5.760	1728.930	7.670	2301.210	2014.620	7.850	2365.180	8.310	2484.530	2438.855	195
-3.830	0.155	0.120	-4.970	0.120	0.086	5.930	0.037	5.220	0.032	0.034	5.860	1764.930	7.900	2370.210	2048.120	8.240	2472.180	8.580	2575.530	2523.855	200
-3.750	0.158	0.124	-4.920	0.122	0.088	5.940	0.037	5.220	0.032	0.035	5.960	1783.930	8.180	2454.210	2108.120	8.580	2574.180	8.910	2674.530	2624.355	205
-3.640	0.163	0.128	-4.880	0.124	0.090	5.940	0.037	5.220	0.032	0.034	6.130	1839.930	8.530	2558.210	2178.120	8.980	2697.180	9.270	2782.530	2738.855	210
-3.540	0.168	0.133	-4.830	0.127	0.092	5.940	0.037	5.220	0.032	0.035	6.020	1828.930	8.600	2540.210	2173.120	9.080	2694.180	9.810	2944.530	2924.355	215
-3.400	0.174	0.138	-4.800	0.128	0.093	5.940	0.037	5.220	0.032	0.035	6.030	1808.930	8.930	2579.210	2184.120	9.350	2685.180	12.740	3823.530	3844.355	220
-3.380	0.175	0.140	-4.780	0.128	0.094	5.940	0.037	5.220	0.032	0.035	6.030	1808.930	8.930	2579.210	2184.120	9.350	2685.180	12.740	3823.530	3844.355	225
-2.913	0.198	0.147	-4.840	0.126	0.094	5.930	0.032	5.220	0.032	0.032	5.450	1635.930	13.600	4080.210	2500.000	13.580	4077.180	13.650	4086.530	4086.855	228

1	01	01 actual	2	02	02 actual	3	03	4	04	3&4 average	5	05	6	06	5&6 average	7	07	8	08	7&8 average	Lead
-7.880	0.000	0.000	-7.120	0.000	0.000	5.550	0.000	6.400	0.000	0.000	1.570	0.000	1.562	0.000	0.000	0.868	0.000	1.886	0.000	0.000	0
-7.820	0.003	0.003	-7.080	0.003	0.002	5.550	0.000	6.420	0.001	0.000	1.523	106.900	1.923	108.300	107.100	0.838	-9.000	1.978	24.600	7.600	5
-7.540	0.007	0.006	-7.000	0.005	0.004	5.550	0.000	6.450	0.002	0.001	2.126	188.800	2.180	185.400	178.100	0.910	12.600	2.058	48.900	30.750	10
-7.470	0.010	0.008	-6.950	0.008	0.006	5.540	0.000	6.440	0.004	0.002	2.281	207.300	2.345	234.800	221.100	0.981	33.900	2.182	88.800	61.380	15
-7.400	0.013	0.010	-6.880	0.010	0.008	5.550	0.000	6.570	0.006	0.003	2.352	234.600	2.478	275.100	264.888	1.025	50.100	2.380	145.200	97.850	20
-7.320	0.016	0.013	-6.830	0.013	0.009	5.560	0.000	6.571	0.008	0.004	2.508	281.700	2.665	339.900	308.300	1.078	63.000	2.575	203.700	133.360	25
-7.270	0.018	0.011	-6.790	0.015	0.008	5.700	0.007	6.571	0.008	0.007	2.633	318.900	2.808	373.200	346.050	1.098	68.100	2.677	234.300	151.200	30
-7.210	0.021	0.013	-6.750	0.017	0.008	5.710	0.007	6.580	0.008	0.008	2.738	350.700	2.948	415.200	382.888	1.124	76.800	2.844	284.400	180.600	35
-7.180	0.024	0.016	-6.710	0.018	0.011	5.710	0.007	6.580	0.008	0.008	2.837	380.100	3.071	452.700	416.400	1.151	84.900	2.987	330.300	207.600	40
-7.080	0.027	0.018	-6.680	0.020	0.011	5.710	0.007	6.610	0.008	0.008	3.205	480.500	3.442	564.000	527.250	1.167	88.700	3.098	360.900	225.300	45
