Shear Behavior of Prestressed Concrete Girders and Structural Health monitoring using Fiber Bragg Grating Sensors

A Thesis

Presented to

the Faculty of the Department of Civil & Environmental Engineering

University of Houston

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in Civil Engineering

by

Aadit Kapadia

August 2013

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ACKNOWLEDGEMENTS

The author wishes to thank his advisor Dr. Y.L. Mo for his guidance throughout the project. The author would also like to thank his committee comprising of Dr. C Vipulandan and Dr. Gangbing Song for serving on the committee.

The Texas department of transportation (TXDOT) funded the research with the girders being cast at the Texas Concrete Company plants in Victoria and Waco. I would like to express gratitude to all of them. Special thanks go to Gerald McTigret and Jeffrey Miller for lending their technical support to the project. I would also like to thank Dr. Emad Labib, Dr. Siu-Chun Ho, Sinjaya Tan and Ken Luu for their help throughout the project. Along with them a lot of graduate and undergraduate students gave their time and assistance to the project, the author is grateful to them.

Last but not the least the author is grateful to his parents, Saurin and Roma Kapadia, and his friends without whose love and support none of this would have been possible.

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ABSTRACT

This research deals with six Prestressed girders that were tested to observe the shear behavior and investigate the failure mode. Three of the girders had a top slab of eight inches and were constructed with TXDOT specifications. The other three were constructed without the top slab with AASHTO specification. These were tested for bond slip behavior and with minimum reinforcement. The primary objective was to investigate the type of failure in all the girders. It was found that all of them failed in web shear and none in bond slip. One of the girders also had Fiber Bragg Grating sensors on the inside surface to observe localized bond slip. This was compared to the global slip given by the conventional sensors which led to conclusions about using those sensors instead of the conventional ones for structural health monitoring.

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Chapter 1: Introduction

1.1 Background

Since the popularity of concrete use in everyday construction is on the rise, Prestressed concrete has been the preferred form for highway construction. With the use of reinforced concrete there are problems of cracking and the inability of the usage of steel. To fix this problem Prestressed concrete (PC) was tried and after its successful deployment it was used in buildings, super structures, transportation and a variety of construction things. Prestressed concrete was invented and patented in 1886 by Henry Jackson, a San Francisco engineer. PC became the primary material to be used in Europe and the United States especially after World War II, due to the shortage of steel. The Walnut Lane Memorial Bridge, built in 1951 in Philadelphia, Pennsylvania, became the first structure in the US made of this type of material. Thus in the last 60 years PC has been the primary material used in the structural engineering industry.

The research focused on the bridge girders which have been constructed with high strength concrete and assembled. The prestressing in the girders gave it higher ductility. Economically it is very sustainable and has gained popularity over the years. This research focused on I beams cast with TXDOT specifications. These beams were reinforced with Prestressed tendons on the bottom flange and the web with transverse reinforcement. These increase the strength of the girder. PC is used mainly so that the maximum use of steel can be made in its contribution towards to shear strength of the girders.

Figure 1.1 (a) Prestressed Concrete I-Girders (Labib 2012)

Figure 1.1 (b) Prestressed Concrete I-Girders

PC girders have various modes of failure. This research primarily focuses on shear failure which is considered to me more dangerous than others such as flexure etc. Shear failures are not particularly ductile thus adequate measures and reinforcements need to be provided for the failure. Essentially there are two types of shear failures predominant: web shear and flexure shear. Web shear occurs near the supports. Here the bending moment is small and shear large, whereas flexure shear occurs at the one third or the one quarter point of the span. Thus, the shear and bending moment both are high throughout the surface of the beam.

Reinforcement of a structure is a very critical component and thus the amount of failure varies with the amount of reinforcement. Excessive reinforcement induces concrete crushing causing brittle failure whereas moderate reinforcement (i.e., an under reinforced section) induces yielding of steel first and thus has the structure develop a ductile failure. Thus, four possible failures modes exist in a PC girder: (1) web-shear failure near the support with yielding of steel, (2) arch-rib failure near the support due to crushing of concrete, (3) flexural-shear failure within the span due to yielding of steel, and (4) compression-shear failure within the span due to crushing of concrete.

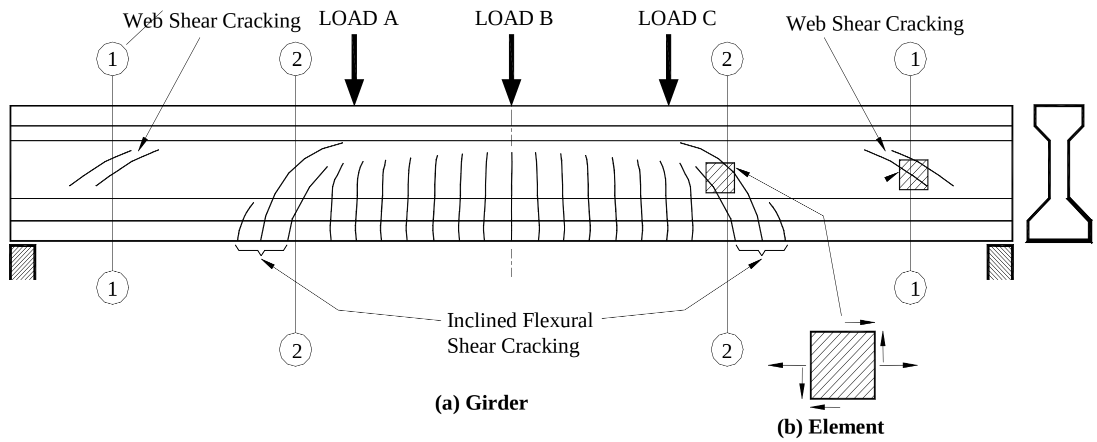


Figure1.2 Shear Failure Modes in I Girders

1.2 Research Significance

For a long time Prestressed concrete has been the preferred method for highway construction because of the availability, cost and quality control. In the usage of Prestressed concrete, high strength concrete is one primarily used. Today the definition of high strength concrete by ACI is concrete which has a compressive strength of 8 ski or higher. This is a higher value than what used to be considered previously as 5 ksi, 6 ksi and 7.5 ksi. To date, design provisions for HSC have been proposed successfully for the AASHTO Load and Resistance Factor Design (LRFD) Bridge Design Specifications for axial loads, bending and bond. For shear, the new section 5.8.3.4.3 of the AASHTO LRFD (2010) Specifications allows engineers to return to the pre-1994 shear provisions, which were based on the ACI Code on the recommendation of NCHRP Report 549 (Labib 2012) (Hawkins et al., 2005). It is almost impossible to extend the assumption for normal strength concrete to high strength so it was a challenging aspect. But, In 2010, the University of Houston developed a rational approach to estimate the maximum shear strength based on the extensive studies of two-dimensional (2-D) membrane elements using the Universal Panel Tester at the University of Houston, (Laskar et al. 2010).

After reviewing papers extensively the maximum shear strength Vn, max was plotted in the graphs according to the three codes (AASHTO 2010, ACI-318 2011, NCHRP-579 2007) and the UH equation established in 2010 (Laskar). This is plotted w.r.t. concrete compressive strengths and it compares it to results of the previous tests performed by (Bennett and Balasooriya 1971, Rangan 1991, and Ma et al. 2000) (Labib 2012).

The codes lack in the description of girders with strengths greater than 8 ksi. Thus more research on high strength girders whose compressive strength is greater than 8 ksi should be thoroughly investigated.

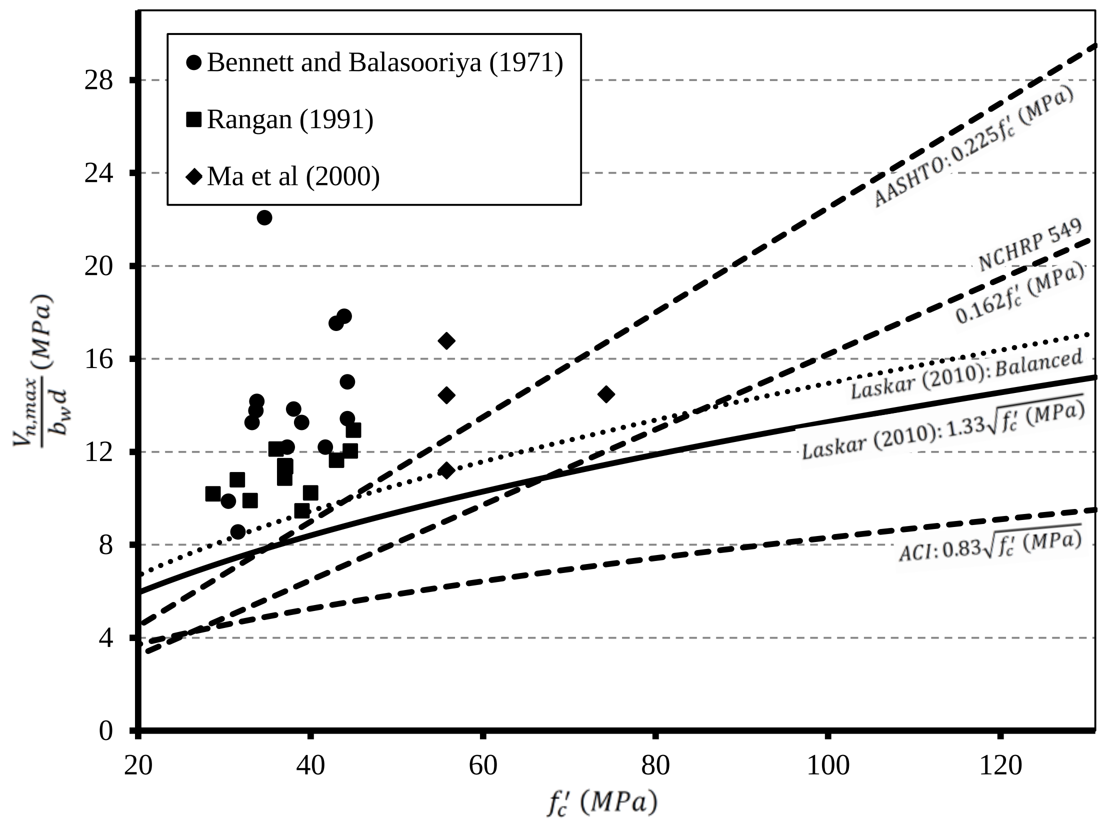


Figure 1-3 Variation of Maximum Shear Strength $V_{n,max}$ with Concrete Strength $f_c{}'$ (Labib 2012)

Amongst other things it was also proposed to amalgamate the concepts of structural health monitoring with the research of bond slip in the girders. Structural Health monitoring is considered to be the future of civil engineering. Thus it was proposed that in one of the girders G2 Fiber Optic Sensors (FBG)'s be used to monitor the bond slip in the girders and hence compare it with the strains measured with the conventional sensors.

1.3 Objectives of Research

A major reason to investigate the bond slip of the girders was that it was believed that the Prestressed shear girders would fail by shear bond where in the first recorded bond slip was recorded. Thus, we proposed to test six Prestressed girders based on ACI and AASHTO to observe the ultimate shear strength and investigate the failure modes. Our prime purpose was to find out if they fail in the usual modes of shear or by bond slip. Thus it was proposed to carry forward the research done and established through the UH equation and investigate if it holds true for girders with higher depths.

It was also essential to determine the effectiveness of FBG's in large scale girders. The apprehensions raised in the research included their aversion tom temperature and so forth. So it was proposed to install these and monitor the behavior of the beam as the slips recorded by these would be localized and not globalized as is the case with the conventional sensors. It was also essential to use these to investigate whether their use could be standardized and replicated on a much larger scale.

Chapter 2: Literature Review

2.1 Introduction

This part focusses on the reviewing the past works on reinforced and Prestressed concrete. It talks about the designing of high strength concrete girders and shear design. We will also focus on the shear design provisions in the codes and research done on bond slip behavior in the girders. Lastly we will conclude the chapter by explaining about the research and the work done in the field of FBG sensors.

For high strength concrete it is very essential to keep the water to cement ratio in check. According to the ACI committee 363R-92 1997, Water-cementitious material ratios by weight for high-strength concretes typically have ranged from 0.27 to 0.50. Thus it becomes necessary to maintain a balance between the sufficient hydration and over densification. And although decreasing the water does increase strength, it is very essential to add admixtures to the mix to take into account for hydration. The cementitious materials also need to be identified as the most economical ones and only those ones should be used. Thus, apart from the regular Portland cement; we have fly ash and silica fume as the other ones. Owing to the expense that can be incurred by using silica fumes, fly ash is the preferred material to be used with the cement. Apart from extra calcium it also gives it extra strength after 56 days which when compared with regular cement is significantly higher.

An important aspect to check is for the workability of the mix which is usually increased by superplasticizers like Glenium to prevent the addition of excess water.

But fly ash also increases the workability by a fair amount so it is very essential to keep a check on the amount of Glenium used in the mix.

It was found that ACI and AASHTO have severe drawbacks and limitations in their current codes. So the codes and the provisions and enlisted and it is further proposed how the UH equation serves as a better solution than these.

2.2 Shear Design Provisions of Prestressed Girders in Current Codes

As stated in Chapter 1, the shear design provisions in the current codes ACI-318 (2011) and AASHTO LRFD (2010) are empirical, complicated, and have severe limitations. A brief description of the shear design provisions of the ACI Building Code (2011) and AASHTO Specifications (2010) are in Sections 2.2.1 and 2.2.2 respectively.

2.2.1 Shear Provisions of ACI Building Code

Since the ultimate shear capacity of the girder has to be determined the two most commonly used shear design provisions namely the ACI and

Shear Design provisions in the ACI and AASHTO haven't been considered adequate. The equations for the shear strength as follows: One of the major requirements is

$$Shear\ Force\ V_u \leq Nominal\ strength\ V_n * \Phi\ Factor\ of\ safety. \qquad (2.1)$$

$$V_n = V_c(concrete\ contribution) + V_s(steel\ contribution).$$

Concrete Contribution:

$$V_c = \left(0.6\lambda\sqrt{f_c'} + 700\frac{V_u d_p}{M_u}\right) b_w d,$$

$$V_c = \left(0.05\lambda\sqrt{f_c'(MPa)} + 4.8\frac{V_u d_p}{M_u}\right) b_w d. \tag{2.2}$$

This is specifically taken where the effective prestressing force is not less than 40 percent of the tensile strength of the flexural reinforcement

As we stated earlier in the shear mode we expect two types of cracking namely web cracking and shear cracking. ACI (2011) defines the cracking strength as follows.

For Flexure shear:

$$V_{ci} = 0.6\lambda\sqrt{f_c'}b_w d_p + V_d + \frac{V_i M_{cre}}{M_{max}}, V_{ci} = 0.05\lambda\sqrt{f_c'(MPa)}b_w d_p + V_d + \frac{V_i M_{cre}}{M_{max}}, \tag{2.3}$$

d_p need not be taken less than 0.80 h

$$M_{cre} = \frac{1}{y_t}\left(6\lambda\sqrt{f_{c(ksi)}'} + f_{pe} - f_d\right), or\ M_{cre} = \frac{1}{y_t}\left(0.5\lambda\sqrt{f_c'(MPa)} + f_{pe} - f_d\right). \tag{2.4}$$

For web shear the equations for cracking strength are as follows:

$$V_{cw} = \left(0.29\lambda\sqrt{f_c'(MPa)} + 0.3f_{pc}\right)b_w d_p + V_p, \quad (2.5)$$

It is found out that the both in case of the web shear and flexure shear the tensile strength dictates the cracking behavior and henceforth the concrete contribution depends on it. This happens because in both cases the cracking happens at the onset of the tensile stresses exceeding the strength. Thus as a result of this ACI specifies that concrete contribution or V_c should not be less than $2\lambda\sqrt{f_c'}\ b_w d$ and should not be greater than $5\lambda\sqrt{f_c'}\ b_w d$.

The shear strength of the structure depends on the number of stirrups in the structure. The crack is ideally assumed to go from the bottom flange to the top at an angle of 45 degrees. So to get the shear strength the following equation can be used:

$$V_s = A_v f_{yt}\frac{d}{s}. \quad (2.6)$$

ACI in the following equation though specifies the minimum reinforcement that can be used:

For regular Prestressed and non Prestressed section it is to be taken as

$$A_{v,min} = 0.75\sqrt{f_c'}\frac{b_w s}{f_{yt}}\ , A_{v,min} = 0.062\sqrt{f_c'(MPa)}\frac{b_w s}{f_{yt}}, \quad (2.7)$$

$$\text{although it should not exceed } 50b_w\frac{s}{f_{yt}}.$$

For Prestressed members with force not less than 40 percent of the tensile strength it is to be taken as

$$A_{v,min} = \frac{A_{ps} f_{pu} s}{80\ f_{yt} d} \sqrt{\frac{d}{b_w}}. \tag{2.8}$$

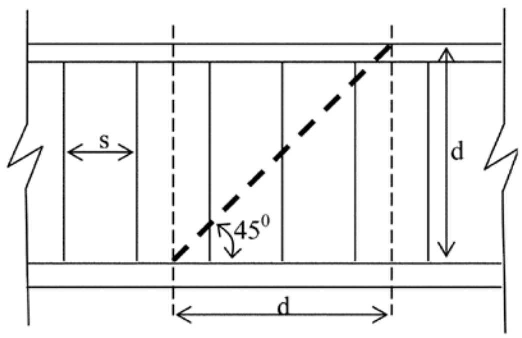


Fig. 2.1 Determination of Number of Stirrups for Contribution of Steel V_s According to ACI 318 (2011) (Labib 2012)

It is also stated by ACI that V_s should not be taken greater than $8\sqrt{f_c'}b_w d$

This is specified to make the material ductile and ensure yielding of the stirrups before concrete failure which will give some ductility and some time before failure.

2.2.2 Shear Provisions of AASHTO LRFD Specifications

To find out the nominal shear resistance of a Prestressed concrete member, AASHTO has the following specification:

$$V_n(nominal\ shear\ resistance) = V_c + V_s + V_p, \tag{2.9}$$

where V_c is defined as the concrete contribution to the shear strength and it is formulated as

$$V_c = 0.0316\beta\sqrt{f_c'}b_v d_v \,. \tag{2.10 a}$$

V_s is defined as the steel contribution to the shear strength and it is formulated as

$$V_s = \frac{A_v f_y d_v cot\theta}{s} \; since \; \alpha = 90 \text{ degrees here} \,. \tag{2.10 b}$$

V_p is the Prestressed contribution to the shear strength

Unlike the previous editions a uniform distribution of the concrete stresses is assumed for AASHTO (2010) thus the parameters are defined as:

$$\beta = \frac{4.8}{1 + 750\,\varepsilon_s}, \tag{2.11}$$

$$\theta = 29 + 3500\,\varepsilon_s\,, \tag{2.12}$$

$$\text{where: } \varepsilon_s = \frac{\left(\frac{|M_u|}{d_v} + 0.5N_u + |V_u - V_p| - A_{ps}f_{po}\right)}{E_s A_s + E_p A_{ps}}. \tag{2.13}$$

In the case of sections without transverse reinforcement or with transverse reinforcement less than the minimum requirements, the factor β becomes a function in the crack spacing parameter,s_{xe} where:

$$s_{xe} = s_x \frac{1.38}{a_g + 0.63}, \quad (2.14)$$

where 305 mm (12 in.) <s_{xe}< 2032 mm (80 in.) and s_x is the lesser of either d_v or the maximum distance between layers of longitudinal crack control reinforcement, where the area of the reinforcement in each layer is not less than $0.003 b_v s_x$. (Labib 2012)

V_n *can also be written as* $V_n = 0.25 f_c' b_v d_v + V_p$. (2.15)

Just as the ACI code there is a cap on the value ofV_n. And to ensure ductility thereby ensuring the steel yields before the concrete crushing they recommend a maximum value of V_n

$$V_n < 0.25\, f_c' b_w d_v\,.$$

Where $d_v = 0.80 \times d$

2.3 Shear Design Provisions of Prestressed Girders at University of Houston

For determining the shear capacity of the girders UH developed an equation to predict the shear capacity. Laskar (2007, 10) used the truss model established by Hsu (1998) and modeled accordingly. This was developed using the Universal Panel Tester where in the initial part of the research (Belarbi and Hsu 1994; 1995; Pang and Hsu 1995), the model did not produce logical data because the cracking wasn't considered and the concrete was determined to be continuous, thus the concrete contribution couldn't be considered. For this (Zhang and Hsu 1998) developed a new model where the stresses and the cracks were proposed as perpendicular to each other. Using the

Universal Panel Tester, a Rotating-Angle Softened-Truss Model (RA-STM) was developed. And for the concrete contribution a Fixed-Angle Softened-Truss Model (FA-STM) was proposed. In FA-STM the crack direction is assumed to be perpendicular to the principal applied tensile stresses at the initial cracking rather than following the rotating cracks. (Labib 2012)

Thus using the established research parameters Laskar (2007 and 2010) used the softened truss model (Zhang and Hsu, 1998) and developed a new term to express the maximum shear strength $\mathrm{V_{n,max}}$. This can be calculated as:

$$V_{n,max} = \sigma_2^c b_w (0.9d) sin\alpha_1 cos\alpha_1 \, , \tag{2.16}$$

where σ_2^c is the compression strength of the concrete struts, 0.9 d represents the truss height measured from the centroid of the steel to the centroid of the compression zone and α_1 is the angle of the normal to failure surface with respect to the longitudinal axis of the girder ($\alpha_1 = 45°$ when an element is subjected to pure shear).

Since $\mathrm{V_{n,max}}$ was applicable to a limited range of concrete strength Zhang and Hsu (1998) tested full-sized reinforced concrete (RC) panel elements (1.4mx1.4mx0.178m) for strengths between 3 ksi and 14.5 ksi. It was also found that the perpendicular principal tensile strain $\overline{\varepsilon_1}$ showed that the concrete struts strength in the principal compressive direction is "softened" by the compressive strength. So the maximum shear strength was expressed as a function of that expression as :

$$V_{n,max} = 5.8\sqrt{f_c'(MPa)} \cdot f(\overline{\varepsilon_1}) \cdot b_w \cdot (0.9d) \cdot (0.5) \, . \tag{2.17}$$

As $V_{n,max}$ is a function of $\sqrt{f_c'}$ for concrete compressive strength f_c' up to 100 MP (14,500 psi), it can be written as:

$$V_{n,max} = C_1\sqrt{f_c'(MPa)} \cdot b_w \cdot d, \tag{2.17}$$

where C_1 is a constant. After assuming balanced condition the constant from literature review was found to be 1.5; but we are assuming these girders to exhibit ductility and ductile failure thus it was concluded to take C_1 to be taken less than 1.5. By calculations it was found to be 1.33; thus equation 2.17 becomes:

$$V_{n,max} = 1.33\sqrt{f_c'(MPa)}b_w d\ . \tag{2.18}$$

The maximum shear strength $V_{n,max}$ in the case of Prestressed girders with only straight tendons is the summation of concrete contribution V_c and steel contributionV_s,

$$V_{n,max} = V_c + V_s\ . \tag{2.19}$$

To calculate the concrete contribution, Laskar (2007) used a concept by Loov (2002) where the concrete contribution was taken as a function of the shear stress. It was calculated by a force taken force ‘S’ taken along the inclined crack. This is contrarian to what is conventionally proposed by ACI (2011) and AASHTO (2010) where in the contribution is taken as a function of the shear failure cracks.

The figure below explains the direction of the force S

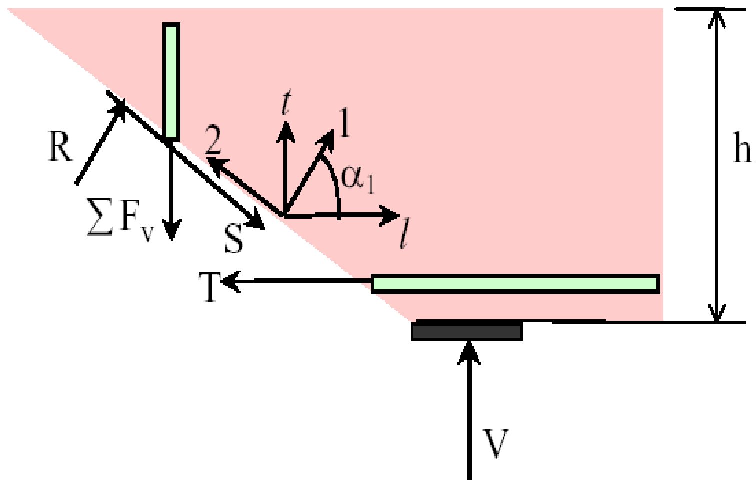


Fig. 2.2 Loov's Analytical Model Used for Calculating Shear Capacities of Girders (Laskar 2009)

Thus taking the force equilibrium of the free body along the crack direction, (Fig. 2.2), the shear capacity of the girder, V, can be calculated as:

$$V = \frac{S - T sin\alpha_1}{cos\alpha_1} + \sum F_v \, , \tag{2.20}$$

where, $\sum F_V$ is the *"contribution of steel in shear"* denoted as V_s and simply it is the summation of the Vertical forces in stirrups intersected by the failure crack at the ultimate shear load. T is the tensile force in the main flexural reinforcement at the ultimate shear load of the girder; and α_1 is the angle between the normal to the failure crack and the longitudinal axis (Labib 2012).

The term $(S - T\sin\alpha_1)/\cos\alpha_1$ in Eq. 2.20 is the "contribution of concrete in shear," the V_c term was derived directly from tests in the literature owing to the complexities in selecting the other constants.

It is mentioned before how with testing high strength concrete (Zhang and Hsu 1998), observed that the compressive softened strength is proportional to $\sqrt{f_c'}$. Taking this further Laskar (2007/10) developed an equation where V_c was a function of the a/d ratio. Thus this was developed into the following equation:

$$V_c = \frac{1.17}{(a/d)^{0.7}}\sqrt{f_c'\ (MPa)}\, b_w d \leq\ 10\sqrt{f_c'}\, b_w d\ , \tag{2.21}$$

where:

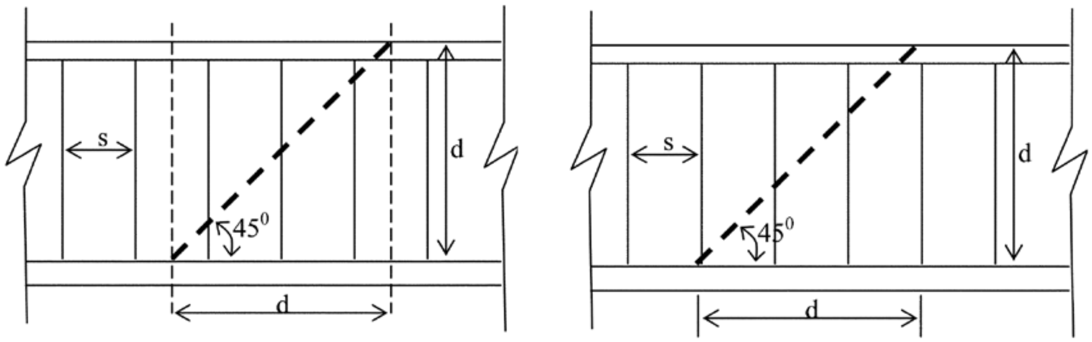
b_w= width of the web of girder, mm,

a = shear span, mm, and

d = effective depth from the centriod of the tendons to the top compression fiber of the girder, mm. The value of d is not taken to be less than 80% of the total girder depth.

Lyngberg (1976) found out that the shear capacity remained unaffected by the prestressing force in the tendons, and thus concluded that V_s, the steel contribution, had to be based of the shear crack ideally taken at a 45^{o} angle like the established codes. Laskar developed a more accurate way to calculate this by taken a new equation for shear contribution unlike the generalized and conservative way proposed by the ACI.

He also concluded that the minimum number of stirrups intersecting the minimum shear resistance line at 45° is taken as $[(\mathrm{d/s}) - 1]$ (Labib 2012).



(a) Smeared Stirrups Method (b) Minimum Shear Resistance Method

Fig. 2.3 Determination of Number of Stirrups for Steel ContributionV_s, Smeared and Minimum Shear Resistance Method (Laskar 2009)

Unlike the ACI code this takes into account the average number of stirrups, $\mathrm{d/s}$, crossing the 45° shear crack. Thus it is as follows:

$$V_s = A_v f_y \left(\frac{d}{s} - 1\right). \quad (2.22)$$

Minimum shear reinforcement, $\mathrm{A_{v,min}}$, in girders is required to prevent the brittle failure of the girders due to the shear reinforcement fracture shortly after the inclined shear cracks formation. Based on a literature review, Laskar et al. (2010) proposed the following equations for $\mathrm{A_{v,min}}$ (Labib 2012):

$$A_{v,min} = \frac{0.0625\sqrt{f_c'(MPa)}b_w s}{f_y}\ , for\, \frac{a}{d} \le 2\ and\ \frac{a}{d} \ge 4\ , \quad (2.23)$$

$$A_{v,min} = \frac{0.125\sqrt{f_c'(MPa)}b_w s}{f_y}\ , for\ 2 < \frac{a}{d} < 4\,, \quad (2.24)$$

$$A_{v,min} \ge \frac{50 b_w s}{f_y}. \quad (2.25)$$

2.4 Shear Tests of PC Girders in Literature

This section describes international researchers' tests on Prestressed concrete girders. The major conclusions drawn from the individual series of tests taking into consideration the used concrete strength are mentioned.

Billet and Appleton (1954) were the first ones to adhere to the concept of shear and bond failures. In their tests of 26-305 mm (12 in.) deep PC I-Beams, they did not have shear reinforcement. The strengths were between 3 and 8.2 ksi. During testing it was found that two beams failed prematurely and much before the design compressive strength. Since there was no steel yielding or concrete crushing this was concluded to happen because of bind failure.

Hernandez (1958) conducted tests of 38 simply supported Prestressed I-beam with dimensions of 6 in by 12 in. Two beams had a deck slabs with 2 in. thickness and 24 inches width at the top. The web thickness of the tested beams was ranging from 1.75 in. to 3.00 in. The Beams had a concrete compressive strength varied from 15.93 to 32.13 MPa (2,310 to 4,660 psi). All the beams were loaded with one or two conc. Loads. After loading it was observed that 11 failed in shear, 23 failed in flexure and 4 in the ‘transition’ zone between flexure and shear. Thus after observing the failures it was concluded that even a minute increase in the number of vertical stirrups can considerably improve the capacity and that we should have a certain amount of reinforcement for a desired shear failure.

MacGregor et al. (1960) were amongst the first researchers to test Prestressed girders with shear reinforcement to try to develop shear provisions. 87 rectangular beams were tested along with certain I beams whose strengths were from 16.55 to 52.57 MPa (2,400 to 7,625 psi). 36 failed in shear, 43 in flexure and 6 in the transition. After looking at the crack patterns, he concluded two types of possible shear cracks which are a basis of the ACI building code namely web shear and flexure shear. But the shear beams on observation had less strength compared to flexure so it was concluded that more vertical reinforcement was essential for the girder to reach maximum strength.

Mattock and Kaar (1961) studied continuous beams with a cantilever and a deck slab. The concrete compressive strength for the beam and the deck slab varied from 41.85 to 47.30 MPa (6,070 to 6,860 psi) and from 15.65 to 24.1 MPa (2,270 to 3,490 psi), respectively. After testing it was observed that these failed due to concrete crushing along the diagonal.

Bruce (1962) tested 24 simply supported Prestressed I-beams with height of 305 mm (12 in.). Deck slab was added to eight beams of them to have an overall height of 356 mm (14 in.). The web thickness of all beams was 44.50 mm (1.75 in.). The used concrete compressive strength used in casting these beams had a range from 19.24 to 27.23 MPa (2,790 to 3,950 psi). He developed a method for designing the shear reinforcement and for predicting the shear strength of beams. The contribution of concrete and steel to the shear strength of the beam were evaluated. He concluded that the extra shear capacity after the formation of the inclined cracks is mainly due to the vertical stirrups.

Evans and Schumacher (1963) tested 54 simply supported Prestressed rectangular- and I-beams with overall depth between 152 mm (6 in.) and 304 mm (12 in.). Not all had shear reinforcement. Thus they were loaded in a certain way to check the reinforcement and other structural parameters resulting in a concrete compressive strength was from 24 to 50.33 MPa (3,480 to 7,300 psi). A result of this was various modes of failure and then equations and expressions were established for various modes of predictions.

Bennett and Balasooriya (1971) tested 26 PC I-beams. The overall depth of these beams ranged from 254 mm (10 in.) and 457 mm (18 in.) and web thickness 25 mm (1 in.) and 32 mm (1.25 in.). All had a variety of prestressing force and reinforcements. The compressive strength ranged in from 30.48 to 44.26 MPa (4,420 to 6,420 psi). The major interest of this study was to study the failure modes of these beams. Thus they had different reinforcement and forces and different shear spans were used. It was observed that most beams failed in web crushing. And it was shown that the concrete compression struts in the web with maximum stress of about 0.92 f_c' due to buckling in slender webs.

Elzanaty et al. (1986) tested 34 Prestressed concrete beams. These were divided in to two groups: with and without shear reinforcement. The depth of one series was 356 mm (14 in.) and the other ones were 457 mm (18 in.). The compressive strength ranged from 40 to 73.77 MPa (5,800 to 10,700 psi). The tests interlinked and established proportionality between the concrete strength and the shear strength for beams with stirrups. For the beams without those the concrete strength was proportional to the cracking load. These tests gave a different picture to the ACI code, which at that time was found to be too conservative and thus it proved a benchmark to changing the equations for cracking and shear strength.

Kaufman and Ramirez (1988) tested six girders AASHTO Type I and II that had an overall depth of 711 mm (28 in.) and 914 mm (36 in.), respectively. The web thickness was 152 mm (6 in.) in all girders. The concrete strength in the specimens ranged from 57.50 to 62.67 MPa (8,340 to 9,090 psi). Just like the previous ones we found that the strength capacity is proportional to the diagonal struts. This was found by shifting the Prestressed and the non Prestressed ratios. Alteration of the length zones was another thing proposed which was a successful discovery in the detailing of the members, since the codes at that time weren't adequately detailing,

Ma et al. (2001) tested two girders for shear failure. One had draped tendons at one end and straight at the other. The other one was more conventional with straight tendons at both ends. Both were 1092 mm (43 in.) deep NU1100 I-girders and had a 190 mm (7.5 in.) thick deck slab. The web thickness was 150 mm (5.9 in.). The compressive strength of the concrete ranged from 55.85 to 74.33 MPa (8,100 and 10,780 psi). The tendons were anchored and since the diaphragms they were anchored to were strong and effective shear bond failure did not happen. In fact because of this the web crushed and the stirrups yielded thus giving a web shear failure. For reinforcement conventional rebars vertical welded wire fabric (WWF), and orthogonal WWF with two different yield stress 413 MPa (60 ksi) and 552 MPa (80 ksi) were used. After the observations there was a retest with the sawed-off failed end with the tendons against it. It was found that after this the girder had failure due to shear bond. Thus it was concluded that the anchors prevented the shear bond and that the lack of good anchorage would lead to a shear bond failure. This was about 25% less than the web crushing thereby reducing the capacity of the girder. It also showed that the AASHTO LRFD specs could differ by 100% and found out limitations in the AASHTO specs on full scale tests.

Teoh et al. (2002)'s tests were majorly focused in the determining whether the minimum shear reinforcement requirements in the ACI (1999) and Canadian code (1994) provisions were adequate. It was found that the provisions are inadequate and more reinforcement was needed to guarantee a margin of safety in the PC girders after the onset of cracking. Six girders were tested with two different prestressing forces and, four were non Prestressed girders. All the tested girders were I beams with the same cross section of 711 mm (28 in.) in depth and had a web thickness of 150 mm (5.9 in.). The girders had a low-stirrup ratios ranged from 0.11% to 0.22%. The compressive strengths of concrete ranged from 43 to 100 MPa (6,240 to 14,500 psi). It was concluded that the cracking and the shear strengths increased with the compressive strength and that the compressive strength change gave a slight change to the load deflection pattern. They also observed that during testing the shear cracks intersected which affected the strength of the girders after cracking.

Laskar et al. (2007 and 2010) performed tests on TXDOT Type A girders to observe their failure modes. The girders were 25 ft. (7.62 m) with the design strength to be 9370 t0 10800 psi (64.6 to 74.5 MPa). The girders were divided into two groups with the three girders (B1, B2, B3) were designed to fail in web shear and (B4, B5) were designed to fail in flexure shear. For B1, B2 and B3 the loads we applied 3 ft. from the supports and they had a min. transverse steel ratio of 0.17% and the a/d ratio was 1.6. As designed they failed in web shear. For the ones in flexure shear the min reinforcement of 0.95%. The load was placed at 8 ft. from the support which gave them an a/d ratio of 4.3. After using the panels tested at the universal panel tester and the models developed before, a new equation was developed to calculate the maximum shear strength of Prestressed concrete girders.

2.5 Shear-bond Studies and Background in Literature

Shear bond studies, it was found, were performed in a variety of places under varying conditions. Thus the factors between the tendons and the slip caused and the subsequent effect on the surrounding concrete were found to be a consequence of various factors. Amongst the many known ones the major ones are adhesion, friction and resistance; mechanical resistance that is.

The first known bond slip studies concluded that most of them occurred due to adhesion. This, they said was in direct correlation to the surface conditions in the tendons as noted by Janney (1963). And many conclusions proved one thing and they said in concurrence that the first bind slip should govern and not the final bond failure since the bond slip in the first case occurs due to the concept of adhesion. Thus this conclusion by Hanson and Kaar (1959) proved to a pioneer in the concrete bond slip research.

A major breakthrough and one of the most important phenomenons for Prestressed concrete was the Hoyer effect which can be defined as, “In Prestressed concrete, the frictional forces resulting from the tendency of the tendons to assume their original diameter (i.e., their diameter before prestressing),” (Hoyer and Friedrich 1939). Thus the tendon expands due to contraction in the longitudinal direction. Complementing this effect, Stocker and Sozen (1970) stated that the small changes in the tendon cross section cause a wedging upon tendon movement relative to the concrete (Labib 2012).

Shahawy and Batchelor (1996) carried out tests in girders having a/d ratios from 1.37 to 1.52 and observed that in the AASHTO type II girders the tendon slip reduced the shear strength. It was also found that the shear bond failure loads were significantly less than the one with web crushing and other modes of failures. The same authors in 1997, also investigated the differences between the AASHTO and the ACI methods and thereby testing girders and observing for bond type failures. They found that the AASHTO method led to the predictions of bond failures the end of the beam. They concluded that to prevent this it is essential to provide well anchored reinforcing bars over the support.

Hanson (1964) tested various Prestressed girders with varying a/d ratios to observe the different modes of shear failure. And although the a/d ratios were higher for the ones in flexure and shear; he tested some beams with shear span to total depth ratios of 1.5. It was observed that in these beams the Strand slip, however, caused bond failures in beams with a 2-1/2 in. overhang. And it was also found that the slip significantly affected the shear strength of the girders. Hanson and Kaar (1959) also talked about the bearing stress between the tendon and the concrete and the fact that it provides additional capacity. This concept is known as interlock. But this capacity would be dependent on a variety of factors, structural and nonstructural. So in spite of it increasing the strength and providing some extra capacity to consider; interlocking by and large in considered unreliable and thus more often than not, it is not taken into account.

Abrishami and Mitchell (1993) used a seven wire tendon with diameters of 9.5, 13, and 16 mm (3/8, ½, 0.60 in) to test for the embedment of the tendon and check for bond slip. Thus three girders were tested for different diameters to check for bond failure. Since the specimens were tested in flexure they found that the ductility increased where during the regular test pertaining to the transfer length the material showed brittle modes of failure.

Yerlici and Özturan (2000) found out a correlation between the concrete strength and the bond strength. By performing pullout tests on high-strength and high performance concrete specimens, they found out that the bond strength increased by increasing the concrete strength and web reinforcement. But if a bar of a higher diameter was used, the strength was found to be decreasing. After the tests, the concrete strength was determined to be between 60 to 90 MPa (8,700 to 13,000 psi) which was higher than the usual high strength concrete, which as defined by ACI is 8000 psi.

The AASHTO LRFD (2007) code according to NCHRP (2008) was found inadequate for bond strength as it did not cover a lot of properties such that concrete strength, tendon size etc. in its report. With this research we present the shear bond effect in the girder and explain its shear behavior in the end region of the Prestressed girders. It also covers the slip measurement through the conventional sensors and comparing it to the Fiber Bragg grating Sensors (FBG).

2.6 Applications of FBG strain sensors in structural sensing

Fiber Bragg Sensors are currently one of the most sought after sensors in the field of Civil/Structural Engineering. Since Structural Health Monitoring holds a very important place in our current field these sensors hold an important place in that regard.

Various researchers have proposed a variety of solutions to encompass these sensors. A major issue with them is the fragility of these sensors. And since the structures we propose to put these in are enormous in nature with long spans there sustainability is a major issue. We also need to find out how durable it is for the proposed girder.

Schulz, Conte and Udd (2001) used long gauge sensors for structures. The research talks about embedding these in concrete structures or bonds them with steel structures and monitored them at real-time speeds from DC level to over 10 MHz with strain resolutions from 0.02 micro strains (DC to 10 kHz) to 25 micro strains (10 MHz). Thus this will give a macroscopic deformation measurement of the structure and will be also be essential in earthquake monitoring as a response to ground motions. These will also be used for the calculations and evaluations post an event.

Leng et al (2005) talk about specific development of these sensors in concrete structures. Specifically, two kinds of protection system of fiber optic sensors were developed: (1) surface-mounted and (2) embedded protection system. The cylinder tests concluded that the sensors exhibit good linear behavior in accordance with the conventional electronic strain gauges and thus can be used for monitoring of bigger structures. And thus these can be used for health monitoring in bridges, highways and buildings. They also concluded that FBG sensors can predict failures of a structure better than strain gauges because they have a higher resolution.

Chung and Kang used an often used method in FBG installations where they placed a FBG fiber in the steel rebar and bonded it with an adhesive. This was then used for monitoring the localized strain. This is quite commonly used in the industry and for concrete structures and research oriented studies.

Zhou and OU (2004) talk about fabrication and the installations of the FBG sensors in civil structures and talk about the cost of implementing and putting these in regular infrastructure. They also talk about how these can not only be installed in concrete structures but also in offshore structures. Thus the strain monitoring is discussed in depth by the authors. They talk about installation in bridges and using high frequency, low cost demodulation devices which will change the complexion of disaster monitoring and structural health monitoring.

Lin et al. (2005) talk about the 'in situ' characteristic of the sensors. They describe how the FBG's were installed to find out more about the behavior of the material during the hydration period when it is curing. They also observed the data during the prestressing processes which gave them an idea of the behavior of the structure during the tendon release and later. Since the initial strain does affect values like shrinkage, creep and so forth, the installation of these sensors can be useful throughout the life of the structure. These can be used for monitoring at certain pre-determined intervals. When compared to another sensor, RSGs the FBG's were found to be more accurate and more competent to be used in the future and thus they were used. Since the remote monitoring of structures is the decisive way forward, FBG structures are the way forward

Shulcz et al. (2000) talked about the installation of 26 FBG’s to monitor the Horsetail Falls Bridge for two years, where long gauge sensors were used. Due to localized strain value that they provided they can be measured to a very low resolution and thus proved to be very essential.

Majumder et al. (2008) talked about the current research in FBG and how it should be implemented in concrete structures. It was observed that since they are lightweight and immune to harsh environmental conditions, they are suitable to be used in the measuring longitudinal strains. Although in SHM presently conventional sensors are the most ones used, FBGs do have a potential to capture the market. The major reason they haven’t done that yet is the non-standardization of these sensors worldwide and there not being any suitable method to proceed. The temperature effects on FBG’s are also a major reason of unreliability and that needs to be addressed immediately. Thus it says although FBG’s only constitute 15-20% of the current market, with good research and adequate addressing of all the issues the market for these is set to increase by a higher margin.

Chapter 3 Construction and Instrumentation

3.1 Introduction and Objective

In this chapter we will talk about the manufacturing of the six girders with three different sizes. This chapter talks about the construction procedure of each of the girders and how these were manufactured. It also talks about the test set up that was provided and assembled to test these large scale girders. Since testing on this scale had never been done before it was a challenge to assemble the set up.

In addition to that this chapter also talks about the instrumentation and other devices used for calculating and recording data for these girders. The experimental data will be used validate the UH shear strength equation.

3.2 Manufacturing of the Test Girders

The casting of the test girders was contracted to two different companies in Texas. The first set of girders was manufactured at the Texas Concrete Company in Victoria, Texas. The first set of three Girders, G1 (Tx28), D1 (Tx46), and E1 (Tx62), was cast at Texas Concrete Company in Victoria, Texas, in July 2011. Two girders of the second set of three girders, Girders D2 (Tx46) and E2 (Tx62), were cast at Texas Concrete Company in Victoria, Texas, in April 2012. Because of the steel form availability, Girder G2 (Tx28) was cast at Texas Concrete Partners in Waco, Texas in May 2012. All the girders were casted individually because of a different arrangement of tendons in each of them.

The process of casting was started by prestressing tendons by hydraulic jacks placed on a prestressing steel platform/bed. Along with those we also had transverse steel rebars placed at a certain distance. Some of these were instrumented with strain gauges so that the concrete beam could be embedded with these and thus its failure and behavior can be monitored effectively. Other reinforcement like flexural reinforcements and confining ones were installed as shown in the Figure.

Figure 3.1 Reinforcement layout (Labib 2012)

A major concern was to secure the rods which mount the Linear Variable Displacement Transformer (LVDT), which served as instrumentation to measure the average or smeared strains in the girders during the load testing. So for that we came up with a solution to put coupling nuts of 50.8 mm (2 in.) length in the web of each girder on the steel sides at pre-determined locations as depicted in Fig. by drilling holes in the steel form with a diameter 9.5 mm (3/8 in.).

Figure 3.2 Foam Work to be used for casting concrete installed with coupling nuts

The concrete was mixed in the plant in a mixer and transported and poured at the site using a hopper. The slump test was performed for each beam where the range was from 8 in. to 9 in. and the average slump being around 8.5 inches (210 mm). To prevent water retention it was very necessary to vibrate the concrete and it being a moist atmosphere we made sure the vibration process was paid very significant attention to. A bed vibrator was fixed on the side form and individual spud vibrators were used throughout the surface of the beam to compact the concrete.

Cylinders were casted in the cylinder room where the slump test was recorded. Seven cylinders of 6 inch diameter and 12 inch length were casted. One of them was tested before the release to determine the adequate release strength. And cylinders were also tested at the 28 day mark and before the testing of the girders to get an idea of the compressive strength of the concrete girder.

Fig. 3.3 Concrete Placement Using a Hopper

Fig. 3.4 Bed Vibrator Attached to Steel Forms

After casting the girders, the cylinders would be tested by the company at intervals and once adequate strength was achieved, the prestressing tendons were released. This typically happened the nest day after the casting. The release strength was 43, 42.75, and 47.92 MPa (6,240, 6,200, and 6,950 psi) for girders G1 (Tx28), D1 (Tx46), and E1 (Tx62), respectively, and 48.95, 43.71, and 42.75 MPa (7,100, 6,340, and 6,200 psi) for girders G2 (Tx28), D2 (Tx46), and E2 (Tx62), respectively. After release, the girders were then kept in the yard and then after a certain time transported to UH

The top which was prepared as per the TxDOT standard was 8 inches. Fig 3.5 shows the formwork and the reinforcement cage. As stated earlier they were only prepared for the first three girders. The concrete was prepared and placed just like in the beams and vibrated accordingly with spud vibrators. Four concrete cylinders that were (102 mm X 203mm) 4 in. in diameter and 8 in. in height were cast as per each girder's slab. Before the beams were tested, a compression test was performed on these cylinders to ascertain a compressive strength of the slab.

Fig. 3.5 Reinforcement Cage for Top Slab

3.3 Test Set Up

During testing these beams were subjected to vertical loading up to their maximum shear capacity using a steel loading frame. This is illustrated in the picture below. Two actuators were used individually to apply loads on north and south sides respectively. The Actuator was placed at a distance of 46” from the end of the beam. The supports at the end of the beam consisted of an assembly of steel plates and a load cell. These actuators individually had a capacity of 2,670 KN (600 kips) in compression. Each actuator was used one by itself and thus these two actuator frames were installed on each end of the girder. Two WF30×173 girders supported the actuator frames from the top and they were thus bolted securely to the strong floor. The length of these two WF30×173girders was 7.62 m (25 ft.) long and the spacing 221 cm (87 in.) center to center. The girder was positioned in the middle of this spacing width on top of two load cells placed at the north and south ends.

Fig. 3.6 Test Setup for Girders

Both the actuators as shown in Fig. 3.6 possessed horizontal pins which rotated the bottom head if there was any curvature due to the girder. This corresponded to the deflection recorded by the specimen. Thus it was concluded that a hoorizontal force was created because of a rotation at the head. So to counter this it was proposed to use a high strength steel rod in each of the girders. This was around 60 mm ($2\ 3/8$ in.) in diameter. Actuator loads were applied through a roller assembly consisting of two to three bearing plates and one roller. The amount of bearing places was exactly determined taking into account the depth of the girder and the limitation of actuator to only go up to a displacement of 10 in. Lead sheets were also used between the beam and the load bearing surface.

Fig. 3.7 Details of Loading Set Up

Due to high loading on the support it was determined to establish a unique set up for the load cell. First a long steel plate was fixed to the strong floor of the lab. On top of this plate 8 high-strength, pre-heat-treated rods with a 51 mm (2 in.) diameter were assembled and connected with a 3mm (1/8 in) gap to form a roller assembly. This allowed the support to move and the gap ensured that the rods would not touch each other. Thus after these changes the load cell of 4,450 KN (1000 kips) capacity was placed on top of a square steel plate 457 mm × 457 mm (18 in. × 18 in.) which in turn was placed on the roller assembly. This allowed the support to move freely. This is shown in Fig 3.8.

Various bearing plates were put on the top of the load cell to support the girder. There was also a hinge that was placed individually on both the sides. Thus, this gave the scope for the girder to rotate freely at both supports and to expand freely along its length.

Fig. 3.8 Details of Support

The usual specified dimensions, specified by TxDOT were used for the bearing plates. This was placed right under the girder and had a uniform length of 21 in (533 mm) for all girders. The width varied and was 8 in. (203 mm) for Tx28 and Tx46 and 9 in. (229 mm) for Tx62. The clearance available vertically dictated the thickness of the plate for each girder. For lateral stability it was ensured that the girder was equipped with lateral supports which provided a safety cushion in case of dire emergencies.

This was all placed taking into account the safety of the researchers and it was made sure that all necessary precautions were taken when dealing with such heavy loads.

3.4 Instrumentation

The primary instruments used to measure strains were the strain gauges on the transverse which was measured as the load was applied and thus local maximum strains can be determined. Through analysis critical locations to place these gauges was determined and they were put accordingly at those points. Thus the average strain was determined with the strain gauge data obtained during the load tests.

The strain gauges had been specifically installed on transverse rebars in the line of the support and along the load points. This had been done because the girders were expected to fail in web shear and it was necessary to get the strains at those points. Since the first three girders, G1 (Tx28), D1 (Tx46), and E1 (Tx62) were designed according to TxDOT specifications so were there the rebars. We had #4 (13 mm) rebars bundled together with #6 (19 mm) rebars, with the gauges being pasted and installed on the #4 rebars. The gauges were placed in staggered formation along the west and the east directions to get the average owing to the two legs in each stirrup. All the data from the gauges is presented in the Appendix.

During testing, linear voltage differential transformers (LVDTs) were used to measure the displacements within the failure regions of the beam adjacent to the points of load application, as shown in Figs. 3.9 and 3.10. These are the conventional sensors that we use to measure displacements. A set of six LVDTs forming a rosette was installed on the East and the West sides of the beam to get the average deformations within the failure zone. These gave the smeared strain in the concrete. Since the LVDT's were placed in the expected failure region, as a result of the readings we would get the smeared strain in the expected failure region. The average strain of both the faces and both the sides was taken to find the strain in a particular direction.

All the data each LVDT from both ends of each girder are presented in the Appendix. Shown below is the LVDT setup from the TX-62 girder and TX-28 girder.

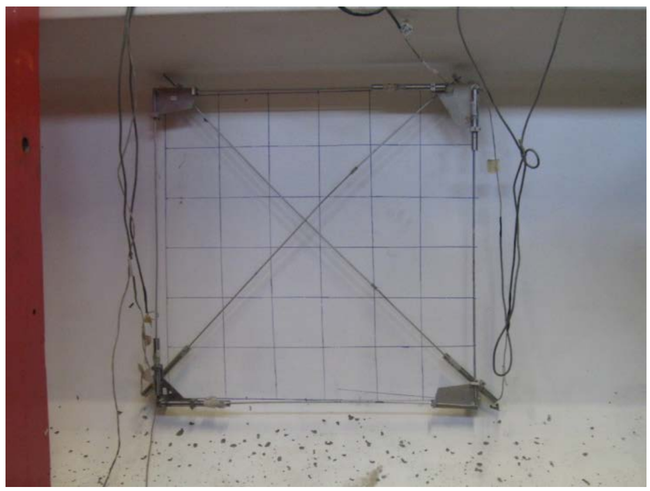


Fig. 3.9 LVDT Rosette Installed on Girders

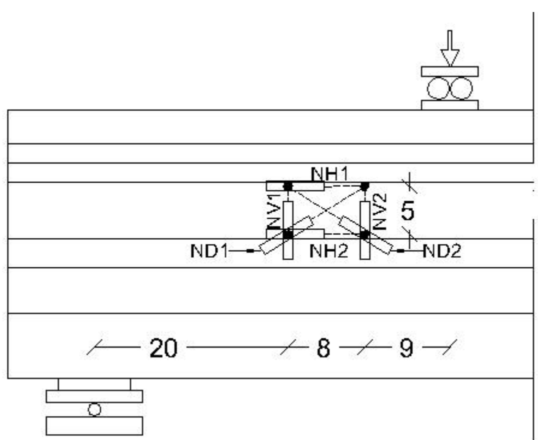


Fig. 3.10 LVDT Rosette Installed on Girders

One of the primary objectives of this project was to study the bond slip in the tendons. This bond slip would lead to shear bond failure where the concrete crushing would take place at the bottom flange between the flange and the web. To capture this slip it was decided to put LVDTs on selected tendons against the concrete surface. These eight LVDTs would give us an accurate value of the bond slip, if any, in the concrete. For both sides, north and south, these LVDTs were simultaneously placed after being leveled. These were tied and secured thereby ensuring no slippage of friction as shown in fig 3.11.

Fig. 3.11 LVDTs installed on the tendons to measure bond slip

For G2, the data from LVDT's on the sensors were compared to data from Fiber Bragg Sensors and thus we analyzed it at different points and different modes of loading in the beams. More details on these are in Chapter 5.

To measure the deflection, which was then plotted against the shear force, six LVDTs were placed under the girder whilst testing. Two were under the actuators to get the total deflection at the loading points. Here the average of the two was taken for the total deflection. From the other four, two each were installed on north and south with one on the east and one on the west to get the support settlement w.r.t the increase in applied load. Thus the net deflection was the settlement subtracted from the average deflection. On an average each girder had around 35-40 LVDTs.

To monitor the data from the LVDTs and the strain gauges HBM 'Spider-8' Data Acquisition System was used. Cracks due to shear and flexure were also marked with

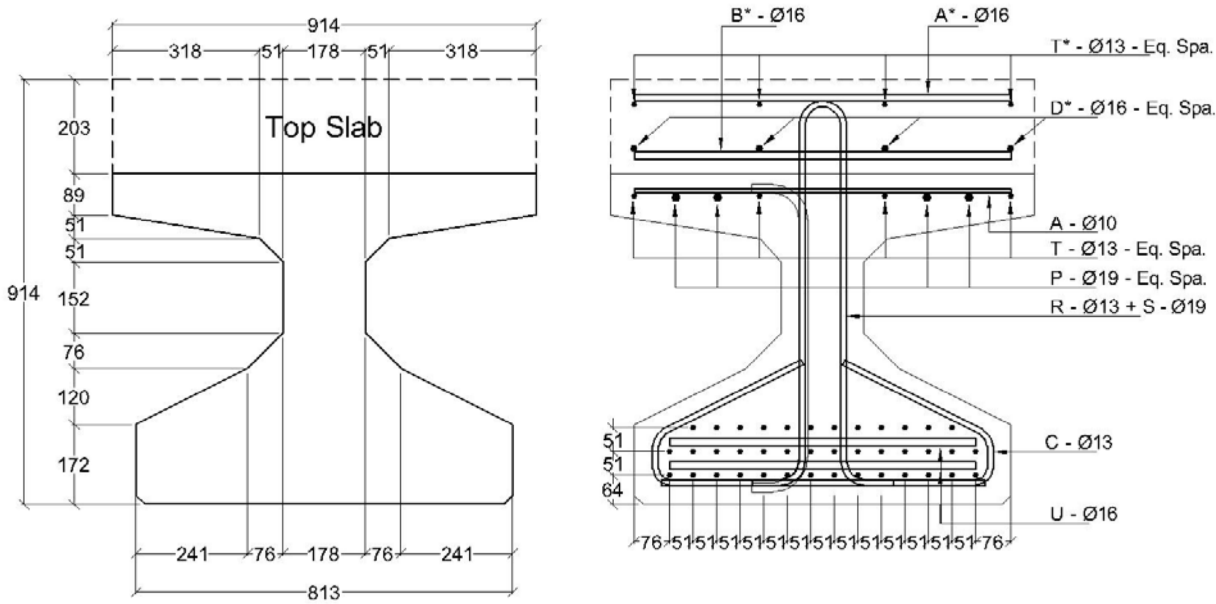
Chapter 4: Shear-Bond Failures versus Web-Shear Failure

4.1 Introduction

As discussed previously the girders were manufactured and then set up for testing. The primary motive was to capture the shear bond failure and compare the bond slip in the tendons for the girder G2 recorded in the conventional strain measuring devices, LVDT’s to the FBG sensors. Primarily, this chapter focuses on the shear bond behavior of the six girders. We observe the shear forces versus the deflection curves, and also the strain behavior in transverse steel reinforcement.