-7.030	0.029	0.021	-6.640	0.022	0.013	5.720	0.008	6.620	0.010	0.009	3.385	544.500	3.640	623.400	583.966	1.185	95.100	3.225	388.700	248.950	50
-6.980	0.032	0.024	-6.600	0.023	0.015	5.720	0.008	6.620	0.010	0.009	3.436	558.800	3.730	650.400	605.100	1.210	102.600	3.356	438.000	270.300	55
-6.950	0.035	0.028	-6.550	0.026	0.017	5.720	0.008	6.630	0.010	0.009	3.550	584.000	3.870	682.400	643.200	1.238	111.300	3.480	475.200	293.250	60
-6.910	0.037	0.028	-6.510	0.027	0.018	5.720	0.008	6.630	0.010	0.009	3.630	618.000	3.970	722.400	670.200	1.281	117.900	3.620	517.200	317.550	65
-6.790	0.040	0.030	-6.480	0.029	0.017	5.850	0.014	6.630	0.010	0.012	3.770	660.000	4.120	767.400	713.700	1.281	123.900	3.740	553.200	338.550	70
-6.740	0.042	0.030	-6.450	0.030	0.018	5.850	0.014	6.660	0.012	0.013	3.810	702.000	4.280	815.400	758.700	1.306	131.400	3.860	589.200	360.300	75
-6.680	0.044	0.032	-6.400	0.032	0.020	5.840	0.013	6.660	0.012	0.012	4.080	753.000	4.450	866.400	808.700	1.322	136.200	3.910	604.200	370.200	80
-6.630	0.047	0.034	-6.360	0.034	0.022	5.850	0.014	6.660	0.012	0.013	4.250	804.000	4.620	917.400	860.700	1.346	143.400	3.690	638.200	340.800	85
-6.570	0.050	0.037	-6.330	0.036	0.023	5.850	0.014	6.690	0.012	0.013	4.390	846.000	4.780	968.400	907.200	1.361	147.800	3.650	628.200	337.050	90
-6.500	0.053	0.040	-6.270	0.038	0.026	5.850	0.014	6.690	0.012	0.013	4.360	837.000	4.840	983.400	919.288	1.385	155.100	3.690	638.200	345.150	95
-6.450	0.055	0.043	-6.230	0.040	0.027	5.850	0.014	6.690	0.012	0.013	4.480	873.000	4.950	1016.400	944.700	1.388	156.000	3.690	638.200	345.600	100
-6.400	0.057	0.045	-6.180	0.042	0.028	5.850	0.014	6.690	0.012	0.013	4.620	915.000	5.100	1061.400	988.200	1.387	158.700	3.700	641.200	349.850	105
-6.350	0.060	0.047	-6.180	0.043	0.031	5.850	0.018	6.690	0.012	0.013	4.780	957.000	5.280	1108.400	1033.200	1.392	157.200	3.750	656.200	356.700	110
-6.290	0.062	0.047	-6.110	0.045	0.031	5.850	0.018	6.690	0.012	0.015	4.830	1008.000	5.440	1163.400	1085.700	1.395	158.100	3.820	677.200	367.650	115
-6.240	0.065	0.050	-6.070	0.047	0.032	5.850	0.018	6.690	0.012	0.015	5.080	1047.000	5.580	1208.400	1127.700	1.404	160.800	3.880	685.200	378.000	120
-6.190	0.067	0.052	-6.030	0.048	0.034	5.850	0.018	6.690	0.012	0.015	5.190	1096.000	5.740	1253.400	1168.700	1.418	165.000	3.950	616.200	380.600	125
-6.140	0.068	0.054	-5.980	0.051	0.036	5.850	0.018	6.690	0.012	0.015	5.340	1131.000	5.910	1304.400	1211.700	1.426	167.400	4.040	643.200	405.300	130