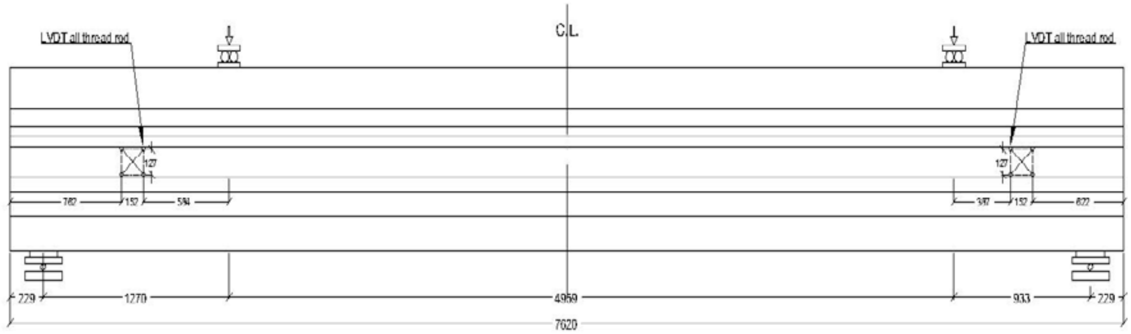
We will also introduce the bond slip recorded by the tendons but we will talk about it in more detail in the next chapter. Also explained will be the crack patterns throughout the various stages of the testing of these girders.

Along with this Laskar’s equation (2010) developed for the maximum shear strength will be also be validated by the data provided by this experiment. It was essential to verify the equation for maximum shear strength for different sizes of girders which had the a/d ratio of less than 1.6.

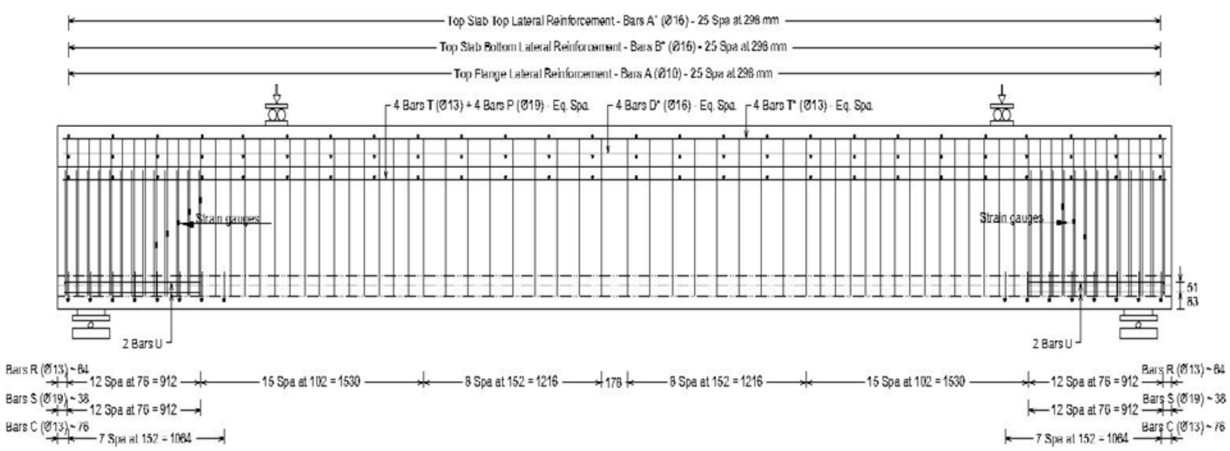


(All dimensions are in mm)

Fig. 4.1 Concrete Dimensions and Reinforcement Details for Girder G1 (Labib 2012)

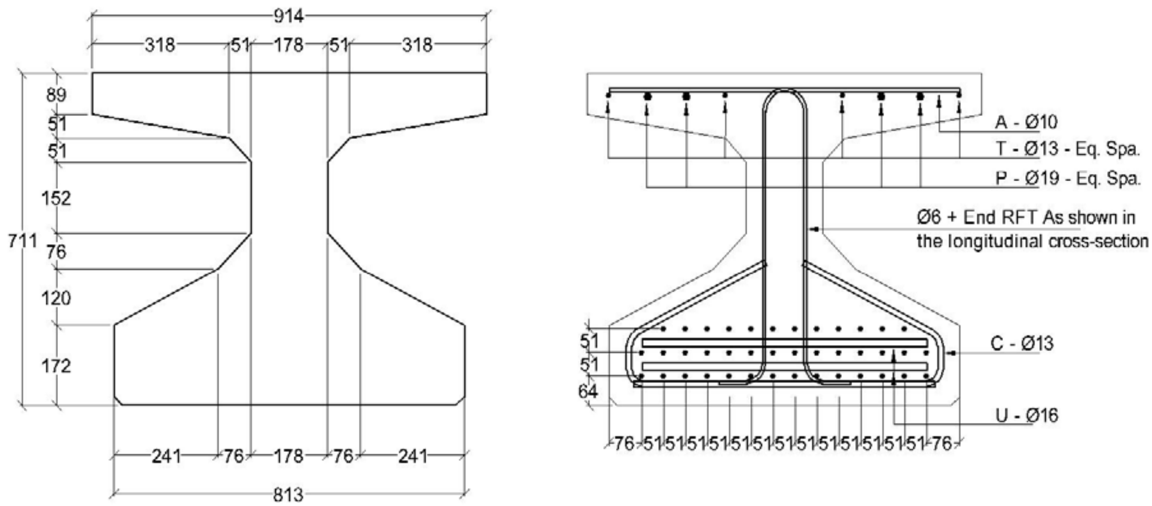


(a) Locations of LVDT Rods, Supports, and Actuators



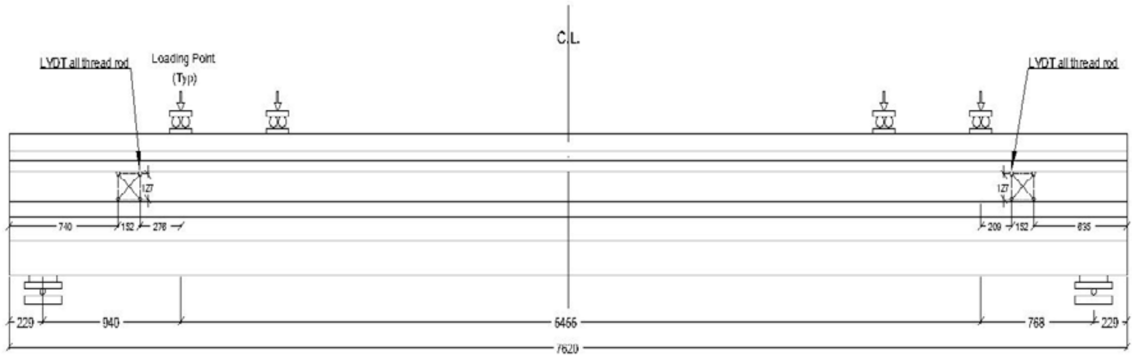
(b) Reinforcement Detailed Longitudinal Cross Section (All dimensions are in mm)

Fig. 4.2 Detailed Longitudinal Cross Sections for Girder G1 (Labib 2012)

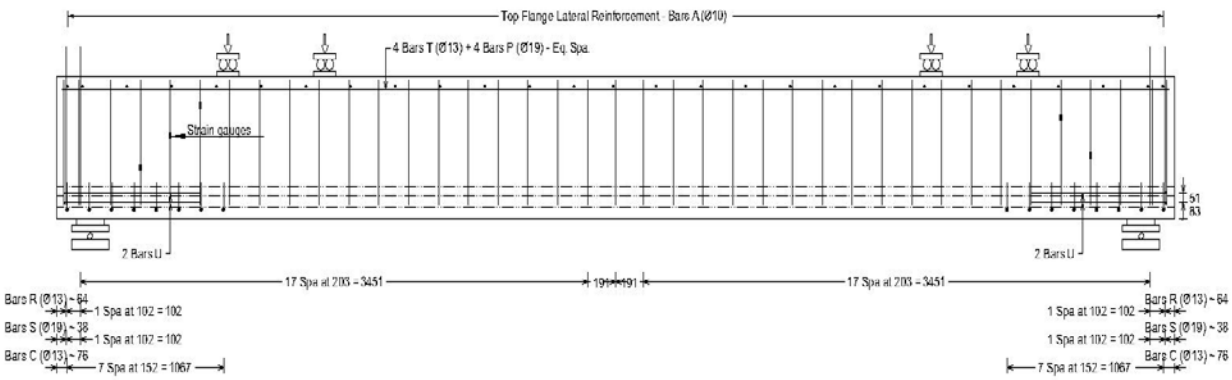


(All dimensions are in mm)

Fig. 4.3 Concrete Dimensions and Reinforcement Details for Girder G2 (Labib 2012)



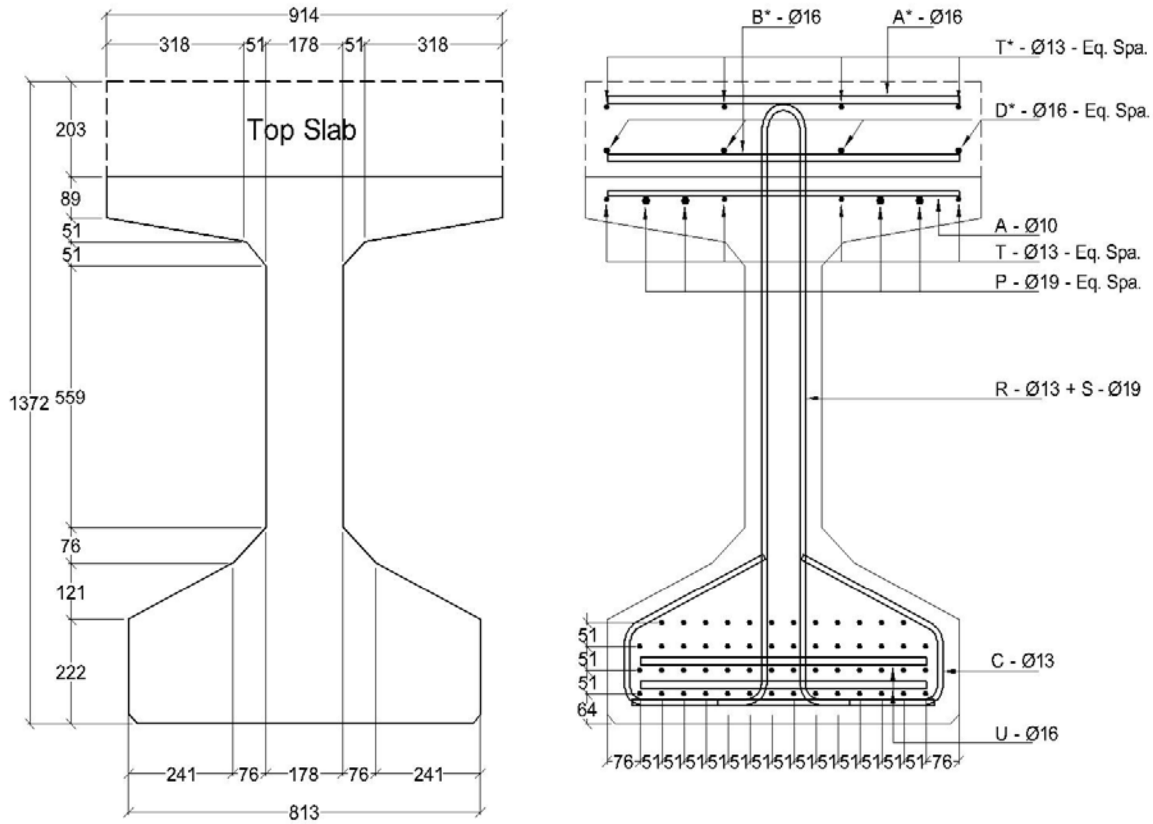
(a) Locations of LVDT Rods, Supports, and Actuators



(b) Reinforcement Detailed Longitudinal Cross Section

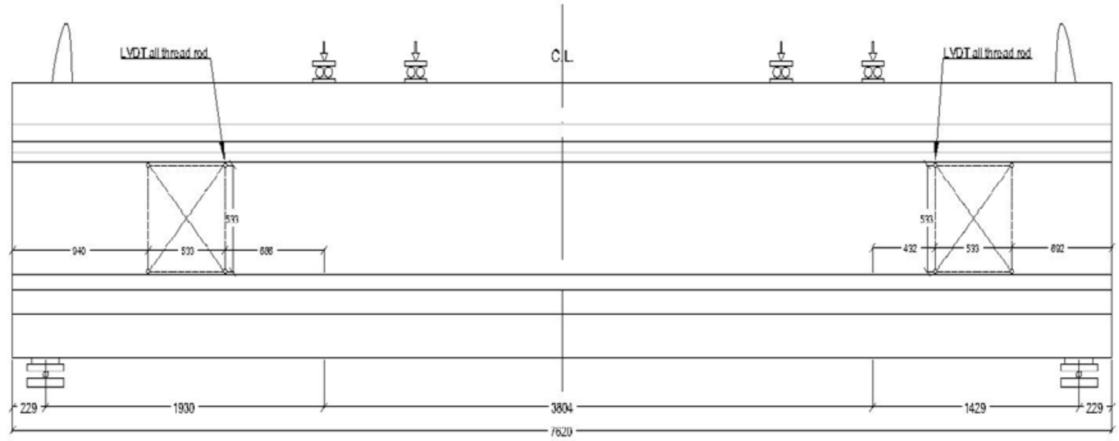
(All dimensions are in mm)

Fig. 4.4 Detailed Longitudinal Cross Section for Girder G2 (Labib 2012)



(All dimensions are in mm)

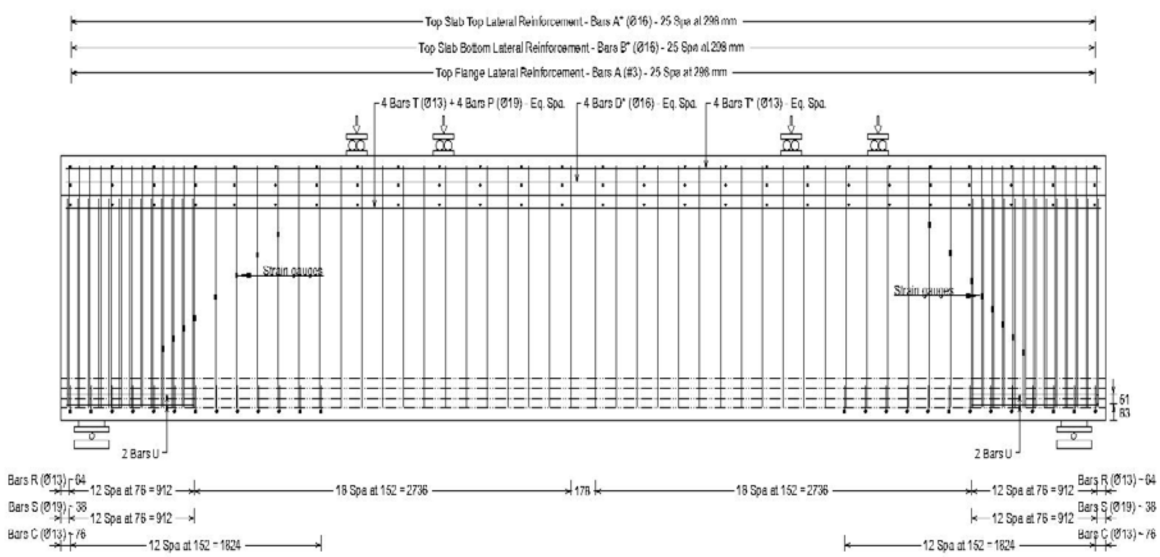
Fig. 4.5 Concrete Dimensions and Reinforcement Details for Girder D1 (Labib 2012)



(a) Locations of LVDT Rods, Supports, and Actuators

(All dimensions are in mm)

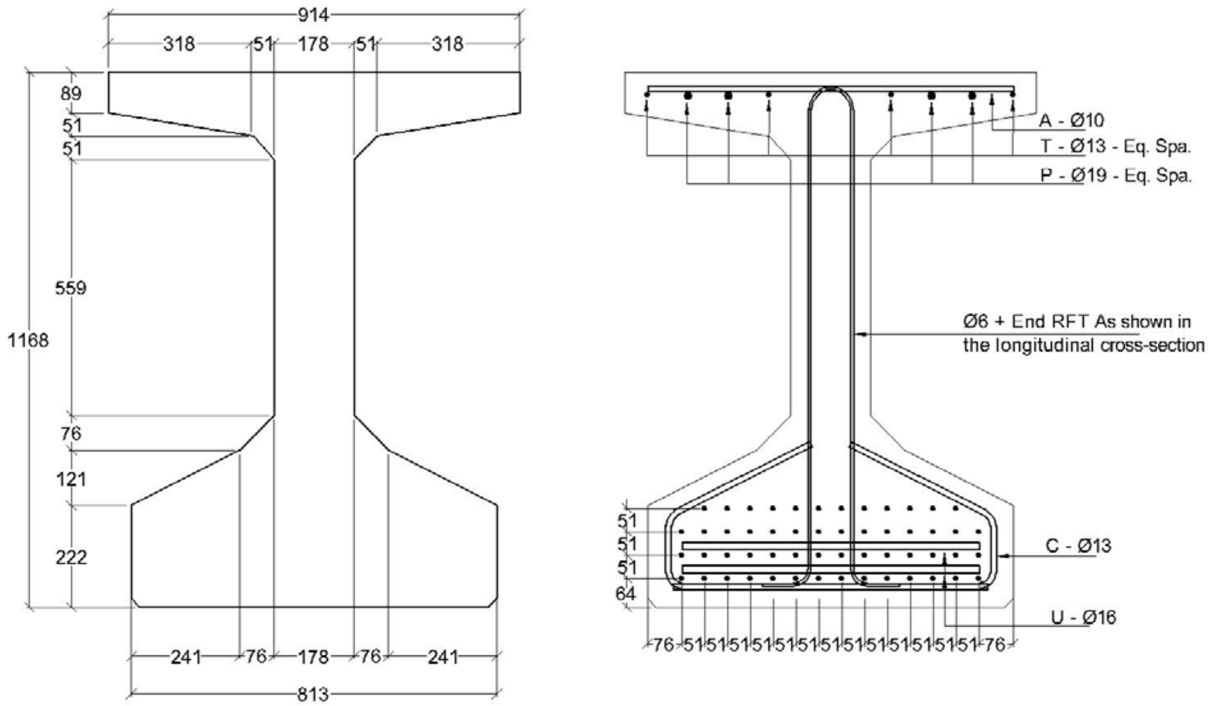
Fig. 4.6 Detailed Longitudinal Cross Section for Girder D1 (Labib 2012)



(b) Reinforcement Detailed Longitudinal Cross Section

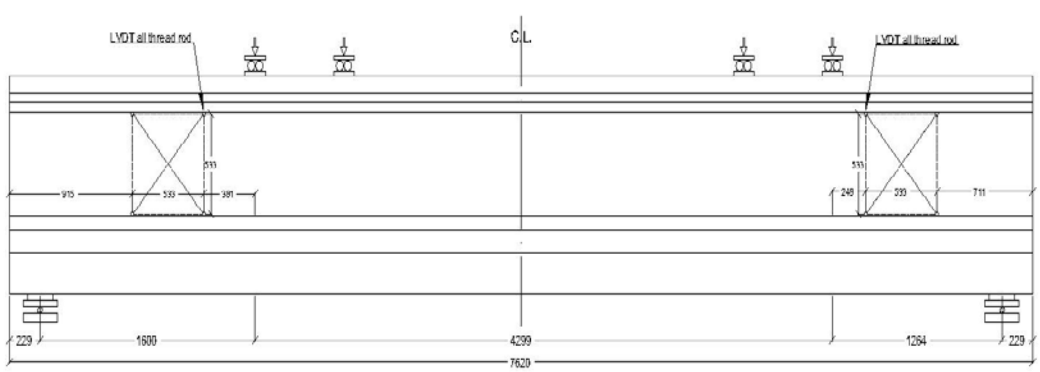
(All dimensions are in mm)

Fig. 4.6 Detailed Longitudinal Cross Section for Girder D1 (Labib 2012)



(All dimensions are in mm)

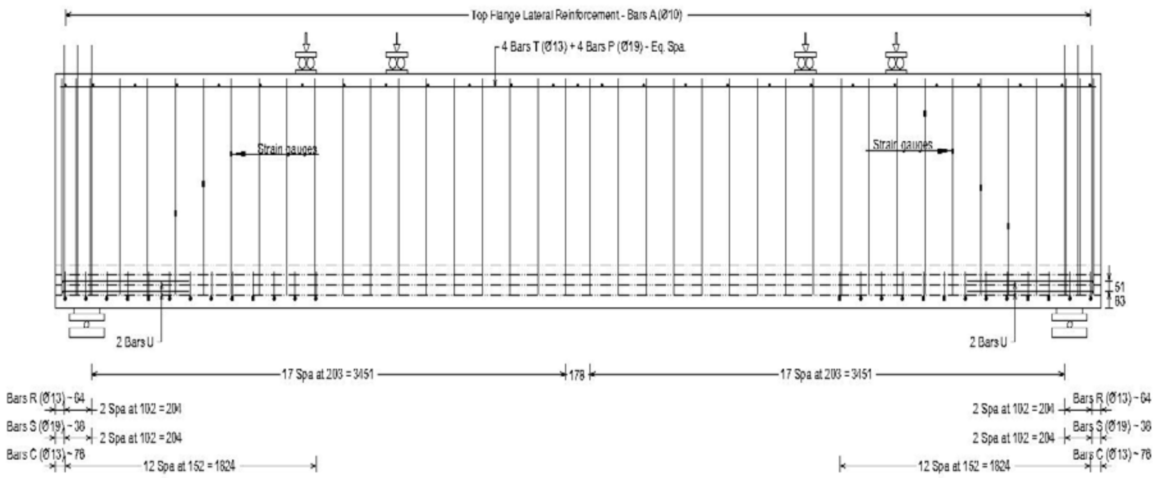
Fig. 4.7 Concrete Dimensions and Reinforcement Details for Girder D2 (Labib 2012)



(a) Locations of LVDT Rods, Supports, and Actuators

(All dimensions are in mm)

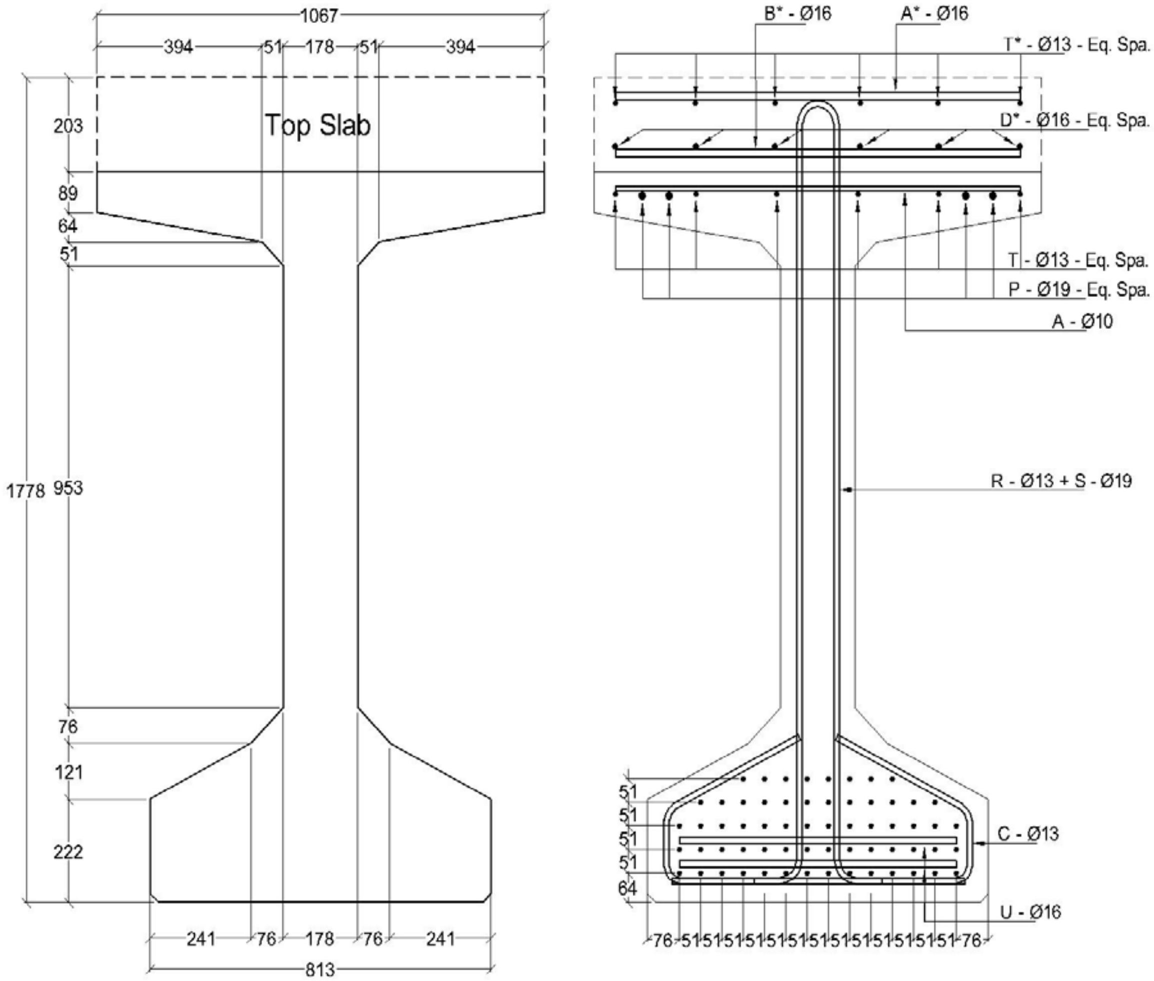
Fig. 4.8 Detailed Longitudinal Cross Section for Girder D2 (Labib 2012)



(b) Reinforcement Detailed Longitudinal Cross Section

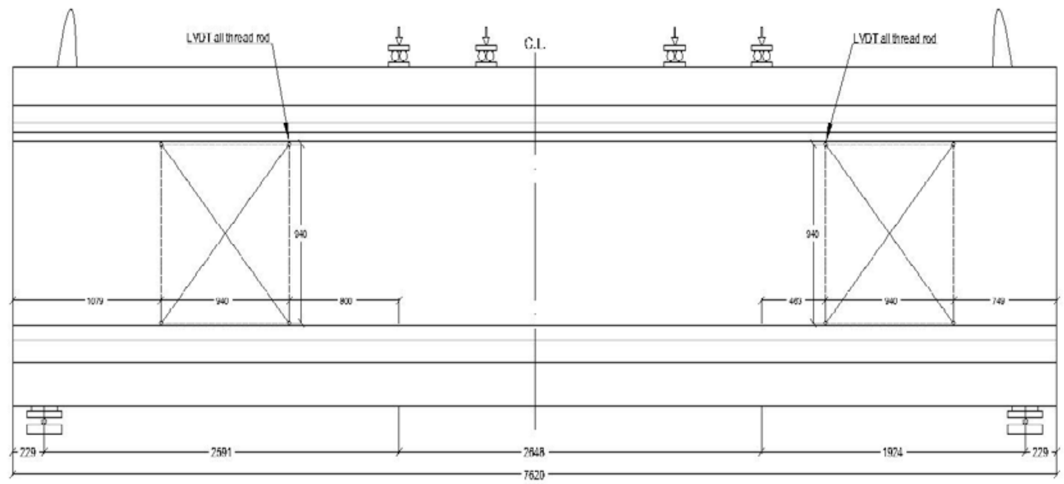
(All dimensions are in mm)