-6.090	0.071	0.056	-5.960	0.052	0.037	5.850	0.018	6.690	0.012	0.015	5.470	1170.000	6.070	1352.400	1261.288	1.438	171.000	4.130	670.200	420.800	135
-6.040	0.073	0.058	-5.920	0.054	0.038	5.880	0.018	6.690	0.012	0.015	5.580	1208.000	6.230	1400.400	1303.288	1.451	174.900	4.240	703.200	438.050	140
-5.980	0.076	0.061	-5.870	0.056	0.041	5.880	0.018	6.690	0.012	0.015	5.580	1208.000	6.400	1451.400	1348.700	1.459	177.300	4.360	739.200	458.250	145
-5.930	0.078	0.063	-5.830	0.058	0.043	5.850	0.018	6.690	0.012	0.015	5.630	1278.000	6.570	1502.400	1390.288	1.459	177.000	4.450	784.200	480.600	150
-5.870	0.081	0.064	-5.780	0.060	0.044	6.030	0.022	6.690	0.012	0.017	5.880	1326.000	6.780	1558.400	1442.700	1.454	175.600	4.770	862.200	519.000	155
-5.810	0.084	0.067	-5.740	0.062	0.045	6.030	0.022	6.690	0.012	0.017	6.100	1358.000	6.920	1607.400	1483.200	1.449	174.300	4.840	913.200	543.750	160
-5.760	0.086	0.069	-5.700	0.064	0.047	6.030	0.022	6.690	0.012	0.017	6.230	1398.000	7.100	1661.400	1529.700	1.452	175.200	5.150	978.200	573.700	165
-5.700	0.089	0.072	-5.650	0.066	0.050	6.030	0.022	6.690	0.012	0.017	6.370	1440.000	7.300	1721.400	1580.700	1.460	177.600	5.380	1045.200	611.400	170
-5.610	0.093	0.076	-5.570	0.070	0.053	6.030	0.022	6.690	0.012	0.017	6.130	1368.000	7.250	1706.400	1537.200	1.490	186.600	6.010	1234.200	710.400	175
-5.540	0.096	0.079	-5.520	0.072	0.055	6.040	0.022	6.690	0.012	0.017	6.300	1418.000	7.420	1757.400	1588.200	1.461	177.800	6.300	1321.200	749.550	180
-5.470	0.099	0.082	-5.450	0.075	0.058	6.040	0.022	6.690	0.012	0.017	6.480	1473.000	7.640	1823.400	1648.200	1.472	181.200	6.800	1471.200	808.200	185
-5.400	0.102	0.084	-5.400	0.077	0.059	6.080	0.024	6.690	0.012	0.018	6.700	1538.000	7.920	1907.400	1723.200	1.484	184.800	7.580	1705.200	945.000	190
-5.320	0.105	0.087	-5.340	0.080	0.062	6.080	0.024	6.690	0.012	0.018	6.870	1628.000	8.280	2018.400	1818.288	1.514	193.800	8.530	1980.200	1082.000	195
-5.220	0.110	0.092	-5.280	0.084	0.066	6.080	0.024	6.690	0.012	0.018	7.980	1823.000	12.630	3320.400	2821.700	1.511	192.800	9.540	2293.200	1263.050	200
-5.120	0.114	0.097	-5.180	0.087	0.070	6.080	0.024	6.690	0.012	0.018	8.030	2238.000	13.800	3611.400	2924.700	1.507	191.700	10.340	2533.200	1382.450	205
-5.010	0.119	0.101	-5.120	0.090	0.072	6.080	0.024	6.690	0.012	0.018	9.470	2370.000	13.610	3614.400	2982.200	1.456	178.700	10.630	2680.200	1428.300	210
-4.940	0.122	0.104	-5.080	0.092	0.074	6.100	0.025	6.690	0.012	0.018	10.090	2556.000	13.610	3614.400	3085.200	1.467	179.700	11.230	2800.200	1488.950	215.5
-4.830	0.123	0.105	-5.040	0.092	0.074	6.100	0.025	6.690	0.012	0.018	9.870	2480.000	13.610	3614.400	3062.200	1.406	161.400	10.980	2725.200	1625.000	220