Fig. 4.8 Detailed Longitudinal Cross Section for Girder D2



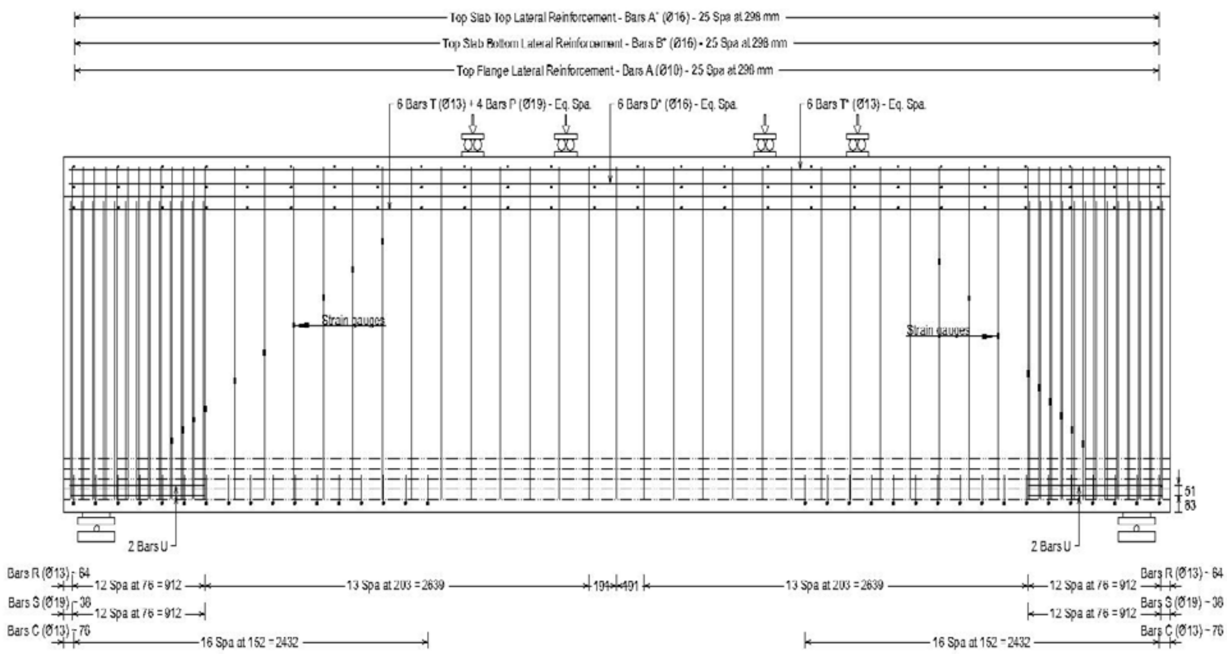
(All dimensions are in mm)

Fig. 4.9 Concrete Dimensions and Reinforcement Details for Girder E1 (Labib 2012)



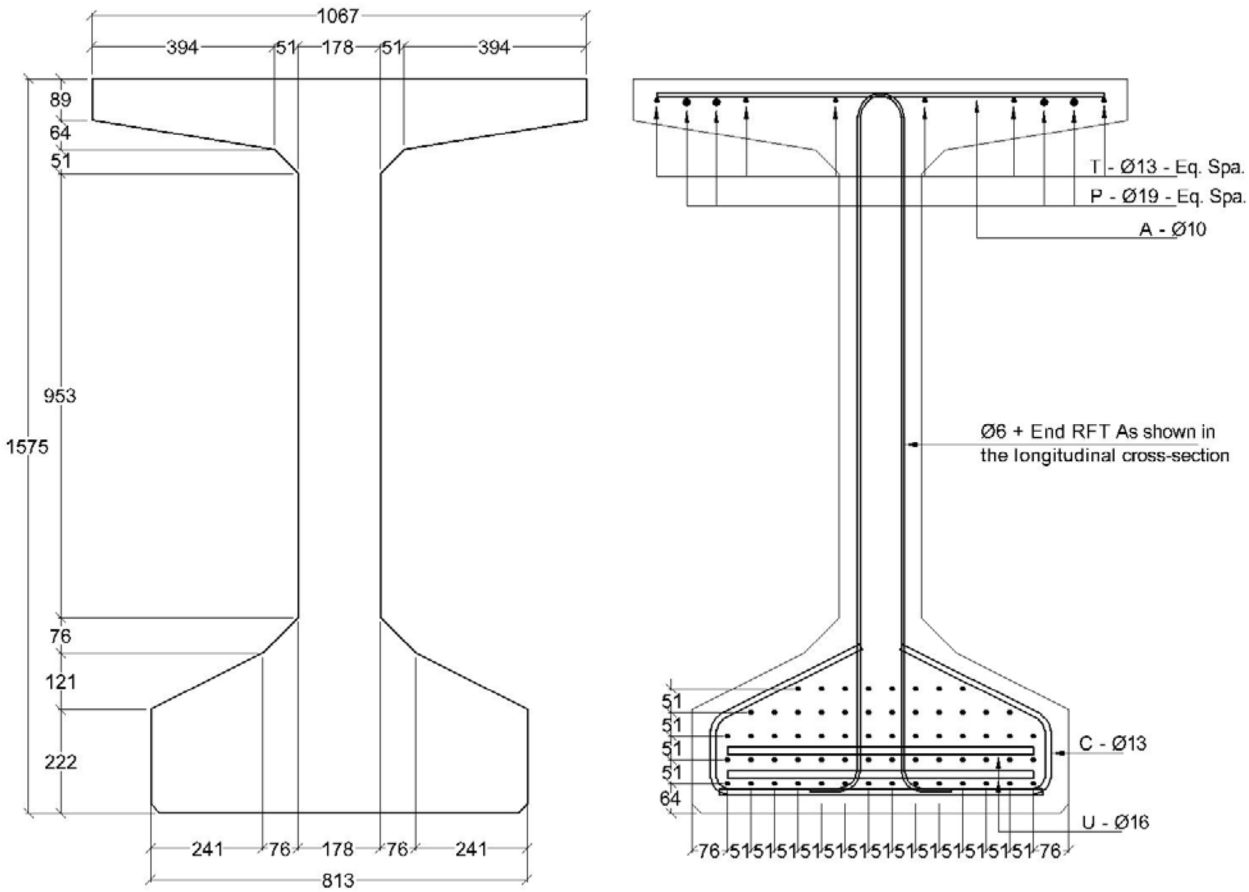
(a) Locations of LVDT Rods, Supports, and Actuators (All dimensions are in mm)

Fig. 4.10 Detailed Longitudinal Cross Section for Girder E1 (Labib 2012)



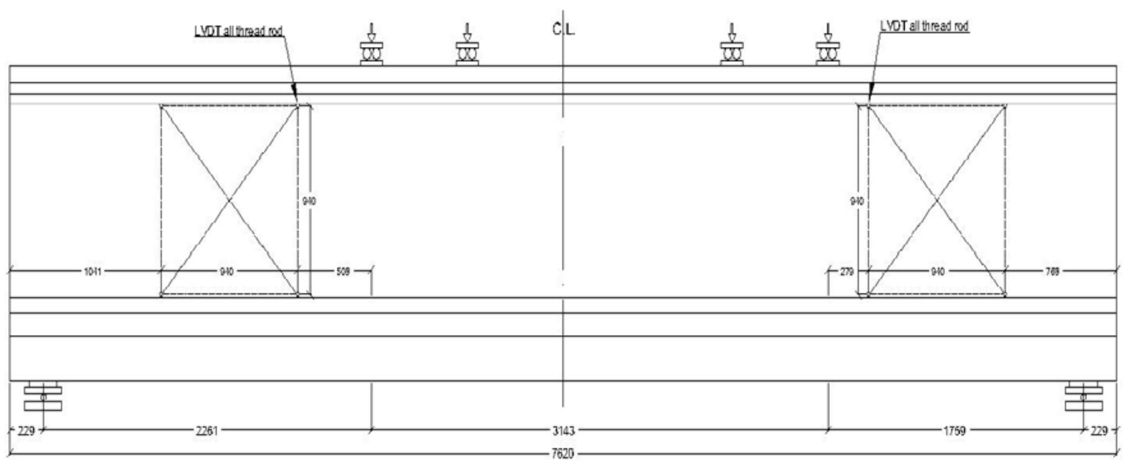
(b) Reinforcement Detailed Longitudinal Cross Section (All dimensions are in mm)

Fig. 4.10 Detailed Longitudinal Cross Section for Girder E1 (Labib 2012)



(All dimensions are in mm)

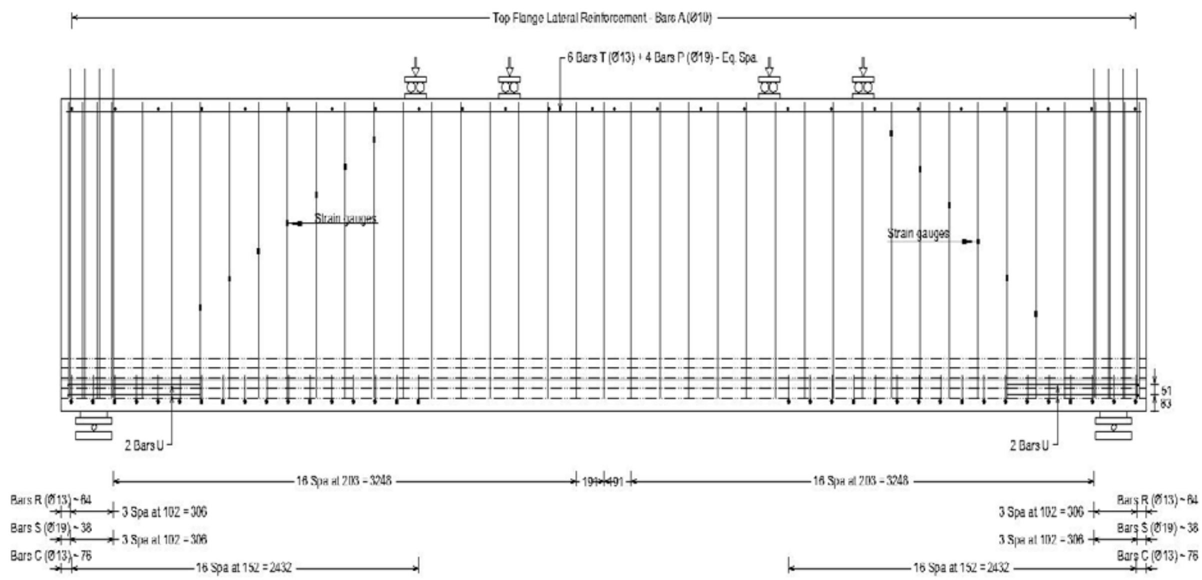
Fig. 4.11 Concrete Dimensions and Reinforcement Details for Girder E2 (Labib 2012)



(a) Locations of LVDT Rods, Supports, and Actuators

(All dimensions are in mm)

Fig. 4.12 Detailed Longitudinal Cross Section for Girder E2 (Labib 2012)



(b) Reinforcement Detailed Longitudinal Cross Section

(All dimensions are in mm)

Fig. 4.12 Detailed Longitudinal Cross Section for Girder E2 (Labib 2012)

4.2 Experimental Results of Group G Girders

Group G comprised of two girders: G1 and G2 reinforced in transverse directions with TXDOT and AASHTO specifications respectively. G1 had an 8 inch top slab where G2 was constructed without a top slab.

The following figure shows the shear force versus net deflection during testing both north and south ends of each girder. The testing procedure, smeared strains in concrete, local strains in transverse steel, and the mechanism of failure of both girders will be discussed in the following sections.

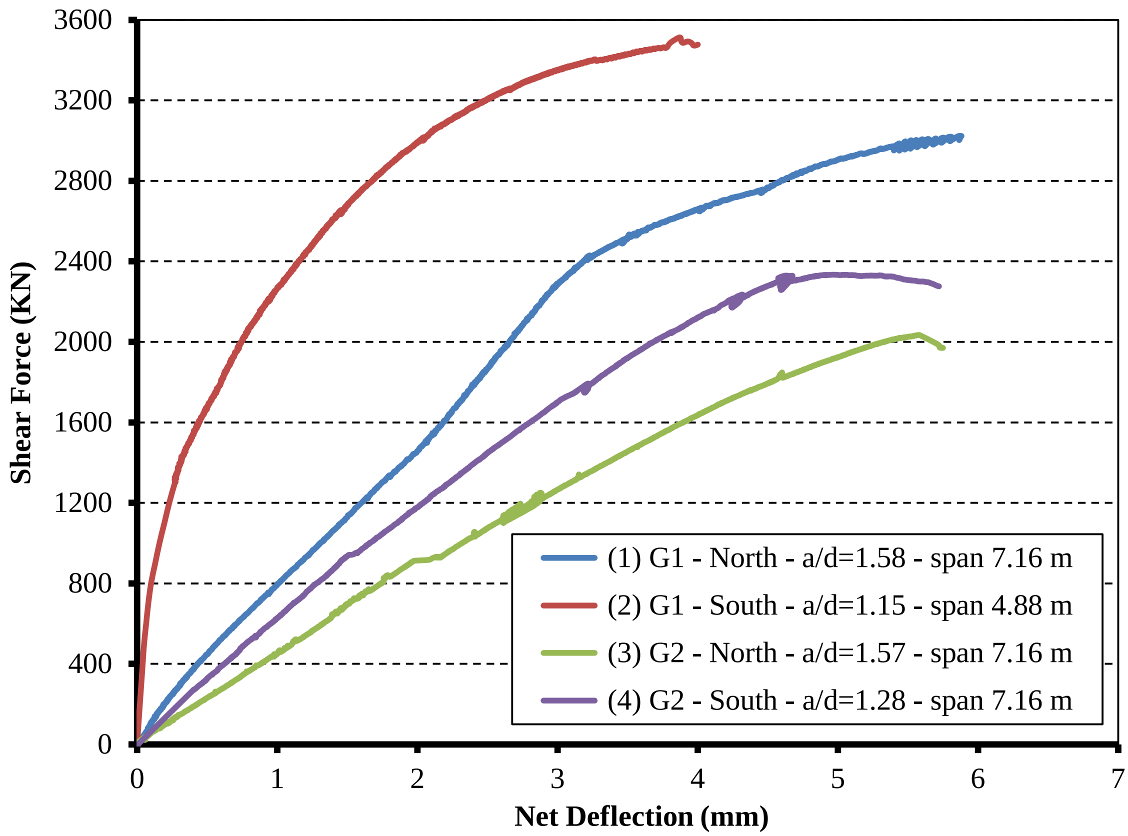


Fig. 4.13 Shear Force vs. Net Deflection Curves for Group G Girders (Labib 2012)

4.2.1 Girder G1

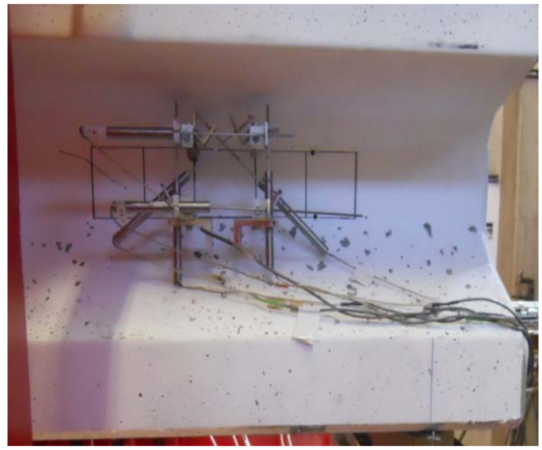
The testing was started by testing the north end of the girder with a shear span-to-depth ratio (a/d) 1.58. The support was moved by about 9 ft. so the total span remained at 16 ft. (4.88 m). Thus this reduced the a/d ratio to 1.15; as a result of this the stiffness for the south side increased.

The cracking load for the north side was 206 kips (916 KN). As expected, more cracks were observed on increasing the load. As the north side neared failure, cracks were observed on the south side when the shear force on the south side was around 120 kips (533.79 KN) and the north end around 500 kips (2224.11 KN). The figure 4.14 shows the crack pattern. Thus after the north failed around 679.65 (3023.3 KN). After failure the south side was tested. During the testing the first new crack was observed when the shear force was 213 kips (947.47 KN). Similar to the north side the cracks kept on increasing with the applied ultimately leasing to the failure of the south end at 789.66 kips (3512.58 KN).

The tendons as described had LVDT's to measure the slip. The slip was measured at selected tendons at both the ends when the respective end was being loaded. The LVDT data at north and south ends are presented in Table 1.2 and Table 1.8 in Appendix, respectively. NT4 at the north end gave the maximum value among other and it was 0.019 in. (0.49 mm). At the south end, ST6 gave the maximum value of 0.026 in. (0.67 mm). This was a very small slip, which clearly did not contribute to failure. Hence it can be concluded that both the girders failed due to web shear.

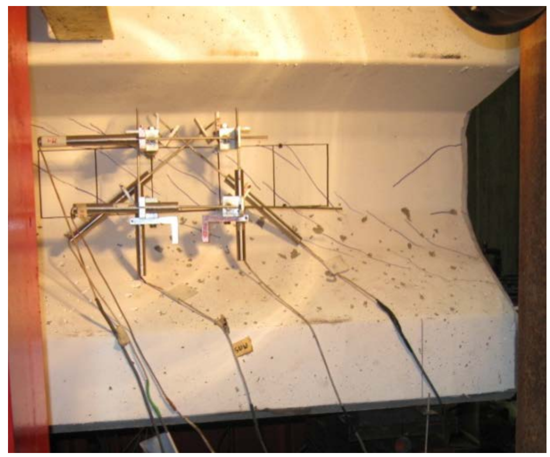
North End **South End**

(a) First shear crack at 916 KN



(b) First shear crack at 947 KN

(c) Shear crack pattern before failure



(d) Shear crack pattern before failure

(e) Shear failure at 3023.23 KN

(f) Shear failure at 3512.58 KN

Fig. 4.14 Shear Crack Pattern and Failure Mode of Girder G1 (Labib 2012)

The smeared strains in concrete at the north end during testing are presented in Table 1.3 in the Appendix. The smeared tensile strain at the North end reached 0.0094 whereas the smeared compressive strain in the concrete struts went up to 0.0023. The values of transverse tensile strains were taken from the measurement by LVDT NV1 and by LVDT NH1. This was measured to be 0.0099 from NV1 and 0.0034 in NV1. The unusually higher values can be attributed to beefed up and bulky flanges.

The south end was reloaded because of the failure as discussed previously by moving the support forward. Table 1.9 shows the smeared strains in the web at the south end. The previous test on the north end already produced cracks thus the new ones formed around the old one and couldn't be indicated like the other. Although nearby LVDT SV1 a new crack did surface at a force of 242 kips (1076.47 kn). The maximum smeared tensile strain at the peak was 0.0124 softened and the compressive stain was 0.0018 at the concrete struts. LVDT SV1 and by LVDT SH2 gave the max. smeared strain in the longitudinal and horizontal directions of 0.0155 and 0.0020 respectively.

4.2.2 Girder G2

G2 is the next girder that we talk about and this is also the girder that we will analyze with the FBG sensors. This girder just as the previous one failed in web shear at 457.22 kips (2033.82 KN) on the north side. The a/d ratio in this one was 1.57. The first crack on the north side was with the shear force at 206 kips (947.4 kn)

North End **South End**

(a) First shear crack at 916 KN

(b) First shear crack at 947 KN

(c) Shear crack pattern before failure

(d) Shear crack pattern before failure

(e) Shear failure at 2033.82 KN

(f) Shear failure at 2333.72 KN

Fig. 4.15 Shear Crack Pattern and Failure Mode of Girder G2 (Labib 2012)

The girder was stable even after the failure at the north end and thus it was possible to retest it without moving the support and using the same span. Thus after this the south side was tested with a shear span-to-depth ratio (a/d) 1.28. After loading, the first shear crack was observed when the shear force was 213 kips (947.4 kn) on the south side as seen in Fig. 4.15 (b). With the increase in the loading the crack width kept increasing ultimately leading to the failure of the girder at 524.74 kips (2333.72 kn).

The bond slip measured at selected tendons, shown in Tables 2.2 and 2.8 in the Appendix. It shows that the maximum slip recorded at the north end was 1.30 mm (0.051 in.) at NT4 and at the south end about 1.27mm (0.050 in). We will talk more about the slip and compare it with the FBG sensors in the next chapter.

The smeared tensile strain at the north end was 0.068 and the compressive about 0.0023 as shown in Table 2.3 in the Appendix. From the stain gauge readings it was found average strain measured locally was $0.8\,\varepsilon_y$. The values of these are in Appendix 2.5. It was assumed that the transverse steel yielded, since because of the min. reinforcement the cracks were not captured in the gauges and the peak values were missed.

From Table 2.10 in the Appendix which shows the local strain in the transverse reinforcement we see that the gauges stopped function before failure and thus due to trends it can be assumed that they were close to yielding.

We had minor smeared strain in the longitudinal and horizontal direction. Table 2.3 and 2.8 show the values of the longitudinal and horizontal respectively. The north end had a strain of 0.003 and the horizontal around 0.0054.

4.3 Experimental Results of Group D Girders

Two girders, Tx46, are studied in this group. The first girder, D1, was reinforced in transverse direction typically according to TxDOT specifications. The second girder, D2, was reinforced in the transverse direction with the minimum reinforcement according to AASHTO LRFD (2010). Girder D1 had a top slab with an eight in. thickness and Girder D2 did not.

Fig. 4.16 shows the shear force versus the net deflection for both ends of each girder. The north end of both girders had less stiffness due to using larger shear span-to-depth ratio and due to the failure at the south end.

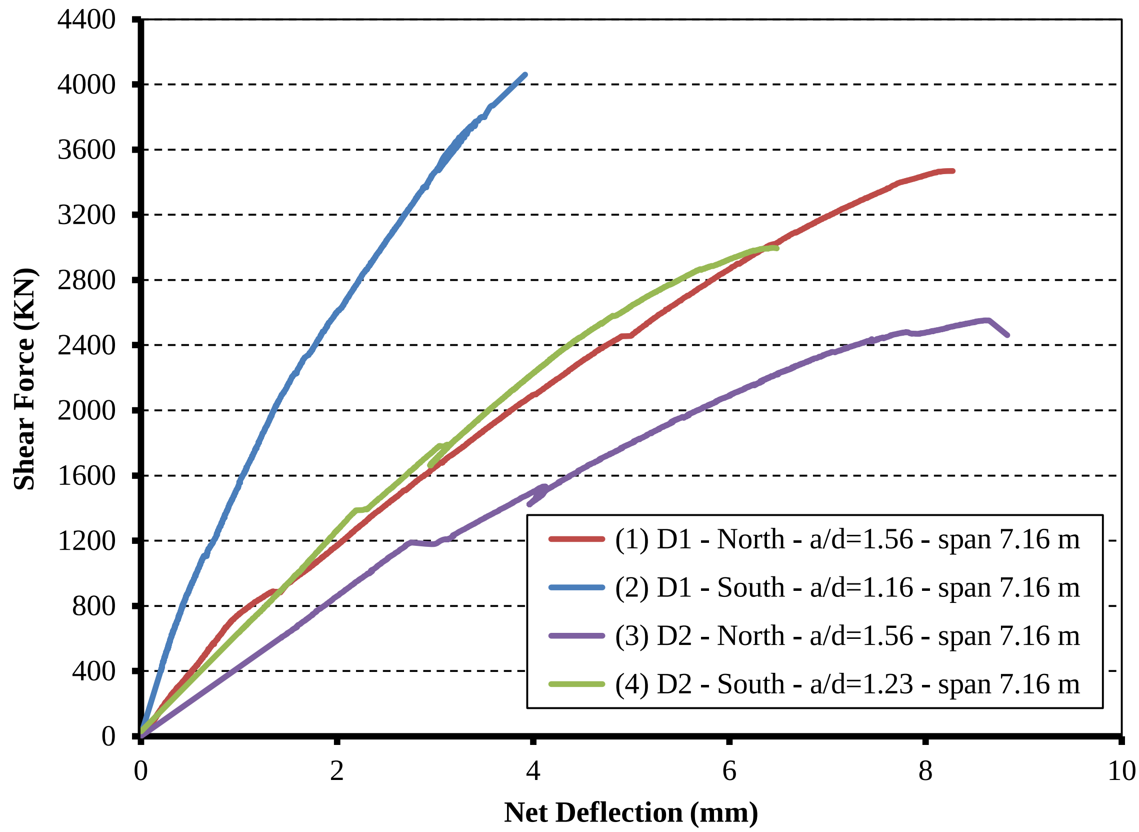
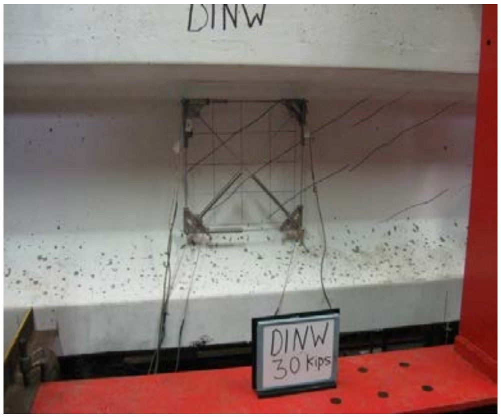


Fig. 4.16 Shear Force vs. Net Deflection Curves for Group D Girders (Labib 2012)

4.3.1 Girder D1

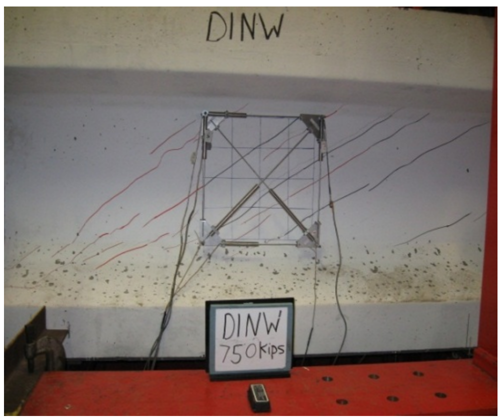
In this girder the a/d ratio for the north side was 1.56 and the south side 1.16. We first tested the south side where the first crack was seen at 241 kips (1072.2 kn). The cracks got wider with the systematic increase in loading with the failure loads being around 912.78 kips (4060.25 kn). The girder on the north end was with a shear span-to-depth ratio (a/d) 1.56. Cracks were also observed at the north side of the girder when the shear force on that side was 170 kips (756.20 kn)

North End | **South End**

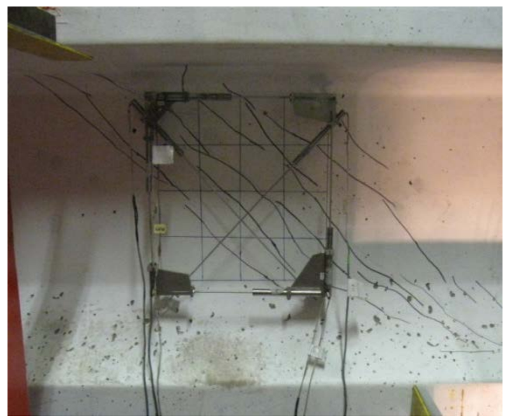


(a) Crack pattern at the start of north end

(b) First shear crack at 1072 KN



(c) Shear crack pattern before failure



(d) Shear crack pattern before failure

(e) Shear failure at 3468.72 KN

(f) Shear failure at 4060.25 KN

Fig. 4.17 Shear Crack Pattern and Failure Mode of Girder D1 (Labib 2012)

After testing the south side we proceeded to test the north end. After reloading it we observed the new shear cracks at the shear force of 190 kips. Fig 4.17 shows the crack patterns from the cracking to the failure. The previous cracks form the south side are marked in black and the new ones in red. The cracks hereby increased in their width with more application of force after which the girder failed at a shear force of 779.80 (3468.72 kn) kips.

As in the other tests, 8 LVDTS were kept at the tendons to record the slip and the maximum slip on the south end occurred on ST2 and was measured to be 0.01 in (0.25 mm) at failure. Similarly at the north end it was at NT6 and about 0.008 in (0.19 mm). The slip was very small and did not contribute to the failure. Thus we observed that both the ends failed in web shear where the maximum smeared compressive strain was 0.0017 in south and 0.0016 in north.

The maximum smeared tensile strain at south and north was 0.0030 and 0.0033, respectively. It was found that when the girder was reloaded at the north end, the smeared transverse strain on the north side increased and reached up to 0.0029. This was closer to the loading point and hence was measured by LVDT NV2.

The smeared strains recorded at both ends during testing the south end are presented in Tables 3.3 and 3.4 in the Appendix, and the smeared strains recorded at north end during retesting are presented in Tables 3.9 in the Appendix.

From the data analysis of the smeared strain we can see that the longitudinal smeared strain depicted that the top and the bottom behavior was similar. The recorded local strain of transverse steel at the south end, as seen in Table 3.5 in Appendix, shows that the average local strain in the transverse reinforcement at south end was $0.7\ \varepsilon_y$. The recorded local strain in transverse steel bars at the north end, can be seen in Table 3.10 in Appendix. Also to be noted was N5 to N8 stopped working before we reached the peak, thus a phenomenon similar to what we discussed before happened and thus it can be concluded that the average local strain in the transverse reinforcement reached the yielding strain.

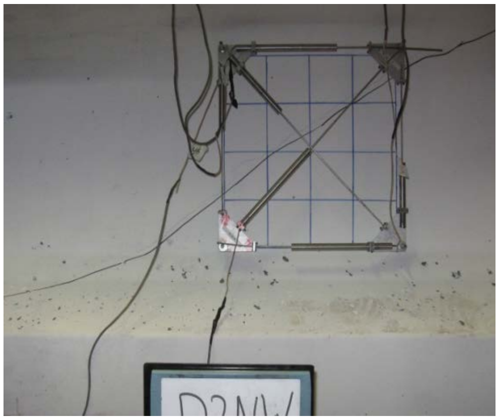
4.3.2 Girder D2

This was the girder that was tested before where in the south side with a/d ratio 1.23. After the testing it was observed that the stability of the girder wasn't affected and thus the north end was tested without changing the shear span with an a/d ration of 1.56. The north end had less stiffness due to using a larger shear span-to-depth ratio and due to the failure at the south end.