-4.700	0.133	0.113	-4.900	0.100	0.087	6.180	0.028	6.690	0.012	0.020	12.120	3165.000	13.610	3614.400	3388.700	1.716	254.400	12.910	3304.200	1779.300	225
-4.520	0.141	0.121	-4.750	0.107	0.097	6.180	0.028	6.690	0.012	0.020	12.780	3357.000	13.610	3614.400	3485.700	1.791	276.900	13.380	3444.200	1862.550	230
-4.450	0.144	0.123	-4.700	0.109	0.098	6.220	0.030	6.690	0.013	0.021	12.800	3399.000	13.610	3614.400	3481.700	1.738	261.000	13.320	3427.200	1844.100	235
-4.280	0.153	0.129	-4.550	0.116	0.093	6.290	0.032	6.720	0.014	0.024	13.670	3630.000	13.610	3614.400	3622.200	1.801	308.900	13.650	3526.200	1918.050	240
-4.070	0.161	0.137	-4.400	0.122	0.099	6.270	0.032	6.740	0.015	0.026	13.670	3630.000	13.610	3614.400	3622.200	2.002	340.200	13.650	3526.200	1933.200	245
-3.710	0.177	0.151	-4.120	0.135	0.108	6.320	0.035	6.770	0.017	0.028	13.670	3630.000	13.580	3608.400	3619.200	2.248	414.000	13.650	3526.200	1970.100	250
-3.440	0.189	0.162	-3.840	0.143	0.116	6.360	0.037														

BEAM 4A

1	#1	2	#2	load
-2.777	0	-2.418	0	0
-2.763	0.0015	-2.41	0.0007	5
-2.753	0.0025	-2.406	0.0014	10
-2.743	0.0045	-2.401	0.002	15
-2.739	0.006	-2.397	0.0029	20
-2.732	0.009	-2.392	0.0035	25
-2.726	0.013	-2.388	0.0043	30
-2.719	0.017	-2.381	0.005	35
-2.708	0.02	-2.376	0.0058	40
-2.702	0.024	-2.371	0.0064	45
-2.691	0.028	-2.365	0.007	50
-2.684	0.031	-2.359	0.0079	55
-2.667	0.034	-2.352	0.0087	60
-2.663	0.038	-2.348	0.0095	65
-2.652	0.042	-2.341	0.0104	70
-2.64	0.046	-2.33	0.0117	75
-2.62	0.051	-2.322	0.0132	80
-2.618	0.053	-2.312	0.014	82.5
-2.624	0.056	-2.304	0.0148	85
-2.623	0.059	-2.302	0.0156	87.5
-2.619	0.062	-2.292	0.0166	90
-2.621	0.065	-2.29	0.0175	92.5
-2.62	0.069	-2.284	0.0185	95
-2.612	0.074	-2.271	0.0205	100
-2.611	0.08	-2.264	0.023	104.5
-2.61	0.088	-2.257	0.0249	100
-2.609	0.09	-2.25	0.0255	97

BEAM 4B

1	#1	#1 actual	2	#2	#2 actual	3	#3	4	#4	3&4 average	Load
-8.930	0.000	0.000	-7.890	0.000	0.000	8.850	0.000	8.680	0.000	0.000	0.00
-8.830	0.004	0.002	-7.820	0.003	0.001	8.920	0.003	8.720	0.002	0.002	4.91
-8.740	0.008	0.004	-7.750	0.006	0.001	8.990	0.006	8.750	0.003	0.005	10.52
-8.670	0.012	0.005	-7.680	0.009	0.002	9.040	0.009	8.780	0.004	0.007	16.80
-8.620	0.014	0.007	-7.660	0.010	0.003	9.060	0.009	8.790	0.005	0.007	20.24
-8.510	0.019	0.009	-7.640	0.011	0.003	9.130	0.013	8.820	0.006	0.009	26.64
-8.450	0.021	0.011	-7.630	0.012	0.004	9.160	0.014	8.830	0.007	0.010	30.04
-8.360	0.025	0.014	-7.610	0.013	0.004	9.180	0.015	8.850	0.008	0.011	35.54
-8.270	0.029	0.017	-7.620	0.012	0.005	9.210	0.016	8.860	0.008	0.012	40.74
-8.200	0.032	0.020	-7.610	0.013	0.006	9.210	0.016	8.860	0.008	0.012	45.84
-8.120	0.036	0.023	-7.600	0.013	0.006	9.240	0.018	8.870	0.009	0.013	50.64
-8.060	0.039	0.025	-7.590	0.014	0.006	9.250	0.018	8.880	0.009	0.013	55.04
-7.940	0.044	0.031	-7.520	0.017	0.007	9.240	0.018	8.880	0.009	0.013	60.64
-7.880	0.047	0.033	-7.500	0.018	0.008	9.270	0.019	8.880	0.009	0.014	65.34
-7.800	0.050	0.036	-7.470	0.019	0.009	9.270	0.019	8.890	0.009	0.014	70.74
-7.720	0.054	0.039	-7.430	0.021	0.010	9.270	0.019	8.900	0.010	0.014	75.44
-7.600	0.059	0.043	-7.350	0.024	0.011	9.330	0.022	8.930	0.011	0.016	80.04
-7.530	0.062	0.045	-7.320	0.026	0.012	9.340	0.022	8.940	0.012	0.017	85.24
-7.450	0.066	0.049	-7.280	0.027	0.013	9.340	0.022	8.960	0.013	0.017	90.74
-7.280	0.073	0.055	-7.190	0.032	0.014	9.360	0.023	8.990	0.014	0.018	95.54
-7.180	0.078	0.059	-7.150	0.033	0.015	9.380	0.024	9.000	0.014	0.019	100.14
-7.010	0.085	0.066	-7.110	0.035	0.017	9.400	0.025	9.010	0.015	0.020	105.54
-6.920	0.089	0.069	-7.000	0.040	0.019	9.440	0.027	9.020	0.015	0.021	104.44
-6.790	0.095	0.074	-7.000	0.040	0.020	9.440	0.027	9.020	0.015	0.021	98.14

BEAM 5A

Load (kips)	1	#1	#1 actual	2	#2	#2 actual	3	#3	4	#4	3&4 average
0	-9.660	0.000	0.000	-8.770	0.000	0.000	7.170	0.000	8.450	0.000	0.000
4.8	-9.480	0.008	0.001	-8.610	0.007	0.000	7.370	0.009	8.560	0.005	0.007
9.7	-9.330	0.015	0.004	-8.500	0.012	0.001	7.480	0.014	8.630	0.008	0.011
15.6	-9.170	0.022	0.006	-8.370	0.018	0.002	7.610	0.020	8.700	0.011	0.016
20.3	-9.070	0.026	0.008	-8.280	0.022	0.004	7.700	0.024	8.730	0.013	0.018
24.9	-9.000	0.029	0.009	-8.220	0.025	0.004	7.770	0.027	8.770	0.014	0.021
30.2	-8.930	0.032	0.010	-8.150	0.028	0.005	7.820	0.029	8.800	0.016	0.022
34.5	-8.880	0.035	0.011	-8.110	0.030	0.006	7.860	0.031	8.820	0.017	0.024
39.9	-8.830	0.037	0.012	-8.050	0.032	0.007	7.890	0.032	8.840	0.017	0.025
45.8	-8.770	0.040	0.014	-8.000	0.035	0.009	7.920	0.034	8.860	0.018	0.026
50.2	-8.730	0.041	0.015	-7.960	0.036	0.010	7.920	0.034	8.870	0.019	0.026
55.2	-8.650	0.045	0.019	-7.920	0.038	0.012	7.920	0.034	8.870	0.019	0.026
60.1	-8.600	0.047	0.020	-7.880	0.040	0.013	7.950	0.035	8.880	0.019	0.027
64.9	-8.540	0.050	0.022	-7.850	0.041	0.014	7.970	0.036	8.880	0.019	0.028
70.1	-8.490	0.052	0.024	-7.810	0.043	0.015	7.980	0.037	8.880	0.019	0.028
75.0	-8.430	0.055	0.026	-7.770	0.045	0.016	7.990	0.037	8.900	0.020	0.029
79.9	-8.370	0.057	0.029	-7.730	0.047	0.018	7.990	0.037	8.900	0.020	0.029
85.3	-8.310	0.060	0.031	-7.690	0.049	0.019	8.020	0.038	8.900	0.020	0.029
89.8	-8.260	0.062	0.033	-7.690	0.049	0.019	8.030	0.039	8.900	0.020	0.029
95.3	-8.180	0.066	0.036	-7.660	0.050	0.020	8.050	0.040	8.900	0.020	0.030