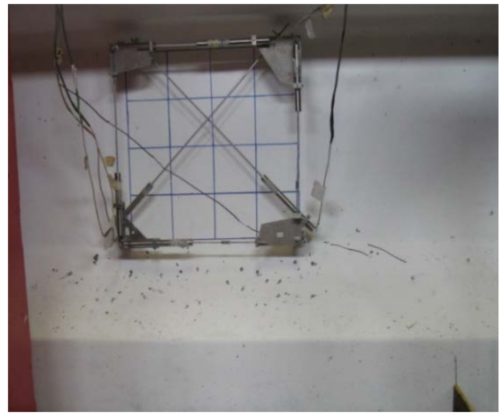
The south end had the first shear crack at 314 kips (1397 kn) and the failure of the beam occurred when the shear force was 673.74 kips (2996.95 kn). The figures below show the first cracks and the final crack pattern.

When the girder was reloaded at the north end the first shear crack happened at 274 kips (1218.81 kn) which led to the failure with the shear force of 578.67 kips (2574.05 kn). The figures below show the initial and the final crack pattern in the south end of the girder.

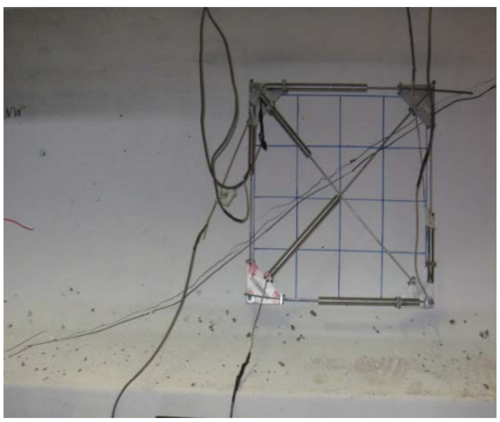
North End | **South End**



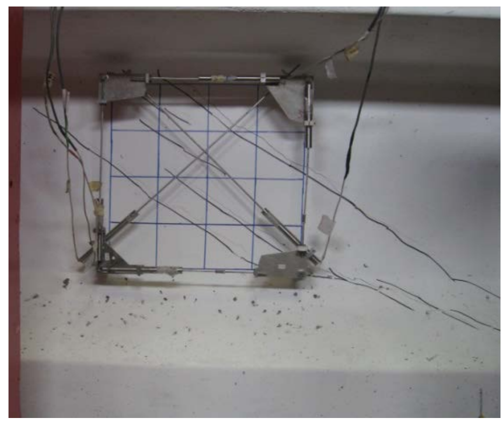
(a) First shear crack at 1218.81 KN



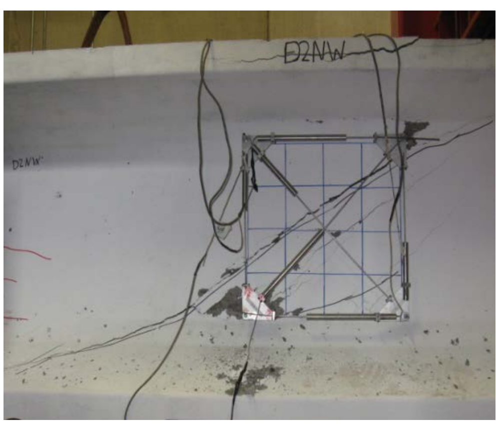
(b) First shear crack at 1396.74 KN



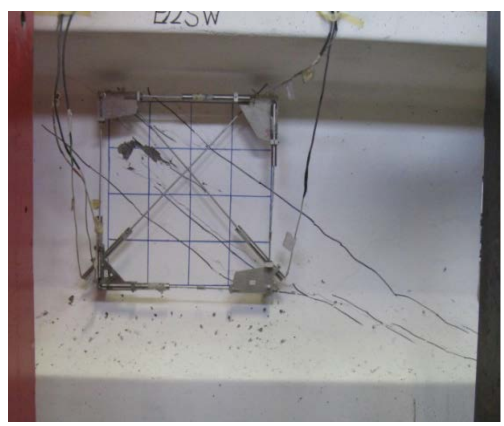
(c) Shear crack pattern before failure



(d) Shear crack pattern before failure



(e) Shear failure at 2574.05 KN



(f) Shear failure at 2996.95 KN

Fig. 4.18 Shear Crack Pattern and Failure Mode of Girder D2 (Labib 2012)

When the bond slip in the tendons was measured we found that just as the other girders it did not significantly affect the failure mode of the girders. The maximum slip on the south was at ST4 was 0.055 in and on the north end NT3 was 0.077 in. The beam just like the previous ones failed in web crushing. The maximum smeared tensile strain across the cracks on the south side was equal to 0.0042 and a maximum smeared compressive strain was equal to 0.0021 in the south side. In the north side the smeared tensile strain was 0.082 but because the diagonal LVDT's had transverse strain instead of going to the compression it jumped to yielding at the onset of cracking and thus as a result we couldn't get the values of the smeared compressive strain. It was interesting to note that the tensile strain on the north side was significantly higher than the south. Tables 4.5 and 4.10 in the appendix show the local strains. It was also noticed that at the onset of cracking the strain in the transverse reinforcement jumped to the yield value.

4.4 Experimental Results of Group E Girders

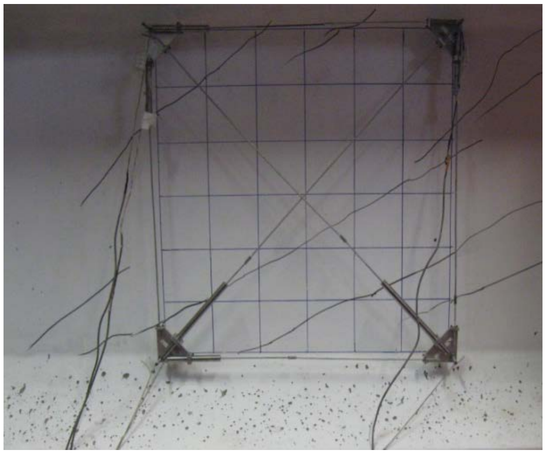
This group of girders had two Tx62 girders where E1 was reinforced with TXDOT specifications and with a top slab of 8 in. thickness. On the other hand E2 was reinforced according to the AASHTO specifications and did not have a top slab.

4.4.1 Girder E1

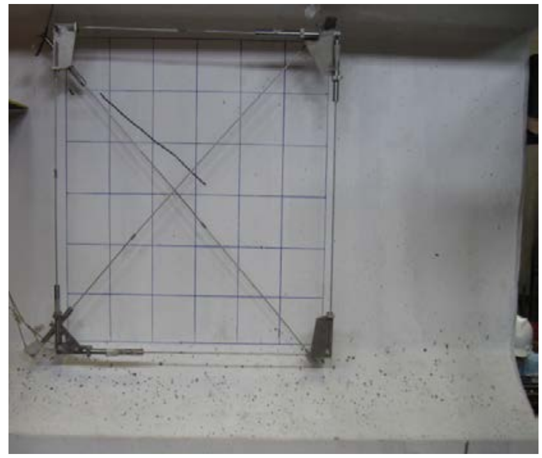
E1 had a shear span-to-depth ratio (a/d ratio) of 1.18 on the north and 1.59 on the south side. The south side was the first one to be tested. The first shear crack was observed when the shear force was 250 kips (1112 kn). And we kept on increasing the load with a possibility of the beam failure; but because of the limitations with the hydraulic jacks the test had to be stopped at a shear force of 853.74 kips (3797.63 kn).

Similarly at the north end once the testing started the first shear crack was seen the load of 241 kips. And as was the case with the north side we had to stop at a certain point before failure, 747.46 kips (3324.87 kn), because of the limited capacity of our hydraulic jacks.

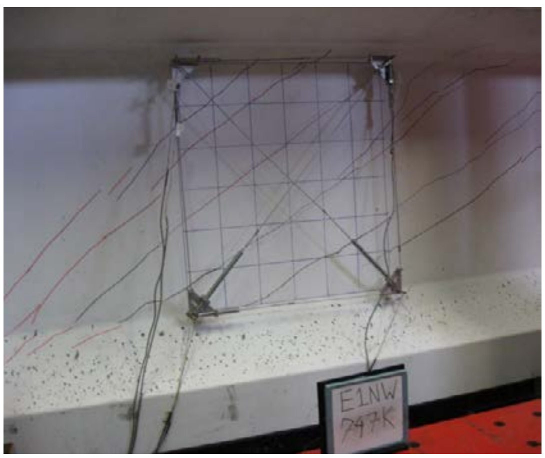
North End **South End**



(a) Crack pattern at the start of north end



(b) First shear crack at 1112.06 KN



(c) Final shear crack pattern

(d) Final shear crack pattern

Fig. 4.19 Shear Crack Pattern of Girder E1 (Labib 2012)

The maximum slip observed in the south end was 0.004 in ST2 and 0.005 at NT2 in the north end. The slip is obviously not affecting the beam since the beam did not fail, thus the slip isn’t that effective.

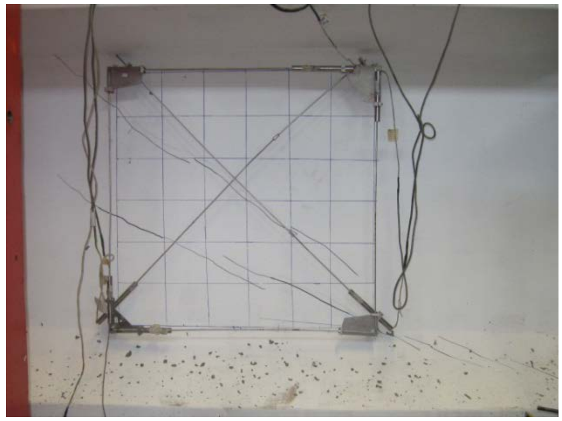
After testing the south side it was found that shear cracks exhibited a very low value of tensile strain, 0.0015 and the strain in the compressive struts even lower at 0.0011. The north side almost duplicated this behavior with the values being very identical. In the north side the smeared tensile strain across shear cracks was only 0.0016, and the smeared compressive strain in concrete struts was only 0.0010. The strain gauges also showed a significant reduction in data with the the measured strain being $0.7\varepsilon_y$ and $0.4\ \varepsilon_y$ and the residuals in the north and south end being $0.18\varepsilon_y$ and $0.45\ \varepsilon_y$. So to find the concrete contribution, they were averaged and a value of $0.63\varepsilon_y$ was considered for calculations.

4.4.2 Girder E2

The girder then tested was E2 which had a shear span to depth (a/d) ratio of 1.23. Fig. 6.7 shows the shear force versus net deflection curve for the south end of Girder E2. The first crack was seen at the south end at a shear load of 416 kips (1850 kn). This as one can see in the graph which caused a significant increase in the deflection. The crack width kept on increasing with more application of load and can be seen in the figure. This culminated with the failure of the girder at 756.42 kips (3364.72 kn). As shown in the figures below it was a web shear failure After testing, it was observed that the failure was destructive and if the other side was tested it may affect the stability of the girder thus the decision was made not to test the north side of the specimen.

The bond slip measured at tendons is shown in table 6.2 in the appendix. This girder had a significant slip on the south side was 0.113 in. (2.86 mm) on the LVDT ST4. This was quite significant from the other girders where the slip wasn't large. But in spite of a higher value the girder still failed in web crushing. From table 6.3 in the Appendix it is seen that the maximum smeared tensile strain was 0.0033 and the maximum smeared compressive strain was 0.0014. The transverse strain was measured by SV1 which was closer to the support and the value of it was 0.027, all the strains are showed in table 6.5. The strain gauges almost stopped working at the onset of cracking thus it can be concluded that the transverse steel yielded at the onset of cracking.

South End



(a) First shear crack at 1850.46 KN

(b) Shear crack pattern before failure

(c) Shear failure at 3364.72 KN

Fig. 4.20 Shear Crack Pattern and Failure Mode of Girder E2

For the bond slip; LVDTs were placed on the south side and the maximum slip at the south end was at ST4 and was 0.113 in (2.86 mm). This was more significant than the previous slips that we had observed but in spite of that the beam failed in web crushing having a maximum smeared tensile strain across the cracks equal to 0.0033 and a maximum smeared compressive strain equal to 0.0014. The maximum smeared tensile strain in transverse direction was 0.0027 measured by LVDT V1 (closer to support).

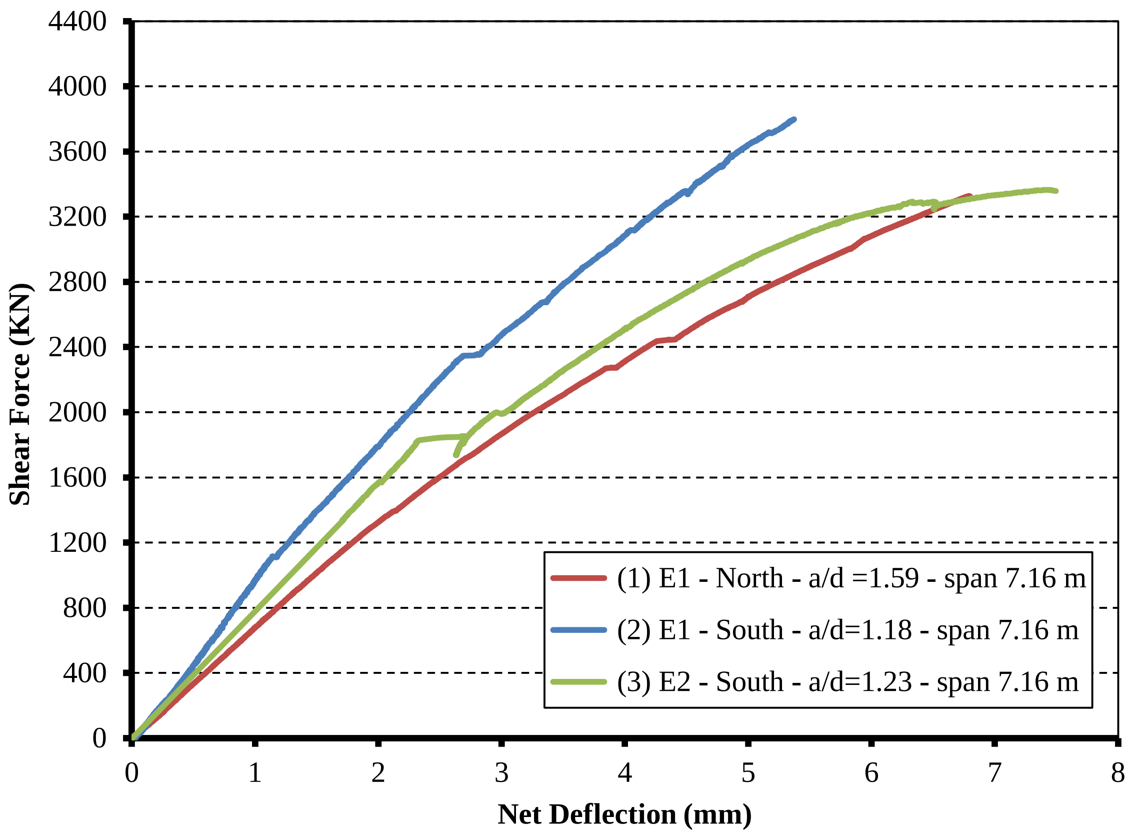


Fig. 4.21 Shear Force vs. Net Deflection Curves for Group E Girders (Labib 2012)

4.5 Maximum Shear Strength for Different Sizes

The shear strengths of the six girders are summarized along with the failure loads, failure modes and the 28 day maximum compressive strength of the concrete in Table 4.1 The strength of each end is inclusive of half of the self-weight of the girder.

As specified earlier the first three girders (G1, D1, and E1) were constructed according to the TxDOT specifications. Thus they had an 8 inch top slab and their transverse reinforcing steel depended on the specifications. So, in fig 4.22 the shear strength of these is compared with the strength provisions of the different codes and the equations provided by Laskar et al (2010). The three other girders (G2, D2, and E2) were designed for bond slip with the minimum possible reinforcement. Since they were highly under reinforced they could not be compared to the provisions.

Table 4.1 Test Variables and Ultimate Shear Strength of Girders (Labib 2012)

<table>
<tr><th>Girder</th><th>D</th><th>a/d</th><th>Concrete strength f'_c (MPa)</th><th colspan="2">Experimental Ultimate Shear Strength, (KN)</th><th>Failure Mode</th></tr>
<tr><td rowspan="2">G1</td><td rowspan="2">803</td><td>1.58</td><td rowspan="2">75.86</td><td>North</td><td>3073.81</td><td>Web-Shear</td></tr>
<tr><td>1.15</td><td>South</td><td>3563.16</td><td>Web-Shear</td></tr>
<tr><td rowspan="2">G2</td><td rowspan="2">599</td><td>1.57</td><td rowspan="2">89.66</td><td>North</td><td>2067.71</td><td>Web-Shear</td></tr>
<tr><td>1.28</td><td>South</td><td>2367.61</td><td>Web-Shear</td></tr>
</table>

Table 4.1 Test Variables and Ultimate Shear Strength of Girders (Labib 2012) (cont'd)

Girder	D	$\mathbf{a/d}$	Concrete strength $\mathbf{f'_c}$ $(\mathbf{MPa})$	Experimental Ultimate Shear Strength, (KN)		Failure Mode
D1	1235	1.56	77.24	North	3529.49	Web-Shear
		1.16		South	4121.01	Web-Shear
D2	1032	1.55	77.24	North	2618.13	Web-Shear
		1.23		South	3041.03	Web-Shear
E1	1624	1.59	75.86	North	3397.02	Web-Shear
		1.18		South	3869.78	Web-Shear
E2	1421	-	73.10	North	-	-
		1.23		South	3417.44	Web-Shear

Thus (G1, D1, and E1) can be used to validate Laskar et al. (2010)'s suggestions and provisions. The equations provided there were validated with these tests and thus they can be used to predict the ultimate shear strength for different sizes of girders. And although the equation is less conservative than ACI (2011) it is applicable to all girders unlike the AASHTO which cannot be duplicated for deep girders and is unsafe for them.

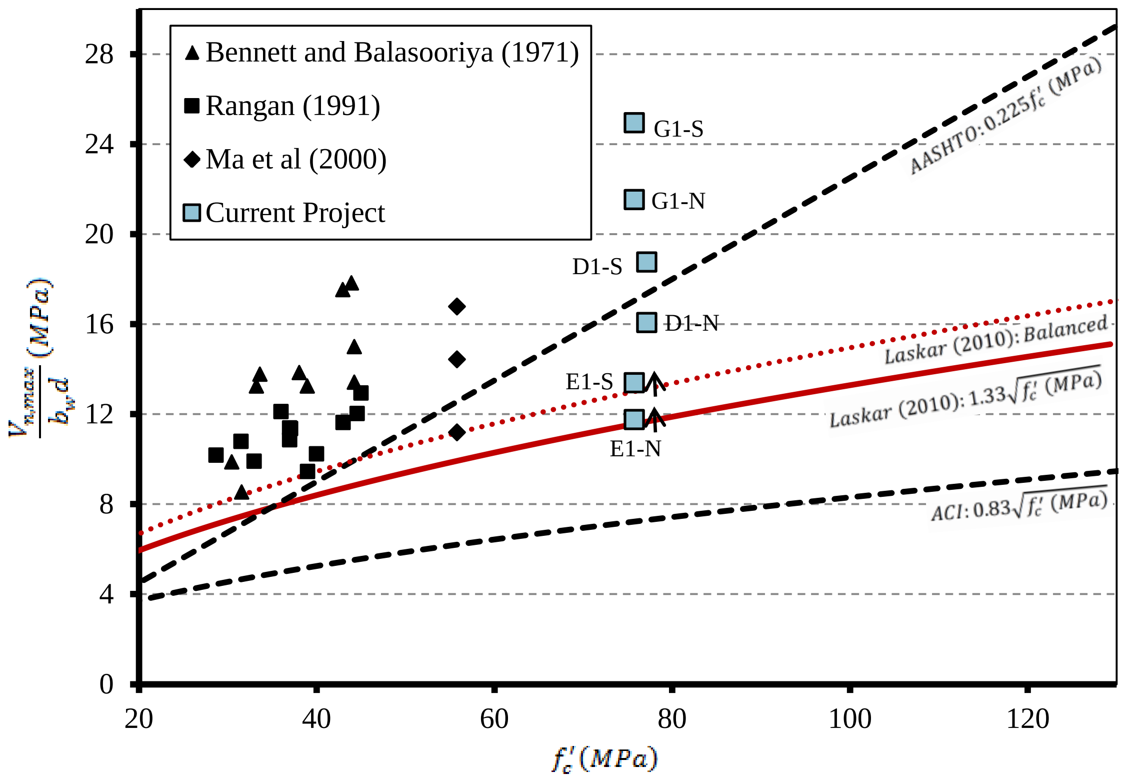


Fig. 4.22 Variation of Normalized Ultimate Shear Strength with Concrete Strength (Labib 2012)

4.6 Steel and Concrete Contributions to Maximum Shear Strength

The total shear strength as shown before can be written as $V_u = V_c + V_s$. Where the steel contribution is V_s and the concrete contribution is V_c. V_s Can be calculated by getting the transverse forces in the rebars. This can be calculated by calculating the average strains where the data is obtained by the strain gauges installed on the transverse rebars. After getting V_s we need to subtract it from V_u and get V_c.

Table 4.2 shows full detailed calculations of steel and concrete contribution for the six tested girders.

Table 4.2 Calculations of Steel and Concrete Shear Contribution (Labib 2012)

Girder I.D.	Ultimate Shear Capacity $(V_{su,exp.}, KN)$	d (mm)	a/d	fc' (MPa)	Average Strain (ε_{avg})	Actual (V_s, KN) (KN)	Concrete Contribution (V_c, KN)
G1	North 3073.81	803	1.58	75.86	$0.80\ \varepsilon_y$	1622.71	1451.10
	South 3563.16		1.15		$0.75\ \varepsilon_y$	1953.66	1609.50
G2	North 2067.71	599	1.57	89.66	ε_y	52.04	2015.67
	South 2367.61		1.28				2315.57
D1	North 3529.49	1235	1.56	77.24	ε_y	1323.79	2205.69
	South 4121.01		1.16		$0.70\ \varepsilon_y$	2376.42	1744.59
D2	North 2618.13	1032	1.55	77.24	ε_y	108.80	2509.33
	South 3041.03		1.23				2932.22
E1	North 3397.02	1624	1.59	75.86	$0.63\ \varepsilon_y$	470.80	2926.22
	South 3869.78		1.18		$0.70\ \varepsilon_y$	1972.87	1896.90
E2	South 3417.44	1421	1.23	73.10	ε_y	159.96	3257.48

To compare the concrete contribution it was plotted against the shear span to depth ratio as shown in figure 4.23. Thus this validates Laskar's (2010) equation which accurately predicts the contribution. In spite of some scatter it can be validated that this equation applies to girders with higher depths. This has been compared to other girder tests and they all have predicted the contribution as less than the UH equation. Thus it can be concluded that the UH equation is less conservative than the other ones and works in finding the concrete contribution of girders with higher depths. The only point which is away from the other points is Girder E1 because it could not be failed.

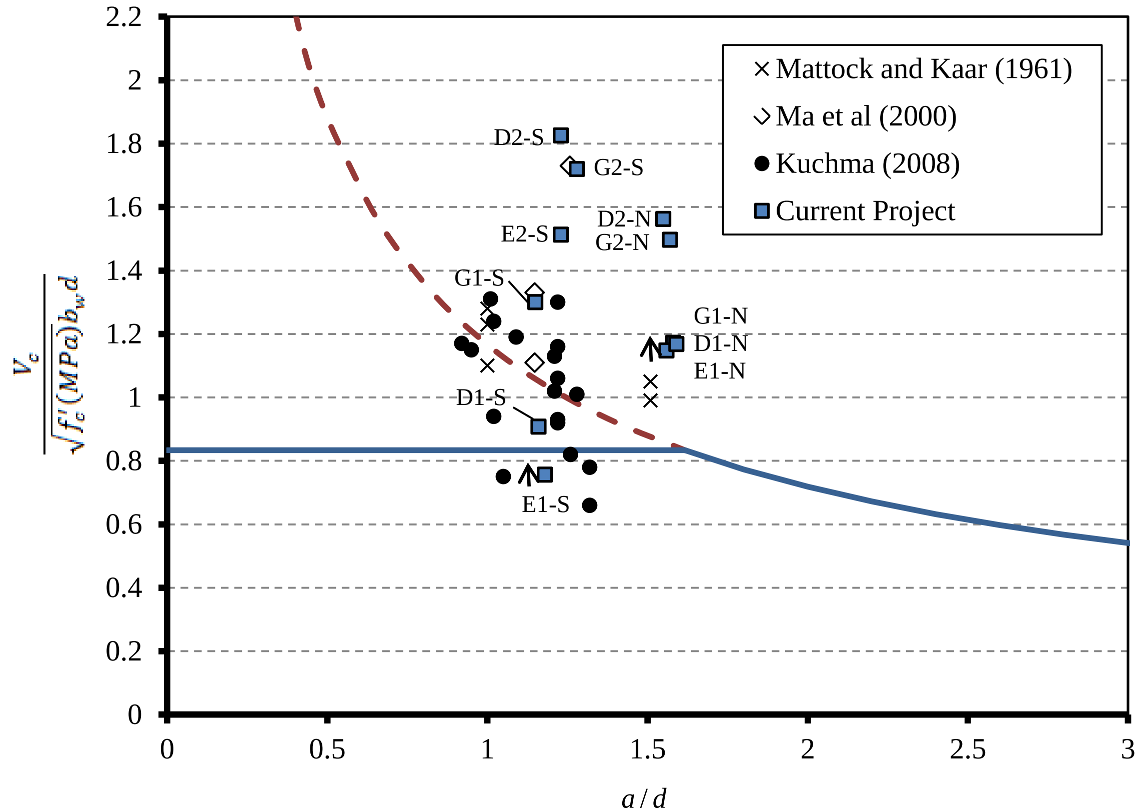


Fig. 4.23 Variation of the Normalized Concrete Shear Contribution with Shear Span to Effective Depth Ratio a/d for Girders (Labib 2012)

Chapter 5: FBG Sensors and Bond Slip

5.1 Introduction

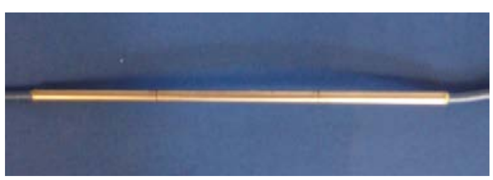
This chapter is about the Fiber Bragg Grating (FBG) sensors which were incorporated in the G2 girder to study and compare the bond slip with the conventional sensors. Recently, many researchers have tried to measure the average slip over the entire transfer length. But with the sensors we would have new insights on measuring the local slip and thus we will be able to measure the local slip at several specific points on the girder. Parts of this chapter have also been referenced from a paper, “FBG based-bond slip detection of prestressed tendons in concrete bridge girders” authored by Siu-Chun Ho, Liang Ren, Emad Labib, Aadit Kapadia, Yi-Lung Mo, Hong-Nan Li and Gangbing Song in 2013.

5.2 Background

Fiber Bragg gratings (FBGs) are small, inexpensive sensors that are sensitive to strain and temperature. They work on the principle of reflection where in light is reflected in and once the wavelength matches the central wavelength of the FBG it reflects it back. FBGs in general and specifically the central wavelength are highly influenced by a variety of environmental factors. These affect the temperatures and the strains. They can form a network and can be extensively used of structural health monitoring (SHM). This is used for observing the structure for long periods. The concept is that strains and vibrations will be measured by keeping these at selected locations of the structures. These help in predicting the behavior of the structures and recognition of the onset of failure of the structure. Thus these are very helpful in the structural engineering field.

Our experimentation pertains to measuring the bond slip in the Prestressed shear girders. Thus for this specific purposes the sensors were installed on the Prestressed tendons of the girders. Bond slip conventionally for the girder is measured using LVDTs by placing them on the selected tendons. But since the LVDTs are placed on the outside it was planned to place these sensors on the inside surface of the beam and compare the slip values to the conventional sensors.

Table 5.1 FBG strain (short and long gauge) and temperature sensors used during the experiment (Ho et al. 2013)

Type	**Picture**	**Size (inches)**
Temperature		2.8 x 0.42 x 0.18
Strain (Long Gauge)		Diameter: 0.15 Length: 7.2
Strain (Short Gauge)		Diameter: 0.13 Length: 2.5

(Each sensor was encapsulated in a stainless steel casing to provide robustness)

Bond slip can be inferred by locally measuring the strain experienced by the tendons during the application of increasing load on the host girder. As the tendon begins to slip from the concrete, less strain will be directly transferred to the tendon and FBG strain readings should show a noticeable divergence between the applied load and the expected strains.

5.3 Construction and Instrumentation

5.3.1 Concrete Girder Construction and Testing

This experimental study was performed on Tx28 girder (G2) which was 25 feet in length and 28 inches in depth. The beam was reinforced in flexure with 40 seven-wire, low-relaxation straight tendons with 12.7 mm (0.5-in.) diameter and cross section area 99 mm^2 (0.153 in^2). The prestressing tendons were pretention by hydraulic jacks placed in a prestressing steel platform/bed. Transverse steel along with all the other confining and flexural reinforcements were installed in the girders. The sensors were placed inside prior to construction. Plastic ties were used to keep them in place so that they do not fall off during the pouring of concrete. Just prior to the actual girder tests, the concrete cylinders were tested to get the representative concrete compressive strength of the girder. One day after casting the girder, the prestressing tendons were slowly released, when the girder reached the required strength. The release strength was 48.95 MPa (7100 psi).

Since the location of the conventional sensors (LVDTs) was already pre-determined; the FBG sensors were placed on the tendons according to the pre-determined location. A total of five FBG (labeled SG1-3 and CS) strain sensors and one FBG temperature sensor (labeled T1) were used in the experiment. In-lab calibration of the strain sensors revealed a sensitivity of 0.2 micro strain/nm.

Four of the strain sensors were bonded at their gripping sections along the length of the tendon using cyanoacrylate (Figure 4). The fifth strain sensor was not bonded to any local structure was allowed to freely be embedded into the concrete. The temperature sensor was placed near the strain sensors to allow temperature compensation of the strain sensors in case of fluctuating temperatures. Figure 5and Table 2 summarizes the positioning of the sensors within the girder.

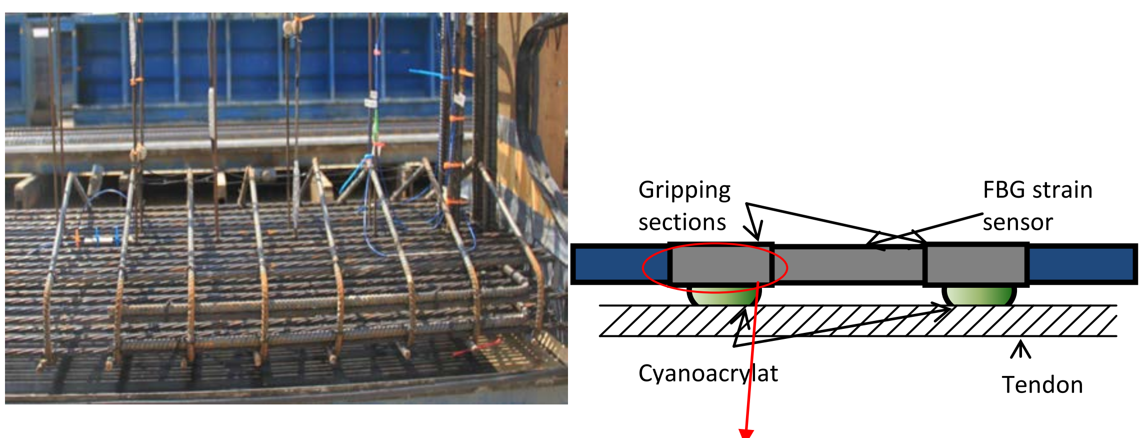


Figure 5.1 (Left) Installation of FBG sensors onto the tendons prior to concrete pouring (Right) Strain sensors are bonded via cyanoacrylate to the tendons (Ho et al. 2013)

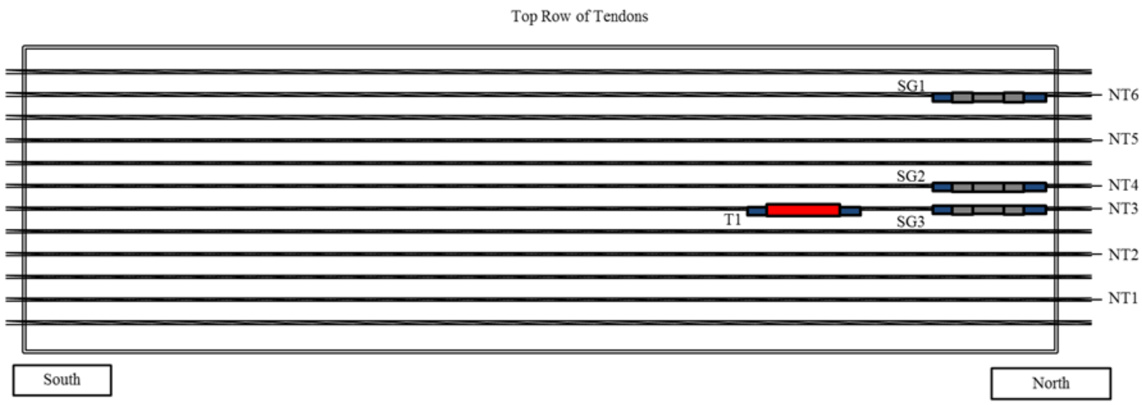


Figure 5.2 Relative placements of FBG sensors in the concrete girder along the top row of tendons. (Note the position of the FBGs and the corresponding LVDT.) (Ho et al. 2013)

Table 5.2 Sensor placement within the girder (Ho et al. 2013)

Sensor	Type	Location	Central Wavelength
SG1	Strain, Short gauge	2nd tendon from east edge, 8 inches from north edge	1512 nm
SG2	Strain, Short gauge	6th tendon from east edge, 8 inches from north edge	1512 nm
SG3	Strain, Short gauge	7th tendon from east edge, 8 inches from north edge	1564 nm
T1	Temperature	7th tendon from east edge, 2 feet south of SG3	1543 nm

A custom made FBG interrogator was used to receive signals from the FBG sensors. A Lab VIEW based application was used to observe and record data (sampling frequency ranged between 8.9 to 9.1 Hz).

Eight LVDTs were positioned on selected tendons against the concrete surface to measure their slip. Because the shear bond failure is known for the crushing of concrete at the intersection between the bottom flange and the web, which indicates that the most effective tendons are the closest ones to that location, six LVDTs were posted on selected tendons of the closest row to the web against the concrete surface. Additional two LVDTs were posted on the closest two tendons to the web center in the most bottom row. Fig.3 shows the LVDTs' locations. These LVDTs were leveled and tied mechanically to the selected tendons against the concrete surface to ensure their free movement with the tendons in the case of any slippage. These LVDTs were connected to computer based software CATMAN where we monitored the displacement in the LVDTs. After the test these were post processed into a graphical format and plotted versus the load.

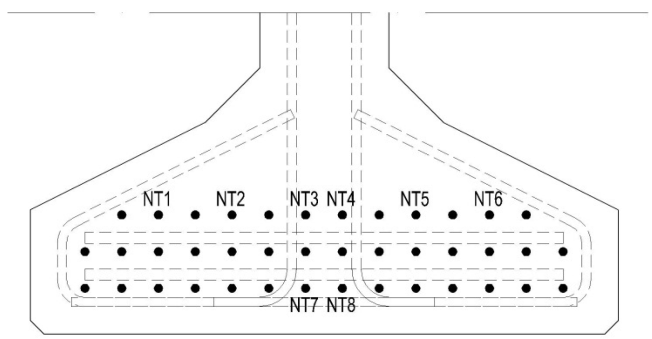


Figure 5.3 Layouts of the Selected Tendons with LVDTs (Labib 2012)

5.4 Experimental Results

5.4.1 Conventional

Initially the north end of the beam was determined to be tested since the sensors were placed there. Thus, it was loaded at 37 inches from the support. The first shear crack was observed at reaction load of 209 kips. The beam failed when the measured reaction was 457 kips. Fig. 6 illustrates the behavior of tendons at different stages of loading. It shows that most tendons start to slip at the shear reaction between 200 and 300 kips. As we get closer to failure the slip increases and there is a massive change close to failure. The tendons closer to the web (T3 and T4) exhibit a higher slip than the ones further away.

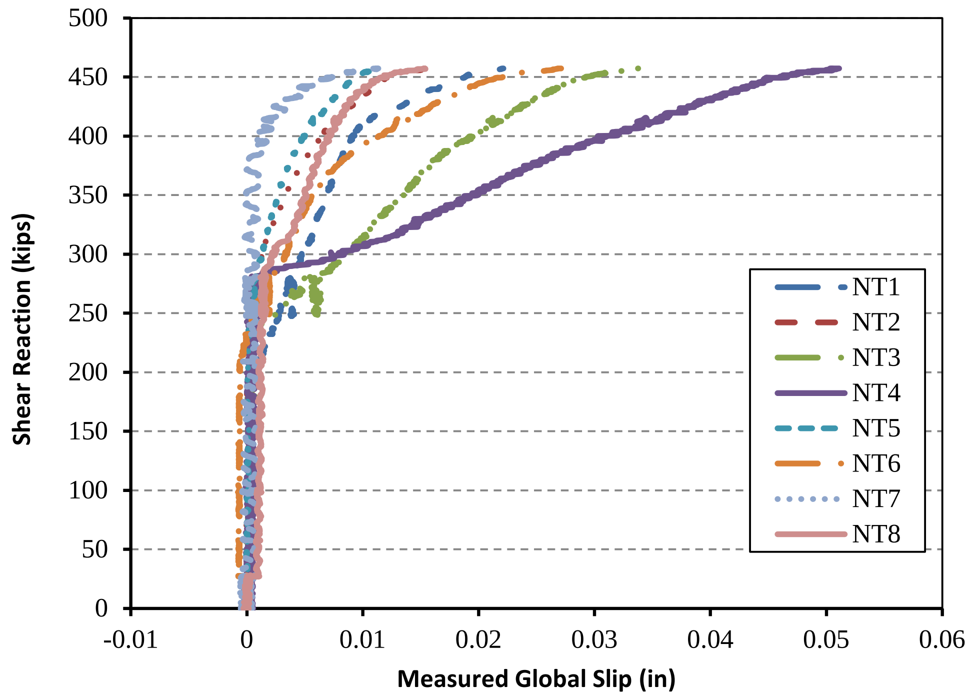
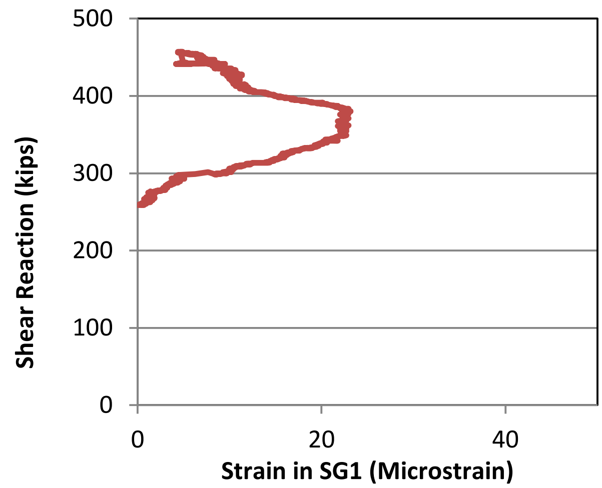


Figure 5.4 Measured Global Slip versus Shear Reaction (Ho et al. 2013)

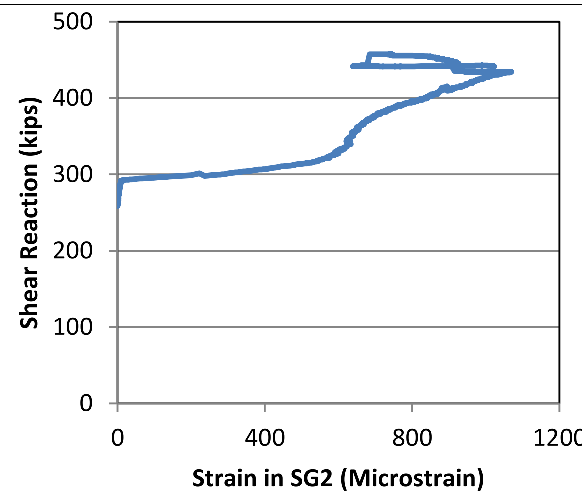
5.4.2 FBG Sensors

The strain readings from the tendon-based FBGs generally increased with increasing loads (Figures 7). However, at 310 kips load (about 2:00 PM), increasing loads caused a reduction of strain measured by the FBGs. A crack was observed at failure (457 kips, about 3:05 PM) and was accompanied by a small, upward peak in strain. Thereafter, the strain once again increased with additional loading.

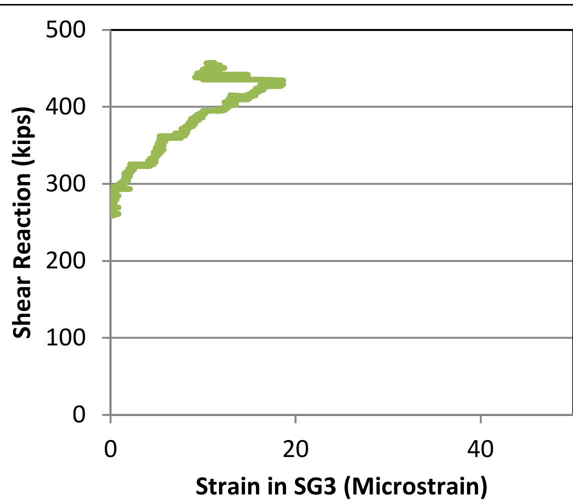
SG2 showed the most change in strain (> 1000 microstrain), while SG1, SG3 and the concrete sensor (CS) showed little change in comparison (< 40 microstrain). On the other hand, all strain sensors bonded to the tendons (SG1-3) exhibited a similar trend, as described above, in the strain throughout the loading process. Since CS was situated relatively far away from the loading site and was not bonded to any tendon, the strain reading was uneventful and only increased slightly due to increasing loads. Temperature was stable throughout the test at 10 °C, thus not requiring any temperature compensation for any of the other sensors.



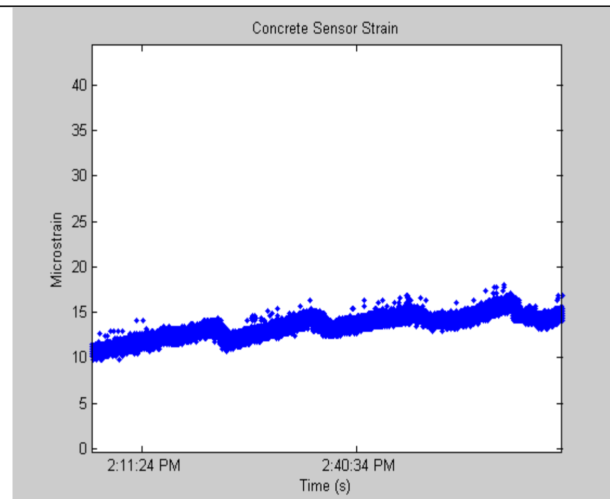
Strain profile for sensor SG1



Strain profile for sensor SG2



Strain profile for sensor SG3



Strain profile for the concrete sensor

Figure 5.5 Measured Local Slip versus Shear Reaction (Ho et al. 2013)

5.5 Conventional Data versus FBG

The LVDT generally gives you the data over the entire surface of the beam whereas the FBG sensors give u the localized failure or slip till the point where the sensors are posted. On observing the trends it is seen that around 300 kips both SG2 and NT4 show slip happening and that point and thus leading to the failure. NT4 has more strain than other LVDT's too. Thus we can conclude that since due their specific location we get a higher strain in NT4 and a higher slip in SG2.

The behavior captured by the LVDT indicates the average slip happen over the entire transfer length but the FBG sensors giving the local slip till the point where the sensor are posted. But it is obvious that the trend recorded by SG2 and NT4 are match perfectly. Both ways stated that the slip start to happen at the same load around 280 kips. LVDT NT4 has the higher amount of slip comparing to the other LVDTs. The same with SG2 has the higher local strain comparing to the SG1 and SG3.

5.6 Discussion of FBG Based-Bond Slip Detection

FBG sensors were primarily used to innovate the bond slip failure concept and give it an alternative view to what the conventional sensors, in this experiment, LVDTs provided. And although the strains and the behavior of the sensors coincided with each other, as we near the failure the differences between the sensors was stark.

In the figure point A (280 kips) was when bond slip started whilst point B (430 kips) was the failure of the bond, which according to the sensors indicated that it was due to tensile force. Which in turn give positive strain and a positive force; it correlated to the increase in the slip measured by the LVDTs. But as we observe at point B there is a sharp decrease and thus can be characterized as a bond slip failure. One thing to note was that although the effect was observed in a point SG2, it wasn't replicated at SG1 and SG3. A potential reason for that could be a stronger bonds between the tendon and the concrete these. Thus we can conclude that although we did observe bond slip we did not observe the complete loss. So it can be concluded that bond slip did not contribute to the failure of the girder and as indicated earlier the girder failed in web shear.

The maximum bond slip in the tendons after calculations was pre-determined to be closer to the web. As the test progressed this did turn out to be the case as NT3 and NT4 gave a much higher reading. Correspondingly SG2 which was close to the web gave a higher strain reading (>1000 microstrain) compared to the other sensors (<40 microstrain). And although the bonding conditions may have a partial contribution; the significant gap was due to the tendon positions. So the location is a significant contributor to the slip. The cyanoacrylate bond was also a factor in the strain reactions of the FBG sensors. The concrete bond albeit minor also contributed to the strain values.

After the failure the strain values increased which would normally suggest that the girder in under tension but that was not the case since it was found that due to the failure the bond stress wasn't present. It was also noticed that the cables and the sensors were firmly bonded with the concrete. If they weren't then we would see some relative displacement, which was not the case.

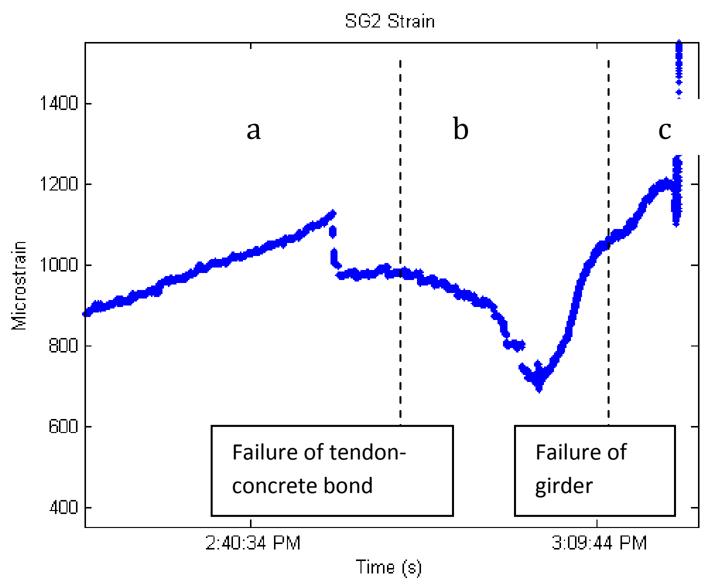


Figure 5.6. Close up of SG2 readings near girder failure, with three stages marking different bonding regimes (Ho et al. 2013)

The strain drop indicates that the concrete bond was lost and the tendons relaxed. There was also some tension created between the sensor and the fiber which resulted in an accurate measurement of the relaxation in the transfer length.

Figure 5.6 gives an over view of the test. Stage A, represented the initial portion of the test where it shows the tendon and the concrete were bonded perfectly and dominated the forces on the sensor. Stage B was when the bond slip occurred and the strains resulted from the relaxation since the sensor was not bonded with the concrete. Stage C was after failure which showed that tension created by the sensor and the fiber was the major strain contributor.

Hence it can be concluded that although the conventional sensors LVDTs did not show the local bond slip, the FBG sensors could capture it. The complete loss of the tendon concrete bond and the predicting the failure of the girder was possible with FBGs and wasn't with the LVDTs. Thus these two very important factors were a major discovery after comparing the FBGs and the LVDT readings.

Chapter 6: Conclusions and Future Work

6.1 Final Summary

The final summary of the tests for observing the bond slips can be summarized as follows:

- To assess the bond slip behavior, six Prestressed I girders were tested to find out the slip in the Prestressed tendons and find out their ultimate shear strength.
- They were divided into three groups with two groups of TX-28 (Group G), TX 46 (Group D) and TX 72 (Group E). Out of these G1, E1 and D1 had a top slab casted on top of the girders a day after the tendon release. After calculations they were tested to observe whether they fail in shear bond or other modes of failure
- G2, E2 and D2 were constructed according to the AASHTO specifications (2010). Apart for not possessing the top slab they had the minimum vertical (transverse) reinforcement and were done so to determine the minimum capacity.
- According to the UH equation which has been established to account for ductility and account for concrete contribution these tests were used to validate that equation.
- For the Girder G2, Fiber Bragg Grating sensors (FBGs) were installed in the girder during construction on the tendons predicted to have the maximum slip.

- The conventional data for bond slip provided by the LVDT's was proposed to be compared to the localized strains from the sensors to get an accurate picture of the bond slip.

6.2 Conclusions

After performing the tests on the girders, we can come to the following conclusions:

1. The minimum reinforcement does not contribute to a shear bond failure in the girders.
2. Although the current design gave a significant bond slip, it does not show any shear bond failure in the girders.
3. The AASHTO equations are adequate for the maximum depth of the girders that was tested which was 62 in.
4. UH equation is adequate. It provides for reasonable ductility near the ultimate capacity which assures that sudden failure does not take place and we have a fair warning before failure
5. It also reinforces that the depth did not affect the capacity, proving the UH equation correct for all girder sizes.
6. With the FBG sensors installed in the beams, the entire process of tendon release to failure can be observed with these sensors which are impossible with conventional data.

7. It was observed that the total loss of the tendon concrete bond and failure weren't measured by the LVDTs but were recorded by the FBGs, thereby getting the localized bond slip of the girders.
8. During testing it was observed that although adequate the LVDT's give the global measurements whereas the sensors provide localized strain.
9. It is also important to note that the data acquired from the sensors can be remotely monitored also from a certain distance unlike it is with the conventional sensors.

6.2 Future Work Suggestions

1. Structural Health monitoring as indicated by the literature review is undergoing research as we speak. These tests validate FBG's for slips in the tendons, in future they can be place alongside the span for deflections and so forth.
2. Provisions need to be made in the codes for these, and standardize them because there is no industry or code standard for these sensors in concrete structures.
3. Girders although not affected by the force, the stiffness's are affected, thus more research could be done in that area by correlating it with the transverse reinforcement or the Prestressed tendons.
4. The sensors could be used in elements such as panels, columns and thus giving scope for its regular use in superstructure starting with university structures and bridges and going to other structures soon.

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APPENDIX

APPENDIX: EXPERIMENTAL DATA OF STUDYING SHEAR BOND FAILURE

1. General Description

This appendix deals with the data of the TX girders. In all the girders the same procedure was followed whereby each of the girders was loaded till failure on the one side and subsequently tested on the other side. The data includes the shear force measured by the load cells followed by the strains by LVDT's in various directions. The shear force was plotted with the deflection which was measured by an LVDT under the surface of the beam.

The second part contains the bond slip in the tendons on the tested side of the beam. After these the smeared strains are presented which concludes with the local strains in the vertical transverse reinforcement.

The next table gives a general idea of the symbols used in the LVDTs and is presented henceforth:

.**Table A.1 Tables and Page Numbers of Data of the Girders**

Girder	Page	Tables	Girder	Page	Tables
G1	112	A.1.1 to A.1.10	G2	136	A.2.1 to A.2.10
D1	161	A.3.1 to A.3.10	D2	185	A.4.1 to A.4.10
E1	209	A.5.1 to A.5.10	E2	233	A.6.1 to A.6.6

A.1 Symbols Used For Measured Forces (Labib 2012)

During loading the shear force that was applied on both the ends was recorded using load cells. In the following figures and tables, the label N. LC will be used to represent the load cell Measurements at the north end, and the label S. LC will be used to represent the load cell Measurements at the south end.

A.2 Symbols Used For Measured Deflections and Settlements (Labib 2012)

The labels of used LVDTs underneath girders for measuring deflections and settlements are explained below:

N. Def. =Deflection under north actuator

S. Def. = Deflection under south actuator

NW Sett. = Settlement of North support measured at West side

NE Sett. = Settlement of North support measured at East side

SW Sett. = Settlement of South support measured at West side

SE Sett. = Settlement of South support measured at East side

If any of these LVDTs was not installed during the test, the data obtained from these LVDTs is reported as Not Recorded (N.R.) data.

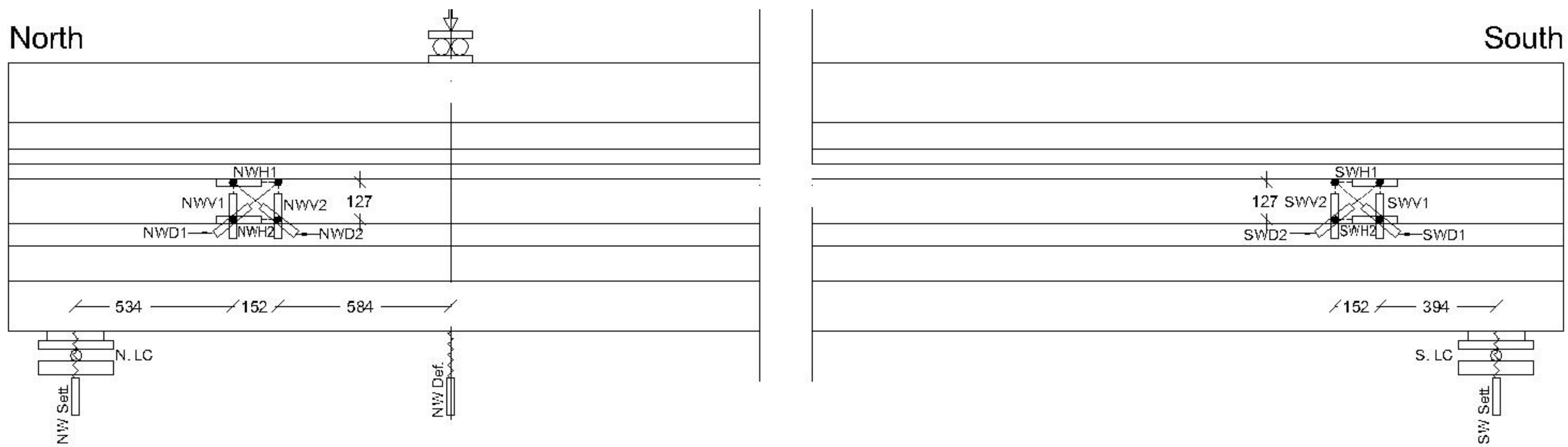
A.3 Symbols Used For LVDTs in Rosette Strains (Labib 2012)

Each LVDT in rosette strain was labeled using four characters. Three of them are letters and the fourth is a number. First letter indicates the girder end which accommodates this LVDT. Thus it is either N or S for north or south end, respectively. Since the strain at any location was measured at both west and east sides of each end, the second letter is either W or E. The third letter stands for the direction of the measured strain. The strain in each rosette is measured in three directions: Diagonal, Vertical and Horizontal. Thus the third letter is D, V or H. The fourth character will be a number indicates the sequence of the LVDT in each direction. Next to the east and west records in the tables, the average strain was calculated and reported having the same label without E nor W and followed by the term of AVG. If any of these LVDTs had a problem during the test, the data which could not be recorded will be mentioned as Malfunction (MF.). But if any of these LVDTs was not installed during the test, the data obtained from these LVDTs is reported as Not Recorded (N.R.) data.

A.4 Symbols Used For Strain Gauges (Labib 2012)

The label of each of all strain gauges always starts with letter S followed by a number. This number indicates the sequence of the strain gauges starting from the closest bottom of the beam. If any of strain gauges stopped to work at any moment during the test, the data is recorded as Broken Gauge (A.G.).