100.2	-8.090	0.070	0.040	-7.590	0.053	0.023	8.050	0.040	8.910	0.021	0.030
105.1	-8.010	0.073	0.043	-7.550	0.055	0.025	8.050	0.040	8.910	0.021	0.030
110.1	-7.940	0.077	0.045	-7.550	0.055	0.024	8.090	0.041	8.910	0.021	0.031
115.2	-7.870	0.080	0.049	-7.510	0.057	0.026	8.090	0.041	8.910	0.021	0.031
120.0	-7.800	0.083	0.051	-7.470	0.059	0.027	8.090	0.041	8.920	0.021	0.031
125.1	-7.720	0.086	0.055	-7.420	0.061	0.029	8.100	0.042	8.920	0.021	0.031
130.2	-7.630	0.090	0.059	-7.390	0.062	0.031	8.090	0.041	8.920	0.021	0.031
135.1	-7.560	0.093	0.062	-7.370	0.063	0.032	8.090	0.041	8.920	0.021	0.031
140.0	-7.480	0.097	0.066	-7.310	0.066	0.034	8.100	0.042	8.920	0.021	0.031
150.0	-7.330	0.104	0.072	-7.210	0.070	0.039	8.090	0.041	8.920	0.021	0.031
155.0	-7.250	0.107	0.076	-7.130	0.074	0.042	8.100	0.042	8.920	0.021	0.031
160.0	-7.170	0.111	0.079	-7.060	0.077	0.046	8.100	0.042	8.920	0.021	0.031
165.0	-7.070	0.115	0.084	-6.990	0.080	0.049	8.090	0.041	8.920	0.021	0.031
170.0	-6.920	0.122	0.090	-6.930	0.083	0.051	8.100	0.042	8.920	0.021	0.031
165.0	-6.820	0.126	0.095	-6.890	0.085	0.053	8.100	0.042	8.920	0.021	0.031

1	#1	#1 actual	2	#2	#2 actual	3	#3	4	#4	3&4 average	5	#5	6	#6	5&6 average	7	#7	8	#8	7&8 average	Load
-6.400	0.000	0.000	-6.040	0.000	0.000	7.320	0.000	8.150	0.000	0.000	-0.001	0.000	-0.005	0.000	0.000	-0.005	0.000	-0.001	0.000	7&8 average	0
-6.280	0.005	0.000	-7.980	0.003	-0.003	7.560	0.011	8.150	0.000	0.006	0.050	15.300	0.073	23.220	19.260	0.018	6.810	0.046	14.280	10.545	5
-6.130	0.012	-0.002	-7.780	0.012	-0.002	7.750	0.018	8.330	0.008	0.014	0.087	28.370	0.141	43.710	38.540	0.033	11.370	0.087	28.400	18.885	10
-7.980	0.019	0.001	-7.880	0.017	0.000	7.870	0.025	8.370	0.010	0.017	0.151	46.600	0.211	64.800	66.200	0.048	15.630	0.124	37.440	28.538	15
-7.900	0.022	0.002	-7.680	0.017	-0.004	7.870	0.029	8.420	0.012	0.021	0.228	67.980	0.298	90.960	79.670	0.082	20.010	0.148	51.210	35.810	20
-7.790	0.027	0.004	-7.580	0.021	-0.003	8.060	0.033	8.450	0.013	0.023	0.301	90.600	0.378	114.810	102.705	0.074	23.460	0.213	64.410	43.835	25
-7.740	0.029	0.003	-7.510	0.024	-0.003	8.140	0.037	8.520	0.017	0.027	0.381	114.570	0.475	143.910	128.240	0.080	25.410	0.281	78.810	52.110	30
-7.690	0.033	0.006	-7.440	0.027	-0.001	8.200	0.040	8.520	0.017	0.028	0.513	154.170	0.538	182.810	158.480	0.087	21.300	0.327	96.430	61.865	35
-7.570	0.037	0.007	-7.430	0.027	-0.002	8.250	0.042	8.540	0.017	0.030	0.618	185.670	0.522	158.010	171.840	-0.016	-1.300	0.422	126.890	81.845	40
-7.500	0.040	0.008	-7.320	0.030	-0.001	8.280	0.044	8.540	0.017	0.031	0.759	227.870	0.619	187.110	207.540	-0.061	-108.950	0.753	228.290	65.000	45
-7.470	0.041	0.010	-7.320	0.032	0.001	8.320	0.045	8.540	0.017	0.031	0.861	258.570	0.722	218.010	238.280	-1.118	-334.050	1.026	308.180	76.000	50
-7.460	0.042	0.008	-7.290	0.034	0.001	8.360	0.047	8.560	0.018	0.033	0.980	297.270	0.799	241.110	268.180	-1.635	-489.150	1.300	380.380	86.000	55
-7.380	0.045	0.013	-7.290	0.034	0.000	8.380	0.048	8.580	0.020	0.034	1.182	348.870	0.840	253.410	301.140	-1.988	-585.050	1.528	458.780	98.000	60
-7.320	0.048	0.011	-7.290	0.034	0.000	8.420	0.050	8.580	0.020	0.035	1.186	356.070	0.790	285.000	310.535	-1.840	-550.850	1.801	570.690	110.000	65
-7.300	0.049	0.014	-7.220	0.037	0.002	8.430	0.050	8.580	0.020	0.035	1.248	374.870	0.822	280.000	327.335	-1.963	-587.550	2.085	625.880	122.000	70
-7.300	0.049	0.013	-7.180	0.040	0.004	8.470	0.052	8.580	0.020	0.036	1.671	501.570	0.871	282.710	362.140	-2.141	-640.950	2.341	702.680	131.000	75
-7.290	0.049	0.013	-7.110	0.042	0.006	8.480	0.053	8.590	0.020	0.036	2.525	757.770	0.954	287.610	420.080	-2.254	-674.850	2.521	756.680	140.000	80
-7.280	0.048	0.013	-7.110	0.042	0.006	8.500	0.055	8.610	0.021	0.036	2.718	815.670	1.048	316.110	468.080	-2.208	-680.450	2.542	762.960	150.000	85
-7.240	0.052	0.014	-7.070	0.044	0.008	8.540	0.055	8.610	0.021	0.038	3.258	977.670	1.370	412.410	608.080	-2.304	-688.850	2.817	845.480	168.000	90
-7.240	0.052	0.013	-6.870	0.045	0.010	8.560	0.056	8.610	0.021	0.038	3.350	1008.270	1.477	444.510	620.080	-2.324	-685.850	0.528	158.790	178.000	95
-7.210	0.053	0.014	-6.860	0.048	0.009	8.570	0.056	8.640	0.022	0.038	4.120	1238.270	1.680	508.410	860.080	-2.330	-687.650	0.582	177.990	188.000	100
-7.150	0.056	0.015	-6.860	0.048	0.008	8.610	0.058	8.680	0.023	0.041	4.450	1338.270	1.858	558.810	983.080	-2.536	-758.450	0.636	191.190	198.000	105
-7.130	0.057	0.015	-6.860	0.048	0.008	8.600	0.058	8.700	0.025	0.041	2.980	989.870	1.995	586.910	615.080	-2.688	-805.350	0.671	201.680	207.000	110
-7.080	0.060	0.017	-6.860	0.049	0.008	8.630	0.059	8.720	0.026	0.042	3.550	1085.270	2.383	643.110	856.080	-2.824	-845.850	0.681	204.680	217.000	115
-7.060	0.060	0.017	-6.860	0.049	0.008	8.630	0.059	8.720	0.026	0.042	3.520	1056.270	2.382	718.310	890.080	-2.904	-888.850	0.748	224.790	228.000	120
-7.050	0.060	0.016	-6.860	0.049	0.006	8.630	0.059	8.780	0.028	0.044	4.000	1200.270	2.882	808.010	750.080	-2.902	-889.250	0.748	225.090	240.000	125
-7.050	0.060	0.018	-6.860	0.049	0.006	8.620	0.059	8.820	0.030	0.044	4.200	1280.270	2.837	852.510	780.080	-2.771	-828.850	0.872	281.890	246.000	130