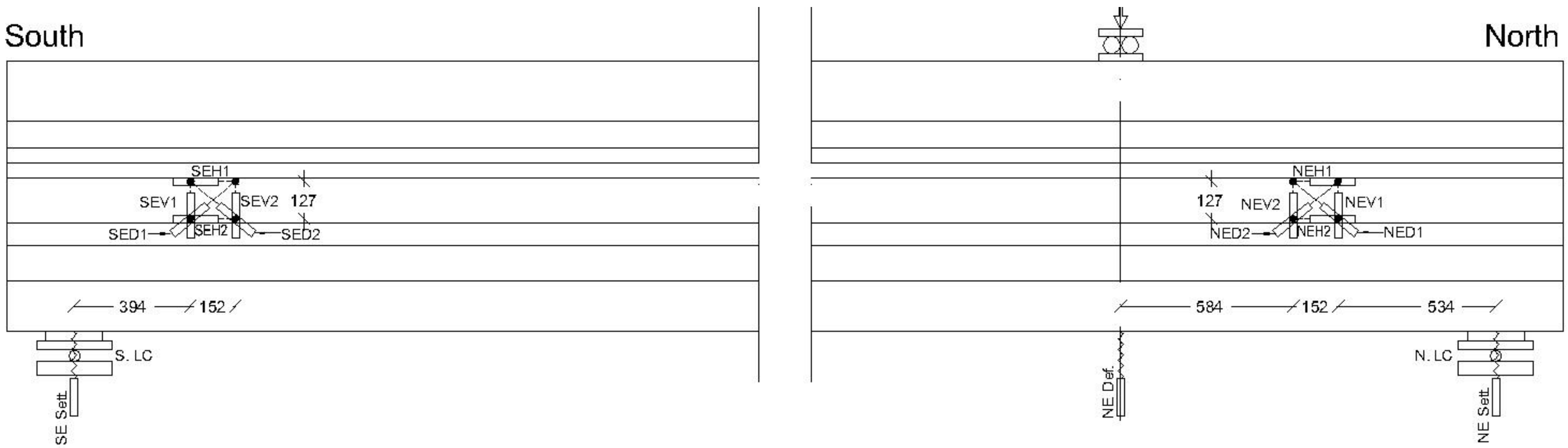
Experimental Data of Girder G1



West View

(All Dimensions are in mm)

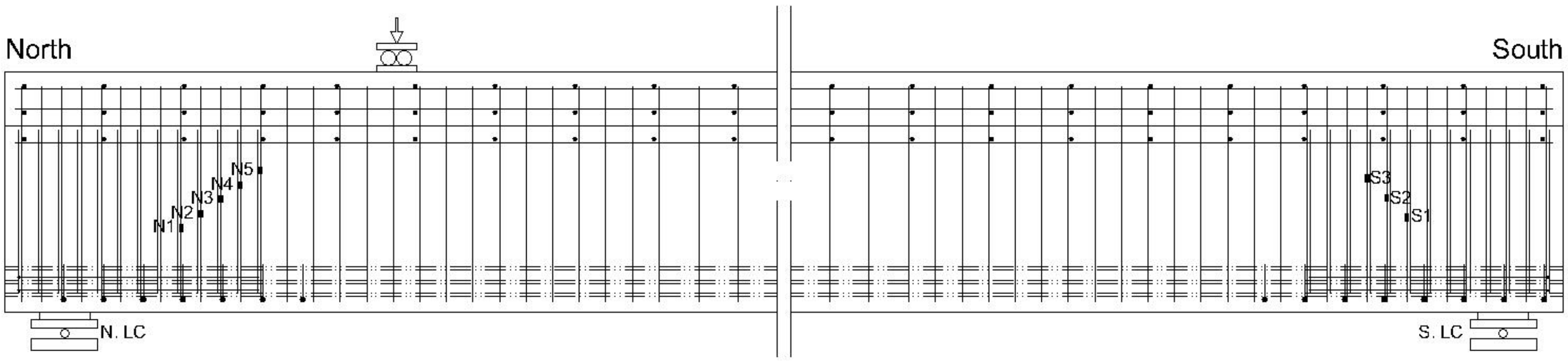
Fig. A.1.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G1-North End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.1.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G1-North End Testing (Labib 2012) (Cont'd)



West View

Fig. A.1.2 Layout of Strain Gauges on Transverse Reinforcement for Girder G1-North End Testing (Labib 2012)

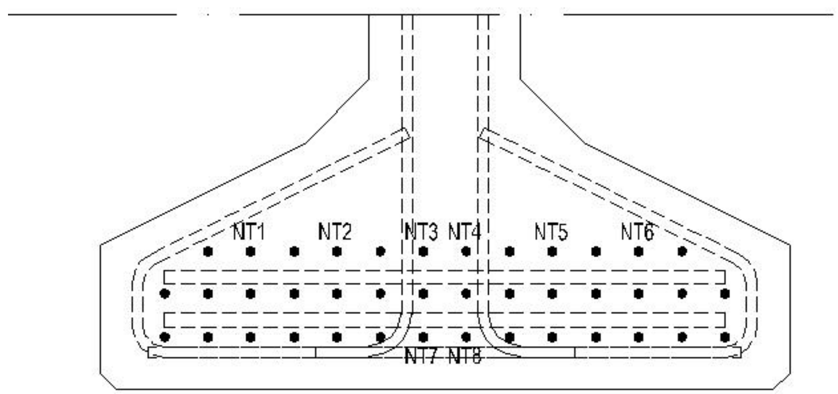


Fig. A.1.3 LVDTs Names on Selected Tendons of Girder G1-North End Testing (Labib 2012)

Table A.1.1 Measurements of Load and Deflection Relationships of Girder G1 – North End Testing (Labib 2012)

N. LC		S. LC		NW Def.		NE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	kips	KN	in.	mm	in.	mm	in.	mm
0.00	0.00	0.06	0.27	-0.001	-0.01	0.000	0.01	0.000	-0.01	0.000	0.01	N.R.	N.R.	N.R.	N.R.
52.44	233.28	12.36	54.98	0.051	1.30	0.053	1.35	0.039	0.98	0.047	1.20	N.R.	N.R.	N.R.	N.R.
93.90	417.71	22.38	99.55	0.076	1.93	0.080	2.03	0.053	1.34	0.067	1.71	N.R.	N.R.	N.R.	N.R.
166.03	738.53	40.14	178.55	0.115	2.93	0.116	2.94	0.071	1.80	0.088	2.24	N.R.	N.R.	N.R.	N.R.
239.77	1066.56	58.44	259.95	0.153	3.90	0.147	3.74	0.086	2.18	0.104	2.64	N.R.	N.R.	N.R.	N.R.
300.44	1336.40	73.68	327.74	0.184	4.67	0.173	4.38	0.097	2.45	0.118	3.00	N.R.	N.R.	N.R.	N.R.
341.18	1517.63	83.88	373.12	0.209	5.32	0.194	4.92	0.107	2.72	0.132	3.36	N.R.	N.R.	N.R.	N.R.
375.56	1670.57	93.00	413.68	0.247	6.27	0.223	5.67	0.132	3.35	0.160	4.05	N.R.	N.R.	N.R.	N.R.
416.06	1850.73	103.44	460.12	0.294	7.46	0.258	6.55	0.163	4.15	0.194	4.93	N.R.	N.R.	N.R.	N.R.
457.70	2035.96	115.08	511.90	0.350	8.89	0.298	7.56	0.201	5.11	0.234	5.94	N.R.	N.R.	N.R.	N.R.
492.80	2192.10	124.62	554.34	0.400	10.16	0.333	8.45	0.236	6.00	0.270	6.86	N.R.	N.R.	N.R.	N.R.
524.19	2331.70	133.02	591.70	0.450	11.42	0.367	9.31	0.270	6.85	0.304	7.73	N.R.	N.R.	N.R.	N.R.
550.17	2447.27	141.18	628.00	0.496	12.60	0.399	10.13	0.300	7.61	0.335	8.52	N.R.	N.R.	N.R.	N.R.
572.13	2544.96	150.96	671.50	0.536	13.62	0.429	10.89	0.322	8.19	0.361	9.17	N.R.	N.R.	N.R.	N.R.
586.83	2610.35	157.92	702.46	0.568	14.42	0.452	11.49	0.338	8.60	0.381	9.67	N.R.	N.R.	N.R.	N.R.
604.59	2689.35	165.72	737.16	0.603	15.32	0.481	12.21	0.356	9.05	0.403	10.24	N.R.	N.R.	N.R.	N.R.
617.37	2746.20	171.90	764.65	0.640	16.25	0.510	12.96	0.373	9.48	0.425	10.81	N.R.	N.R.	N.R.	N.R.
635.43	2826.54	176.04	783.07	0.669	17.00	0.533	13.54	0.389	9.88	0.445	11.30	N.R.	N.R.	N.R.	N.R.
648.45	2884.46	179.10	796.68	0.699	17.76	0.556	14.12	0.404	10.26	0.464	11.79	N.R.	N.R.	N.R.	N.R.
659.67	2934.37	181.44	807.09	0.729	18.52	0.579	14.71	0.418	10.61	0.481	12.23	N.R.	N.R.	N.R.	N.R.
667.11	2967.47	183.48	816.16	0.759	19.29	0.603	15.31	0.431	10.96	0.497	12.64	N.R.	N.R.	N.R.	N.R.
679.65	3023.25	185.28	824.17	0.791	20.10	0.626	15.89	0.444	11.27	0.511	12.98	N.R.	N.R.	N.R.	N.R.
674.91	3002.17	184.74	821.76	0.791	20.10	0.626	15.90	0.444	11.27	0.511	12.99	N.R.	N.R.	N.R.	N.R.

Table A.1.2 Measurements of Tendons' slip at North End of Girder G1 – North End Testing (Labib 2012)

N. LC		NT1		NT2		NT3		NT4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.12	0.53	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
137.05	609.61	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
171.85	764.42	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
207.67	923.76	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
243.19	1081.77	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
276.07	1228.04	0.000	0.00	0.000	-0.01	0.000	-0.01	0.000	0.00
312.20	1388.72	0.000	-0.01	0.000	-0.01	0.000	-0.01	0.000	0.00
360.74	1604.64	0.000	-0.01	0.000	-0.01	0.000	-0.01	0.001	0.02
391.82	1742.90	0.000	-0.01	0.000	-0.01	0.000	-0.01	0.002	0.06
418.76	1862.74	0.000	-0.01	0.000	-0.01	-0.001	-0.01	0.003	0.07
441.38	1963.37	0.000	-0.01	0.000	-0.01	-0.001	-0.01	0.003	0.08
467.00	2077.33	0.000	-0.01	0.000	0.00	-0.001	-0.01	0.004	0.09
491.30	2185.43	0.000	0.00	0.001	0.01	0.000	-0.01	0.004	0.10
512.85	2281.25	0.000	0.00	0.001	0.02	0.000	-0.01	0.005	0.12
539.31	2398.96	0.000	0.00	0.001	0.03	0.000	-0.01	0.005	0.14
555.45	2470.75	0.000	0.00	0.001	0.04	0.000	-0.01	0.006	0.15
571.77	2543.35	0.000	0.00	0.002	0.05	0.000	-0.01	0.007	0.17
590.07	2624.76	0.000	0.00	0.002	0.06	-0.001	-0.01	0.008	0.21
605.13	2691.75	0.001	0.01	0.004	0.10	-0.001	-0.01	0.009	0.24
622.11	2767.29	0.001	0.03	0.006	0.15	0.000	-0.01	0.010	0.26
649.53	2889.26	0.004	0.11	0.009	0.24	0.000	-0.01	0.013	0.33
679.65	3023.25	0.011	0.27	0.017	0.43	0.000	-0.01	0.019	0.49
678.99	3020.32	0.011	0.27	0.017	0.44	0.000	-0.01	0.019	0.49

Table A.1.2 Measurements of Tendons' slip at North End of Girder G1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NT5		NT6		NT7		NT8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.12	0.53	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
137.05	609.61	0.000	0.00	0.000	0.00	0.001	0.03	0.000	-0.01
171.85	764.42	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
207.67	923.76	0.000	-0.01	0.000	0.00	0.001	0.03	0.000	-0.01
243.19	1081.77	0.000	-0.01	0.000	0.00	0.000	0.01	0.000	-0.01
276.07	1228.04	0.000	-0.01	0.000	0.00	0.001	0.03	-0.001	-0.01
312.20	1388.72	0.000	-0.01	0.000	0.00	0.000	0.00	-0.001	-0.01
360.74	1604.64	0.000	-0.01	0.000	0.00	0.000	0.01	-0.001	-0.02
391.82	1742.90	0.000	-0.01	0.000	0.00	0.001	0.02	-0.001	-0.02
418.76	1862.74	0.000	-0.01	0.000	0.01	0.000	0.00	-0.001	-0.02
441.38	1963.37	0.000	-0.01	0.001	0.02	0.000	0.01	-0.001	-0.02
467.00	2077.33	0.000	-0.01	0.001	0.03	0.001	0.02	-0.001	-0.02
491.30	2185.43	0.000	-0.01	0.002	0.05	0.001	0.03	-0.001	-0.02
512.85	2281.25	0.000	-0.01	0.002	0.06	0.001	0.02	-0.001	-0.01
539.31	2398.96	-0.001	-0.02	0.002	0.06	0.001	0.04	-0.001	-0.02
555.45	2470.75	0.000	-0.01	0.003	0.07	0.000	0.01	-0.001	-0.02
571.77	2543.35	0.000	-0.01	0.003	0.08	0.002	0.05	0.000	-0.01
590.07	2624.76	-0.001	-0.01	0.004	0.09	0.001	0.02	-0.001	-0.02
605.13	2691.75	0.000	-0.01	0.004	0.09	0.002	0.04	-0.001	-0.02
622.11	2767.29	0.000	-0.01	0.005	0.12	0.002	0.04	-0.001	-0.02
649.53	2889.26	0.000	-0.01	0.007	0.18	0.002	0.06	-0.001	-0.01
679.65	3023.25	0.000	-0.01	0.012	0.31	0.002	0.05	0.000	-0.01
678.99	3020.32	0.000	-0.01	0.012	0.31	0.001	0.03	0.000	-0.01

Table A.1.3 Measurements of LVDTs for North Rosette Strains of Girder G1 – North End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
0.12	0.53	0.000011	-0.000011	0.000000	-0.000028	-0.000055	-0.000042
137.05	609.61	-0.000061	-0.000197	-0.000129	0.000078	0.000060	0.000069
171.85	764.42	-0.000138	-0.000388	-0.000263	0.000179	0.000235	0.000207
207.67	923.76	-0.000320	-0.000683	-0.000502	0.000403	0.000509	0.000456
243.19	1081.77	-0.000457	-0.000770	-0.000614	0.000514	0.000684	0.000599
276.07	1228.04	-0.000502	-0.000852	-0.000677	0.000811	0.000962	0.000887
312.20	1388.72	-0.000761	-0.001000	-0.000881	0.000883	0.001285	0.001084
360.74	1604.64	-0.000937	-0.001142	-0.001040	0.000962	0.001755	0.001359
391.82	1742.90	-0.001130	-0.001300	-0.001215	0.001051	0.002225	0.001638
418.76	1862.74	-0.001268	-0.001333	-0.001301	0.001342	0.002597	0.001970
441.38	1963.37	-0.001340	-0.001502	-0.001421	0.001683	0.002892	0.002288
467.00	2077.33	-0.001483	-0.001595	-0.001539	0.002197	0.003226	0.002712
491.30	2185.43	-0.001489	-0.001661	-0.001575	0.002527	0.003669	0.003098
512.85	2281.25	-0.001615	-0.001885	-0.001750	0.002936	0.004133	0.003535
539.31	2398.96	-0.001709	-0.001966	-0.001838	0.003277	0.004653	0.003965
555.45	2470.75	-0.001775	-0.002108	-0.001942	0.003568	0.005019	0.004294
571.77	2543.35	-0.001803	-0.002229	-0.002016	0.003802	0.005391	0.004597
590.07	2624.76	-0.001869	-0.002338	-0.002104	0.004110	0.005900	0.005005
605.13	2691.75	-0.001930	-0.002469	-0.002200	0.004317	0.006403	0.005360
622.11	2767.29	-0.001979	-0.002605	-0.002292	0.004613	0.006982	0.005798
649.53	2889.26	-0.001952	-0.002971	-0.002462	0.005407	0.008070	0.006739
679.65	3023.25	-0.000717	-0.003965	-0.002341	0.008058	0.010750	0.009404
678.99	3020.32	-0.000667	-0.003965	-0.002316	0.008131	0.010815	0.009473

Table A.1.3 Measurements of LVDTs for North Rosette Strains of Girder G1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
0.12	0.53	0.000077	0.000038	0.000058	0.000029	-0.000059	-0.000015
137.05	609.61	0.000101	-0.000123	-0.000011	-0.000025	-0.000157	-0.000091
171.85	764.42	0.000126	-0.000293	-0.000084	-0.000013	0.000233	0.000110
207.67	923.76	0.000130	-0.000412	-0.000141	0.000067	0.000851	0.000459
243.19	1081.77	0.000121	-0.000327	-0.000103	0.000042	0.001346	0.000694
276.07	1228.04	0.000193	-0.000072	0.000061	-0.000121	0.001684	0.000782
312.20	1388.72	0.000193	0.000186	0.000190	-0.000538	0.002209	0.000836
360.74	1604.64	0.000208	0.000246	0.000227	-0.000793	0.002806	0.001007
391.82	1742.90	0.000208	0.000407	0.000308	-0.000872	0.003292	0.001210
418.76	1862.74	0.000411	0.000581	0.000496	-0.000884	0.003694	0.001405
441.38	1963.37	0.000705	0.000768	0.000737	-0.000659	0.003999	0.001670
467.00	2077.33	0.001116	0.001027	0.001072	-0.000062	0.004304	0.002121
491.30	2185.43	0.001594	0.001371	0.001483	0.000292	0.004786	0.002539
512.85	2281.25	0.001932	0.001685	0.001809	0.000751	0.005053	0.002902
539.31	2398.96	0.002269	0.002079	0.002174	0.001147	0.005514	0.003331
555.45	2470.75	0.002690	0.002402	0.002546	0.001377	0.005933	0.003655
571.77	2543.35	0.003018	0.002758	0.002888	0.001552	0.006094	0.003823
590.07	2624.76	0.003322	0.003302	0.003312	0.001790	0.006623	0.004207
605.13	2691.75	0.003423	0.003777	0.003600	0.001832	0.006805	0.004319
622.11	2767.29	0.003723	0.004490	0.004107	0.001873	0.007135	0.004504
649.53	2889.26	0.004867	0.006137	0.005502	0.002220	0.007609	0.004915
679.65	3023.25	0.009299	0.010559	0.009929	0.004243	0.008959	0.006601
678.99	3020.32	0.009434	0.010656	0.010045	0.004235	0.009128	0.006682

Table A.1.3 Measurements of LVDTs for North Rosette Strains of Girder G1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
0.12	0.53	-0.000015	MF.	-0.000015	MF.	-0.000007	-0.000007
137.05	609.61	-0.000007	MF.	-0.000007	MF.	0.000041	0.000041
171.85	764.42	0.000000	MF.	0.000000	MF.	0.000021	0.000021
207.67	923.76	0.000147	MF.	0.000147	MF.	0.000163	0.000163
243.19	1081.77	0.000154	MF.	0.000154	MF.	0.000636	0.000636
276.07	1228.04	0.000212	MF.	0.000212	MF.	0.000751	0.000751
312.20	1388.72	0.000248	MF.	0.000248	MF.	0.000921	0.000921
360.74	1604.64	0.000263	MF.	0.000263	MF.	0.001096	0.001096
391.82	1742.90	0.000270	MF.	0.000270	MF.	0.001198	0.001198
418.76	1862.74	0.000285	MF.	0.000285	MF.	0.001319	0.001319
441.38	1963.37	0.000453	MF.	0.000453	MF.	0.001333	0.001333
467.00	2077.33	0.000666	MF.	0.000666	MF.	0.001346	0.001346
491.30	2185.43	0.000681	MF.	0.000681	MF.	0.001292	0.001292
512.85	2281.25	0.000813	MF.	0.000813	MF.	0.001299	0.001299
539.31	2398.96	0.000820	MF.	0.000820	MF.	0.001414	0.001414
555.45	2470.75	0.000952	MF.	0.000952	MF.	0.001420	0.001420
571.77	2543.35	0.000959	MF.	0.000959	MF.	0.001468	0.001468
590.07	2624.76	0.001069	MF.	0.001069	MF.	0.001434	0.001434
605.13	2691.75	0.001077	MF.	0.001077	MF.	0.001562	0.001562
622.11	2767.29	0.001208	MF.	0.001208	MF.	0.001596	0.001596
649.53	2889.26	0.001421	MF.	0.001421	MF.	0.001745	0.001745
679.65	3023.25	0.003371	MF.	0.003371	MF.	0.001292	0.001292
678.99	3020.32	0.003437	MF.	0.003437	MF.	0.001279	0.001279

Table A.1.4 Measurements of LVDTs for South Rosette Strains of Girder G1 – North End Testing (Labib 2012)

S. LC		SED1	SWD1	SD1 AVG	SED2	SWD2	SD2 AVG
kips	KN						
0.00	0.00	-0.000005	0.000027	0.000011	-0.000011	-0.000033	-0.000022
37.68	167.61	-0.000005	-0.000005	-0.000005	0.000022	-0.000038	-0.000008
47.34	210.58	-0.000020	0.000000	-0.000010	-0.000016	-0.000027	-0.000022
57.24	254.62	-0.000035	-0.000011	-0.000023	0.000055	-0.000038	0.000009
67.14	298.65	-0.000046	-0.000005	-0.000026	0.000120	-0.000033	0.000044
76.56	340.56	-0.000071	-0.000038	-0.000055	0.000142	-0.000049	0.000047
76.80	341.62	-0.000010	-0.000005	-0.000008	0.000137	-0.000005	0.000066
88.98	395.80	-0.000020	0.000027	0.000004	0.000099	0.000022	0.000061
97.32	432.90	-0.000025	-0.000027	-0.000026	0.000186	0.000005	0.000096
104.46	464.66	-0.000051	-0.000027	-0.000039	0.000148	-0.000016	0.000066
110.70	492.42	-0.000066	-0.000032	-0.000049	0.000192	0.000016	0.000104
117.66	523.38	-0.000106	-0.000049	-0.000078	0.000230	-0.000011	0.000110
124.26	552.74	-0.000121	-0.000049	-0.000085	0.000257	-0.000011	0.000123
129.90	577.82	-0.000167	-0.000081	-0.000124	0.000493	0.000016	0.000255
137.04	609.58	-0.000182	-0.000114	-0.000148	0.000548	0.000071	0.000310
143.58	638.68	-0.000243	-0.000103	-0.000173	0.000619	0.000077	0.000348
151.20	672.57	-0.000253	-0.000135	-0.000194	0.000734	0.000104	0.000419
159.24	708.33	-0.000339	-0.000124	-0.000232	0.000778	0.000137	0.000458
166.38	740.10	-0.000374	-0.000152	-0.000263	0.000827	0.000165	0.000496
172.98	769.45	-0.000379	-0.000249	-0.000314	0.000969	0.000247	0.000608
179.34	797.74	-0.000369	-0.000238	-0.000304	0.001029	0.000258	0.000644
185.28	824.17	-0.000384	-0.000200	-0.000292	0.001084	0.000264	0.000674
185.16	823.63	-0.000364	-0.000238	-0.000301	0.001090	0.000286	0.000688

Table A.1.4 Measurements of LVDTs for South Rosette Strains of Girder G1 – North End Testing (Labib 2012) (Cont'd)

S. LC		SEV1	SWV1	SV1 AVG	SEV2	SWV2	SV2 AVG
kips	KN						
0.00	0.00	-0.000017	-0.000050	-0.000034	0.000068	-0.000013	0.000028
37.68	167.61	0.000017	0.000014	0.000016	-0.000072	0.000044	-0.000014
47.34	210.58	0.000026	-0.000005	0.000011	-0.000013	-0.000026	-0.000020
57.24	254.62	0.000035	-0.000027	0.000004	-0.000047	-0.000017	-0.000032
67.14	298.65	0.000052	0.000000	0.000026	-0.000008	-0.000022	-0.000015
76.56	340.56	0.000061	-0.000032	0.000015	-0.000004	-0.000030	-0.000017
76.80	341.62	0.000130	-0.000018	0.000056	0.000038	0.000022	0.000030
88.98	395.80	0.000147	-0.000005	0.000071	-0.000017	0.000105	0.000044
97.32	432.90	0.000112	0.000014	0.000063	-0.000008	0.000009	0.000001
104.46	464.66	0.000112	-0.000014	0.000049	-0.000038	0.000026	-0.000006
110.70	492.42	0.000095	0.000032	0.000064	-0.000030	0.000091	0.000031
117.66	523.38	0.000087	-0.000005	0.000041	0.000042	-0.000017	0.000013
124.26	552.74	0.000087	0.000041	0.000064	-0.000025	-0.000030	-0.000028
129.90	577.82	0.000061	0.000014	0.000038	0.000246	0.000035	0.000141
137.04	609.58	0.000130	0.000136	0.000133	0.000191	0.000105	0.000148
143.58	638.68	0.000130	0.000154	0.000142	0.000348	0.000061	0.000205
151.20	672.57	0.000156	0.000190	0.000173	0.000450	0.000004	0.000227
159.24	708.33	0.000164	0.000190	0.000177	0.000607	-0.000030	0.000289
166.38	740.10	0.000199	0.000190	0.000195	0.000649	-0.000004	0.000323
172.98	769.45	0.000286	0.000222	0.000254	0.000845	0.000087	0.000466
179.34	797.74	0.000363	0.000176	0.000270	0.000879	0.000074	0.000477
185.28	824.17	0.000415	0.000276	0.000346	0.001036	0.000035	0.000536
185.16	823.63	0.000433	0.000258	0.000346	0.000972	0.000048	0.000510

Table A.1.4 Measurements of LVDTs for South Rosette Strains of Girder G1 – North End Testing (Labib 2012) (Cont'd)

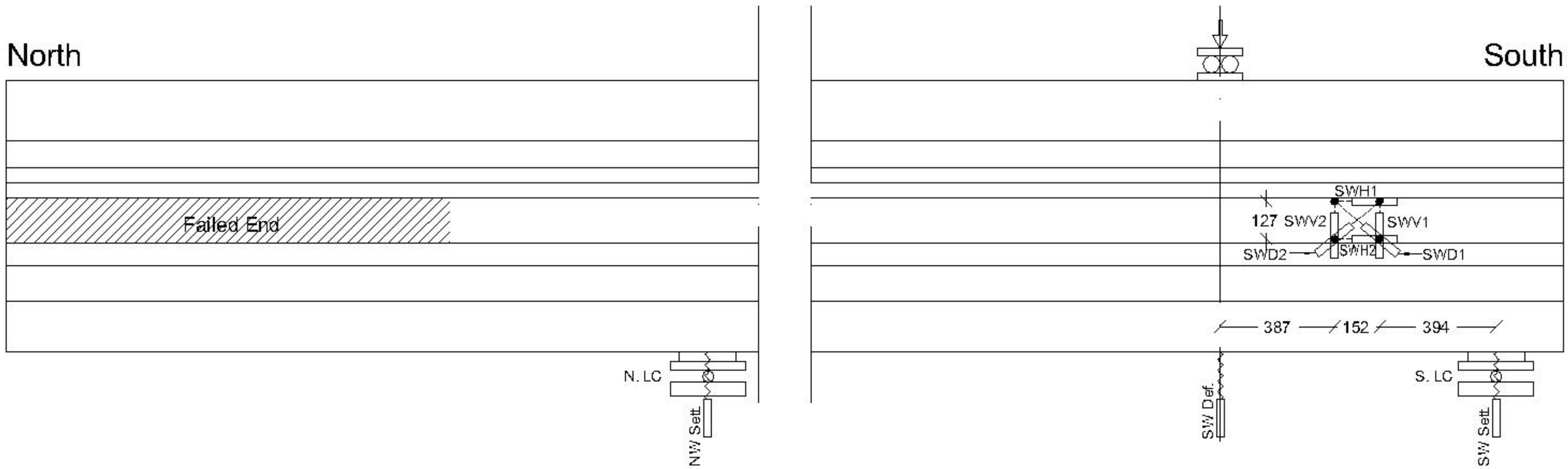
S. LC		SEH1	SWH1	SH1 AVG	SEH2	SWH2	SH2 AVG
kips	KN						
0.00	0.00	0.000000	0.000007	0.000004	0.000028	-0.000007	0.000011
37.68	167.61	0.000000	0.000014	0.000007	0.000021	0.000000	0.000011
47.34	210.58	-0.000002	0.000014	0.000006	0.000021	0.000000	0.000011
57.24	254.62	0.000000	0.000000	0.000000	0.000007	0.000007	0.000007
67.14	298.65	-0.000002	-0.000007	-0.000005	0.000014	0.000007	0.000011
76.56	340.56	-0.000002	0.000007	0.000003	0.000007	0.000007	0.000007
76.80	341.62	0.000000	0.000007	0.000004	0.000007	0.000007	0.000007
88.98	395.80	0.000000	-0.000022	-0.000011	0.000000	0.000007	0.000004
97.32	432.90	0.000000	-0.000014	-0.000007	0.000000	0.000007	0.000004
104.46	464.66	0.000000	-0.000014	-0.000007	0.000014	0.000007	0.000011
110.70	492.42	0.000000	-0.000007	-0.000004	-0.000021	0.000007	-0.000007
117.66	523.38	0.000002	-0.000022	-0.000010	0.000000	0.000007	0.000004
124.26	552.74	0.000034	0.000000	0.000017	0.000014	0.000007	0.000011
129.90	577.82	0.000084	-0.000014	0.000035	0.000007	0.000014	0.000011
137.04	609.58	0.000145	0.000007	0.000076	0.000000	0.000014	0.000007
143.58	638.68	0.000194	0.000000	0.000097	0.000014	0.000014	0.000014
151.20	672.57	0.000223	-0.000007	0.000108	0.000007	0.000014	0.000011
159.24	708.33	0.000233	-0.000007	0.000113	0.000021	0.000021	0.000021
166.38	740.10	0.000233	-0.000007	0.000113	0.000021	0.000014	0.000018
172.98	769.45	0.000233	-0.000007	0.000113	0.000028	0.000021	0.000025
179.34	797.74	0.000233	0.000022	0.000128	0.000021	0.000014	0.000018
185.28	824.17	0.000233	-0.000014	0.000110	0.000021	0.000014	0.000018
185.16	823.63	0.000233	-0.000007	0.000113	0.000007	0.000014	0.000011