-7.050	0.060	0.014	-6.860	0.049	0.003	8.630	0.059	8.870	0.032	0.046	4.430	1329.270	3.024	908.610	825.080	-2.872	-860.250	0.891	287.690	266.000	135
-7.050	0.060	0.014	-6.860	0.049	0.003	8.620	0.059	8.920	0.035	0.047	2.511	753.570	3.200	981.410	857.680	-3.046	-912.450	0.905	271.890	287.000	140
-7.000	0.062	0.014	-6.860	0.049	0.001	8.650	0.060	8.950	0.036	0.048	2.645	793.770	3.388	1017.810	905.780	-2.648	-783.050	0.937	281.490	310.000	145
-6.980	0.063	0.014	-6.860	0.049	0.000	8.680	0.060	9.000	0.038	0.048	2.768	830.870	3.580	1075.410	953.840	-2.634	-788.850	0.988	298.790	340.000	150
-6.980	0.064	0.014	-6.860	0.049	-0.001	8.680	0.060	9.080	0.042	0.050	2.983	881.170	3.830	1150.410	1024.280	-2.834	-861.050	1.078	323.790	370.000	155
-6.980	0.064	0.013	-6.860	0.049	-0.002	8.680	0.060	9.080	0.042	0.051	3.450	1035.270	4.230	1270.410	1182.840	-2.937	-908.750	1.340	402.380	400.000	160
-6.980	0.064	0.011	-6.860	0.049	-0.004	8.700	0.062	9.110	0.043	0.053	3.850	1085.270	4.480	1348.410	1221.840	-1.808	-541.050	1.544	463.580	430.000	165
-6.980	0.064	0.011	-6.860	0.049	-0.004	8.700	0.062	9.140	0.044	0.053	3.980	1197.270	4.760	1429.410	1313.340	1.876	504.150	1.808	543.080	460.000	170
-6.980	0.064	0.008	-6.860	0.049	-0.008	8.740	0.064	9.160	0.045	0.055	4.360	1308.270	5.080	1525.410	1416.840	2.045	614.650	2.080	624.380	523.820	175
-6.960	0.064	0.007	-6.860	0.049	-0.008	8.830	0.068	9.170	0.046	0.057	4.700	1410.270	5.480	1648.410	1529.340	2.408	723.150	2.276	643.180	703.170	180
-6.910	0.066	0.007	-6.860	0.049	-0.010	8.890	0.068	9.210	0.048	0.058	5.040	1512.270	6.050	1816.410	1664.340	2.715	815.850	2.512	753.980	784.820	185
-6.890	0.067	0.007	-6.860	0.049	-0.011	8.870	0.070	9.230	0.048	0.058	5.560	1688.270	7.780	2335.410	2001.840	3.288	962.050	2.878	883.790	837.820	190
-6.890	0.067	0.007	-6.860	0.049	-0.011	8.870	0.070	9.280	0.050	0.060	7.380	2217.270	9.000	2701.410	2488.340	3.770	1132.350	3.337	1001.480	1068.920	200
-6.850	0.078	0.017	-6.780	0.057	-0.004	8.870	0.070	9.290	0.050	0.061	7.750	2325.270	8.810	2844.410	2484.840	4.050	1216.350	3.440	1032.380	1124.370	205
-6.500	0.085	0.023	-6.670	0.062	-0.009	8.930	0.073	9.290	0.051	0.062	8.960	2688.270	8.450	2536.410	2812.340	6.130	1840.350	4.640	1382.380	1616.370	210
-6.300	0.083	0.032	-6.630	0.063	0.002	8.930	0.073	9.280	0.051	0.062	10.560	3168.270	7.830	2350.410	2758.340	7.220	2167.350	5.060	1524.380	1845.670	215
-5.940	0.108	0.048	-6.460	0.071	0.010	8.930	0.073	9.280	0.051	0.062	11.180	3357.270	7.440	2233.410	2795.340	9.000	2701.350	5.650	1695.380	2198.370	219
											10.500	3150.270	7.120	2137.410	2643.840	11.910	3574.350	6.280	1884.380	2729.370	215