Table A.1.5 Measurements of North Strain Gauges on Transverse Steel Bars of Girder G1 – North End Testing (Labib 2012)

N. LC		N1	N2	N3	N4	N5
kips	KN					
0.12	0.53	0.007454	-0.000006	-0.000005	-0.000006	-0.000004
137.05	609.61	0.007454	-0.000005	-0.000004	0.000030	0.000015
171.85	764.42	0.007454	0.000013	0.000037	0.000091	0.000078
207.67	923.76	0.007454	0.000163	0.000160	0.000244	0.000202
243.19	1081.77	0.007454	0.000256	0.000274	0.000320	0.000220
276.07	1228.04	0.007454	0.000323	0.000357	0.000417	0.000292
312.20	1388.72	0.000000	0.000401	0.000451	0.000518	0.000356
360.74	1604.64	0.000000	0.000464	0.000582	0.000595	0.000474
391.82	1742.90	0.000000	0.000530	0.000650	0.000674	0.000564
418.76	1862.74	0.000000	0.000584	0.000713	0.000753	0.000661
441.38	1963.37	0.000000	0.000632	0.000763	0.000826	0.000738
467.00	2077.33	0.000000	0.000693	0.000826	0.000903	0.000818
491.30	2185.43	0.000000	0.000745	0.000880	0.000971	0.000888
512.85	2281.25	0.000000	0.000789	0.000932	0.001022	0.000958
539.31	2398.96	0.000000	0.000858	0.001006	0.001103	0.001051
555.45	2470.75	0.000000	0.000899	0.001058	0.001160	0.001124
571.77	2543.35	0.000000	0.000942	0.001101	0.001217	0.001193
590.07	2624.76	0.000000	0.001016	0.001167	0.001315	0.001283
605.13	2691.75	0.000000	0.001073	0.001220	0.001392	0.001364
622.11	2767.29	0.000000	0.001132	0.001272	0.001481	0.001447
649.53	2889.26	0.000000	0.001209	0.001358	0.001619	0.001592
679.65	3023.25	0.000000	0.001311	0.001464	0.001800	0.001827
678.99	3020.32	0.000000	0.001312	0.001465	0.001800	0.001828

Table A.1.6 Measurements of South Strain Gauges on Transverse Steel Bars of Girder G1 – North End Testing (Labib 2012)

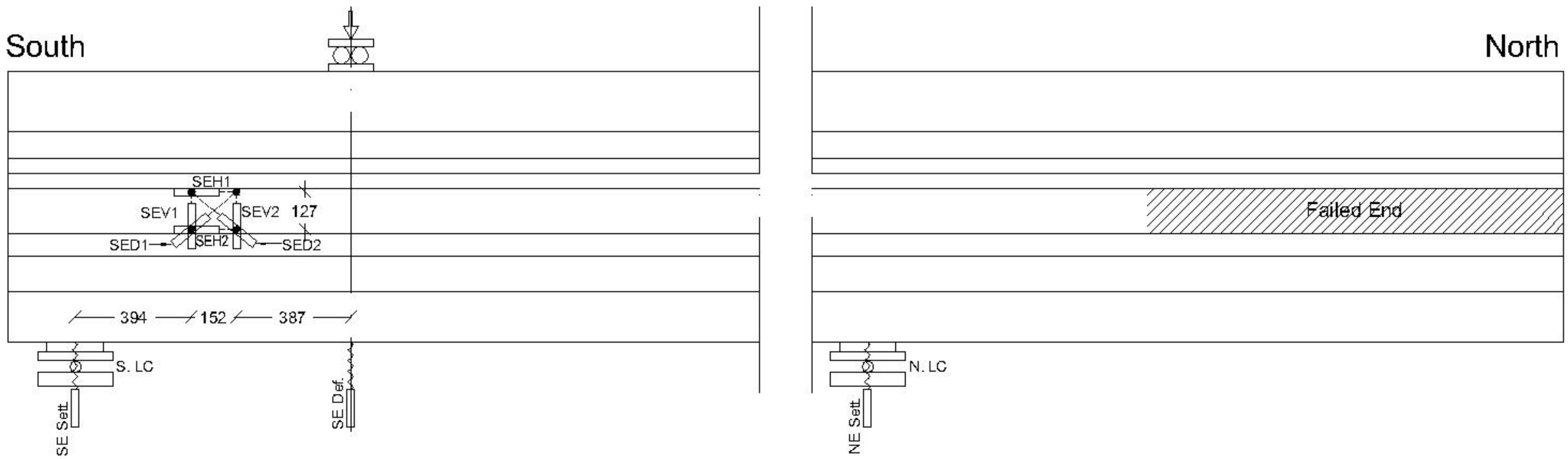
S. LC		S1	S2	S3
kips	KN			
0.00	0.00	0.000000	0.000000	-0.000005
37.68	167.61	0.000002	0.000002	0.000007
47.34	210.58	-0.000006	-0.000003	0.000004
57.24	254.62	-0.000004	-0.000003	0.000007
67.14	298.65	-0.000005	-0.000003	0.000010
76.56	340.56	-0.000005	-0.000004	0.000011
76.80	341.62	-0.000002	-0.000003	0.000012
88.98	395.80	-0.000004	-0.000005	0.000014
97.32	432.90	-0.000006	-0.000007	0.000014
104.46	464.66	-0.000007	-0.000007	0.000016
110.70	492.42	-0.000008	-0.000007	0.000018
117.66	523.38	-0.000008	-0.000005	0.000021
124.26	552.74	-0.000013	-0.000006	0.000023
129.90	577.82	-0.000009	0.000015	0.000052
137.04	609.58	-0.000008	0.000052	0.000069
143.58	638.68	-0.000009	0.000076	0.000086
151.20	672.57	-0.000007	0.000105	0.000099
159.24	708.33	-0.000003	0.000147	0.000142
166.38	740.10	0.000001	0.000180	0.000170
172.98	769.45	0.000008	0.000211	0.000195
179.34	797.74	0.000019	0.000236	0.000216
185.28	824.17	0.000029	0.000256	0.000235
185.16	823.63	0.000028	0.000256	0.000235



West View

(All Dimensions are in mm)

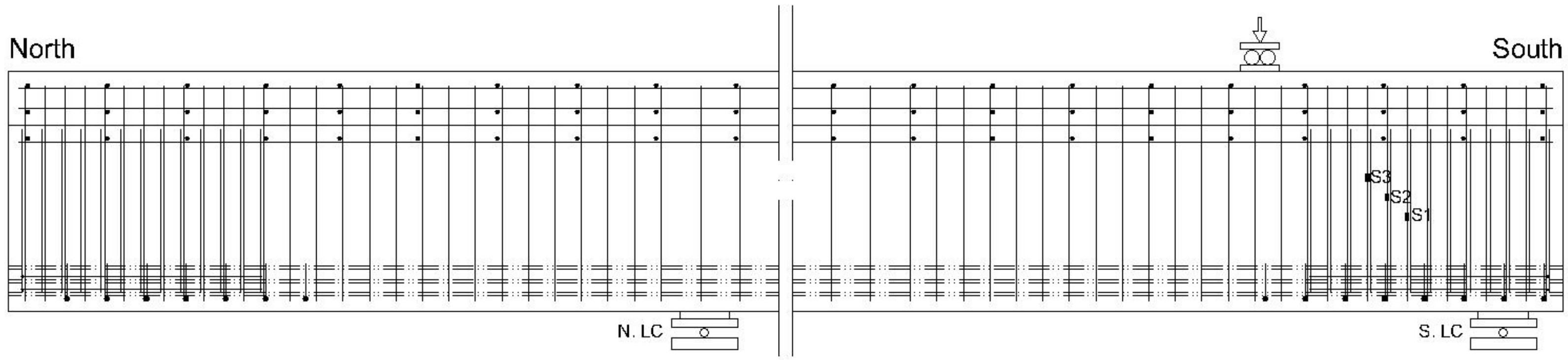
Fig. A.1.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G1-South End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.1.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G1-South End Testing (Labib 2012) (Cont'd)



West View

Fig. A.1.5 Layout of Strain Gauges on Transverse Reinforcement for Girder G1-South End Testing (Labib 2012)

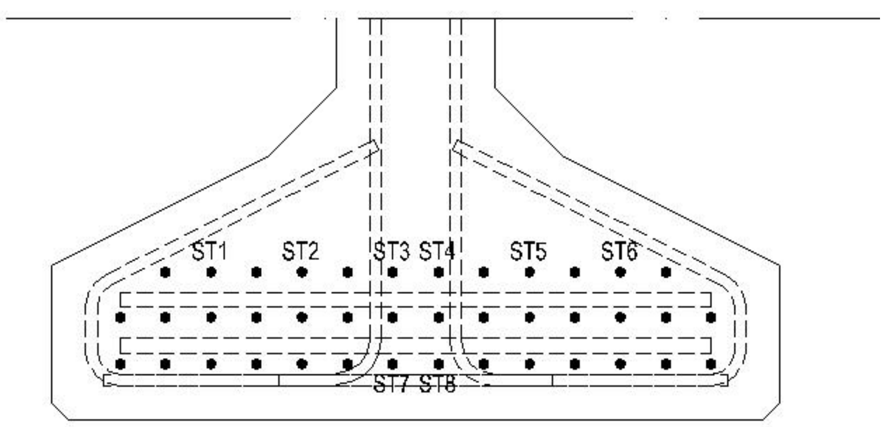


Fig. A.1.6 LVDTs Names on Selected Tendons of Girder G1-South End Testing (Labib 2012)

Table A.1.7 Measurements of Load and Deflection Relationships of Girder G1 – South End Testing (Labib 2012)

N. LC		S. LC		SW Def.		SE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	kips	KN	in.	mm	in.	mm	in.	mm
0.24	1.07	0.00	0.00	0.001	0.01	0.000	-0.01	N.R.	N.R.	N.R.	N.R.	0.000	0.00	0.000	0.00
34.68	154.27	90.00	400.34	0.071	1.80	0.063	1.61	N.R.	N.R.	N.R.	N.R.	0.054	1.37	0.060	1.52
50.28	223.67	135.12	601.04	0.112	2.84	0.093	2.36	N.R.	N.R.	N.R.	N.R.	0.087	2.21	0.089	2.25
65.28	290.39	180.06	800.95	0.154	3.91	0.124	3.14	N.R.	N.R.	N.R.	N.R.	0.122	3.09	0.121	3.08
79.74	354.72	225.06	1001.12	0.204	5.17	0.162	4.11	N.R.	N.R.	N.R.	N.R.	0.166	4.22	0.164	4.18
94.56	420.64	270.06	1201.29	0.270	6.86	0.210	5.34	N.R.	N.R.	N.R.	N.R.	0.228	5.79	0.225	5.72
117.61	523.14	347.52	1545.85	0.340	8.63	0.258	6.56	N.R.	N.R.	N.R.	N.R.	0.285	7.25	0.281	7.13
132.31	588.53	395.34	1758.56	0.364	9.25	0.274	6.95	N.R.	N.R.	N.R.	N.R.	0.300	7.61	0.294	7.46
149.05	663.00	448.26	1993.96	0.390	9.91	0.290	7.35	N.R.	N.R.	N.R.	N.R.	0.315	7.99	0.306	7.78
163.57	727.59	496.50	2208.54	0.418	10.62	0.306	7.77	N.R.	N.R.	N.R.	N.R.	0.331	8.41	0.319	8.11
173.11	770.03	525.18	2336.12	0.437	11.10	0.318	8.06	N.R.	N.R.	N.R.	N.R.	0.342	8.68	0.328	8.33
187.03	831.95	565.56	2515.74	0.464	11.80	0.335	8.50	N.R.	N.R.	N.R.	N.R.	0.357	9.06	0.341	8.66
196.39	873.59	592.68	2636.37	0.486	12.35	0.349	8.87	N.R.	N.R.	N.R.	N.R.	0.369	9.37	0.352	8.94
209.29	930.97	628.68	2796.51	0.510	12.96	0.365	9.26	N.R.	N.R.	N.R.	N.R.	0.381	9.67	0.362	9.21
220.99	983.02	661.92	2944.37	0.538	13.66	0.382	9.71	N.R.	N.R.	N.R.	N.R.	0.395	10.03	0.374	9.50
230.53	1025.46	687.24	3057.00	0.560	14.22	0.397	10.08	N.R.	N.R.	N.R.	N.R.	0.406	10.31	0.384	9.74
241.45	1074.03	710.04	3158.42	0.584	14.83	0.412	10.47	N.R.	N.R.	N.R.	N.R.	0.417	10.59	0.392	9.96
252.55	1123.41	731.82	3255.30	0.609	15.47	0.428	10.87	N.R.	N.R.	N.R.	N.R.	0.428	10.87	0.400	10.17
260.35	1158.11	748.20	3328.16	0.632	16.06	0.443	11.25	N.R.	N.R.	N.R.	N.R.	0.439	11.14	0.408	10.36
267.85	1191.47	763.80	3397.55	0.662	16.82	0.461	11.72	N.R.	N.R.	N.R.	N.R.	0.451	11.45	0.416	10.58
274.87	1222.70	777.00	3456.27	0.695	17.66	0.482	12.24	N.R.	N.R.	N.R.	N.R.	0.464	11.78	0.424	10.76
277.33	1233.64	789.66	3512.58	0.711	18.05	0.491	12.48	N.R.	N.R.	N.R.	N.R.	0.470	11.94	0.427	10.84
274.15	1219.50	781.62	3476.82	0.720	18.28	0.497	12.62	N.R.	N.R.	N.R.	N.R.	0.473	12.02	0.428	10.88

Table A.1.8 Measurements of Tendons' slip at South End of Girder G1 – South End Testing (Labib 2012)

S. LC		ST1		ST2		ST3		ST4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	-0.01	0.000	0.00	0.000	0.00
20.94	93.15	0.000	0.00	0.000	-0.01	0.000	0.00	0.000	0.00
46.56	207.11	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
74.82	332.82	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
111.48	495.89	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
148.50	660.56	0.000	0.00	0.000	-0.01	0.000	0.01	0.000	0.00
183.84	817.76	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
219.48	976.30	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
253.20	1126.29	0.000	0.01	0.000	0.00	0.000	0.01	0.000	0.00
290.40	1291.76	0.000	0.01	0.000	0.00	0.000	0.01	0.000	0.00
348.30	1549.32	0.000	0.00	0.000	-0.01	0.001	0.02	0.000	0.00
408.90	1818.88	0.000	0.00	0.000	-0.01	0.001	0.02	0.000	0.00
469.56	2088.71	0.000	0.00	0.000	0.00	0.001	0.02	0.000	0.00
516.24	2296.35	0.001	0.02	0.000	0.00	0.000	0.01	0.000	0.00
564.24	2509.86	0.001	0.02	0.000	-0.01	0.000	0.01	0.000	0.00
610.32	2714.84	0.001	0.02	0.000	0.00	0.000	0.01	0.001	0.02
654.54	2911.54	0.002	0.04	0.001	0.03	0.001	0.02	0.002	0.05
689.82	3068.47	0.003	0.07	0.002	0.05	0.003	0.07	0.004	0.09
718.80	3197.38	0.004	0.11	0.003	0.07	0.006	0.14	0.005	0.12
744.48	3311.61	0.007	0.17	0.005	0.12	0.008	0.21	0.007	0.17
766.86	3411.16	0.011	0.27	0.011	0.27	0.013	0.34	0.012	0.30
789.66	3512.58	0.015	0.37	0.016	0.42	0.017	0.44	0.018	0.46
780.48	3471.75	0.016	0.41	0.020	0.50	0.020	0.51	0.021	0.53

Table A.1.8 Measurements of Tendons' slip at South End of Girder G1 – South End Testing (Labib 2012) (Cont'd)

S. LC		ST5		ST6		ST7		ST8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
20.94	93.15	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
46.56	207.11	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
74.82	332.82	0.000	-0.01	0.000	0.00	0.000	0.01	0.000	0.00
111.48	495.89	0.000	-0.01	0.000	0.00	0.000	0.01	0.000	0.00
148.50	660.56	0.000	-0.01	0.000	0.00	0.000	0.01	0.000	0.00
183.84	817.76	0.000	-0.01	0.000	0.00	0.000	-0.01	0.000	-0.01
219.48	976.30	0.000	-0.01	0.000	0.00	0.000	0.00	0.000	0.00
253.20	1126.29	0.000	-0.01	0.000	0.00	0.000	0.00	0.000	0.00
290.40	1291.76	0.000	-0.01	0.000	0.00	0.000	-0.01	0.001	0.04
348.30	1549.32	0.000	-0.01	0.000	0.00	0.000	-0.01	0.002	0.05
408.90	1818.88	0.000	-0.01	0.000	0.00	0.000	0.00	0.002	0.06
469.56	2088.71	0.000	0.00	0.000	0.00	0.000	0.01	0.003	0.08
516.24	2296.35	0.000	0.00	0.001	0.02	0.000	-0.01	0.004	0.09
564.24	2509.86	0.002	0.04	0.001	0.03	0.000	-0.01	0.004	0.11
610.32	2714.84	0.002	0.05	0.001	0.04	0.002	0.04	0.005	0.13
654.54	2911.54	0.003	0.07	0.003	0.08	0.003	0.07	0.005	0.13
689.82	3068.47	0.005	0.12	0.005	0.13	0.005	0.12	0.005	0.13
718.80	3197.38	0.007	0.17	0.007	0.18	0.006	0.16	0.006	0.14
744.48	3311.61	0.009	0.22	0.010	0.26	0.008	0.20	0.006	0.15
766.86	3411.16	0.013	0.32	0.017	0.42	0.010	0.25	0.007	0.17
789.66	3512.58	0.016	0.40	0.023	0.59	0.012	0.30	0.008	0.21
780.48	3471.75	0.018	0.45	0.026	0.67	0.012	0.32	0.009	0.23

Table A.1.9 Measurements of LVDTs for South Rosette Strains of Girder G1 – South End Testing (Labib 2012)

S. LC		SED1	SWD1	SD1 AVG	SED2	SWD2	SD2 AVG
kips	KN						
0.00	0.00	-0.000015	-0.000005	-0.000010	-0.000027	-0.000005	-0.000016
20.94	93.15	-0.000005	-0.000005	-0.000005	-0.000011	0.000022	0.000006
46.56	207.11	-0.000020	0.000000	-0.000010	0.000000	-0.000011	-0.000006
74.82	332.82	-0.000066	-0.000005	-0.000036	0.000142	-0.000022	0.000060
111.48	495.89	-0.000147	-0.000068	-0.000108	0.000422	0.000005	0.000214
148.50	660.56	-0.000228	-0.000174	-0.000201	0.000635	0.000044	0.000340
183.84	817.76	-0.000324	-0.000284	-0.000304	0.000739	0.000154	0.000447
219.48	976.30	-0.000415	-0.000358	-0.000387	0.001019	0.000253	0.000636
253.20	1126.29	-0.000501	-0.000426	-0.000464	0.001177	0.000462	0.000820
290.40	1291.76	-0.000602	-0.000473	-0.000538	0.001380	0.000572	0.000976
348.30	1549.32	-0.000753	-0.000626	-0.000690	0.001780	0.000758	0.001269
408.90	1818.88	-0.000834	-0.000736	-0.000785	0.002212	0.001011	0.001612
469.56	2088.71	-0.000986	-0.000831	-0.000909	0.002793	0.001352	0.002073
516.24	2296.35	-0.001148	-0.000836	-0.000992	0.003176	0.001610	0.002393
564.24	2509.86	-0.001360	-0.000926	-0.001143	0.003696	0.002028	0.002862
610.32	2714.84	-0.001618	-0.001036	-0.001327	0.004315	0.002748	0.003532
654.54	2911.54	-0.001719	-0.001041	-0.001380	0.005153	0.003556	0.004355
689.82	3068.47	-0.001734	-0.001036	-0.001385	0.005870	0.004380	0.005125
718.80	3197.38	-0.001810	-0.001026	-0.001418	0.006692	0.005315	0.006004
744.48	3311.61	-0.001972	-0.000926	-0.001449	0.007989	0.006595	0.007292
766.86	3411.16	-0.002897	-0.000189	-0.001543	0.010229	0.008986	0.009608
789.66	3512.58	-0.004282	0.000731	-0.001776	0.012622	0.012108	0.012365
780.48	3471.75	-0.005066	0.001510	-0.001778	0.013668	0.013504	0.013586

Table A.1.9 Measurements of LVDTs for South Rosette Strains of Girder G1 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEV1 C	SWV1	SV1 AVG	SEV2	SWV2	SV2 AVG
kips	KN						
0.00	0.00	0.000009	-0.000005	0.000002	0.000017	-0.000065	-0.000024
20.94	93.15	0.000000	-0.000009	-0.000005	0.000034	-0.000013	0.000011
46.56	207.11	0.000017	0.000000	0.000009	0.000110	0.000022	0.000066
74.82	332.82	0.000017	0.000018	0.000018	0.000267	0.000113	0.000190
111.48	495.89	0.000026	0.000005	0.000016	0.000488	0.000301	0.000395
148.50	660.56	0.000026	0.000000	0.000013	0.000798	0.000423	0.000611
183.84	817.76	0.000147	0.000009	0.000078	0.001023	0.000610	0.000817
219.48	976.30	0.000389	-0.000018	0.000186	0.001269	0.000697	0.000983
253.20	1126.29	0.000606	0.000828	0.000717	0.001451	0.001011	0.001231
290.40	1291.76	0.000857	0.000832	0.000845	0.001689	0.001233	0.001461
348.30	1549.32	0.001203	0.000837	0.001020	0.002012	0.001629	0.001821
408.90	1818.88	0.001644	0.000837	0.001241	0.002313	0.001965	0.002139
469.56	2088.71	0.002561	0.000810	0.001686	0.002759	0.002217	0.002488
516.24	2296.35	0.003201	0.000805	0.002003	0.003213	0.002222	0.002718
564.24	2509.86	0.003885	0.000968	0.002427	0.003735	0.002352	0.003044
610.32	2714.84	0.004663	0.001823	0.003243	0.004223	0.002479	0.003351
654.54	2911.54	0.005987	0.002832	0.004410	0.004974	0.002605	0.003790
689.82	3068.47	0.007276	0.004203	0.005740	0.005504	0.002988	0.004246
718.80	3197.38	0.009085	0.005270	0.007178	0.006141	0.003454	0.004798
744.48	3311.61	0.011282	0.006772	0.009027	0.007202	0.004295	0.005749
766.86	3411.16	0.014155	0.009573	0.011864	0.009371	0.006377	0.007874
789.66	3512.58	0.016456	0.014572	0.015514	0.010928	0.009614	0.010271
780.48	3471.75	0.017295	0.018051	0.017673	0.011247	0.010772	0.011010

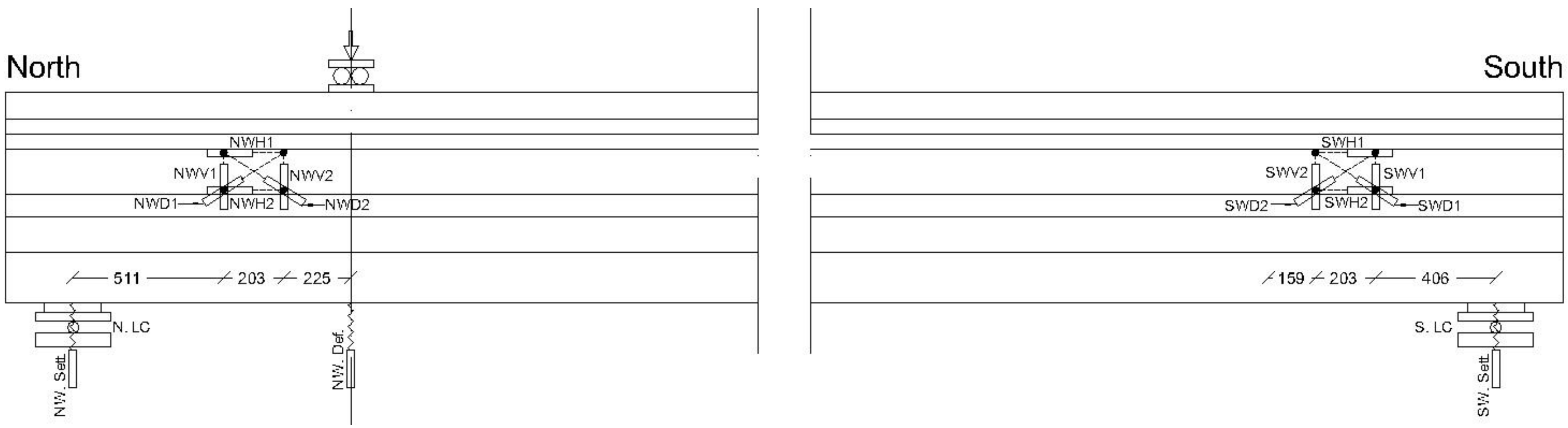
Table A.1.9 Measurements of LVDTs for South Rosette Strains of Girder G1 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEH1	SWH1	SH1 AVG	SEH2	SWH2	SH2 AVG
kips	KN						
0.00	0.00	0.000000	-0.000014	-0.000007	-0.000014	0.000000	-0.000007
20.94	93.15	0.000000	-0.000014	-0.000007	-0.000014	0.000007	-0.000004
46.56	207.11	0.000002	-0.000022	-0.000010	-0.000007	0.000007	0.000000
74.82	332.82	-0.000002	0.000000	-0.000001	-0.000014	0.000021	0.000004
111.48	495.89	-0.000002	0.000000	-0.000001	0.000014	0.000021	0.000018
148.50	660.56	-0.000002	-0.000007	-0.000005	-0.000007	0.000028	0.000011
183.84	817.76	-0.000005	-0.000007	-0.000006	0.000014	0.000035	0.000025
219.48	976.30	-0.000005	0.000000	-0.000003	0.000014	0.000035	0.000025
253.20	1126.29	-0.000007	-0.000014	-0.000011	0.000014	0.000028	0.000021
290.40	1291.76	-0.000010	-0.000022	-0.000016	0.000007	0.000035	0.000021
348.30	1549.32	-0.000012	0.000000	-0.000006	0.000028	0.000035	0.000032
408.90	1818.88	0.000049	0.000000	0.000025	0.000014	0.000021	0.000018
469.56	2088.71	0.000108	-0.000022	0.000043	0.000000	-0.000160	-0.000080
516.24	2296.35	0.000108	-0.000007	0.000051	0.000007	-0.000201	-0.000097
564.24	2509.86	-0.000017	-0.000036	-0.000027	0.000007	-0.000187	-0.000090
610.32	2714.84	-0.000017	-0.000036	-0.000027	-0.000007	-0.000097	-0.000052
654.54	2911.54	-0.000015	0.000000	-0.000008	-0.000028	-0.000021	-0.000024
689.82	3068.47	-0.000012	0.000014	0.000001	-0.000042	-0.000035	-0.000038
718.80	3197.38	0.000012	0.000775	0.000394	-0.000035	-0.000042	-0.000039
744.48	3311.61	0.000233	0.001442	0.000838	-0.000021	0.000389	0.000184
766.86	3411.16	0.000241	0.003150	0.001696	-0.000028	0.001722	0.000847
789.66	3512.58	0.000147	0.003258	0.001703	-0.000042	0.003944	0.001951
780.48	3471.75	0.000081	0.003380	0.001731	-0.000064	0.005132	0.002534

Table A.1.10 Measurements of South Strain Gauges on Transverse Steel Bars of Girder G1 – South End Testing (Labib 2012)

S. LC		S0	S2	S3
kips	KN			
0.00	0.00	A.G.	0.000005	0.000008
20.94	93.15	A.G.	-0.000001	0.000017
46.56	207.11	A.G.	-0.000002	0.000033
74.82	332.82	A.G.	0.000005	0.000055
111.48	495.89	A.G.	0.000032	0.000094
148.50	660.56	A.G.	0.000069	0.000136
183.84	817.76	A.G.	0.000115	0.000180
219.48	976.30	A.G.	0.000165	0.000227
253.20	1126.29	A.G.	0.000210	0.000269
290.40	1291.76	A.G.	0.000261	0.000317
348.30	1549.32	A.G.	0.000343	0.000391
408.90	1818.88	A.G.	0.000436	0.000476
469.56	2088.71	A.G.	0.000566	0.000614
516.24	2296.35	A.G.	0.000668	0.000708
564.24	2509.86	A.G.	0.000769	0.000829
610.32	2714.84	A.G.	0.000868	0.000942
654.54	2911.54	A.G.	A.G.	A.G.
689.82	3068.47	A.G.	A.G.	A.G.
718.80	3197.38	A.G.	A.G.	A.G.
744.48	3311.61	A.G.	A.G.	A.G.
766.86	3411.16	A.G.	A.G.	A.G.
789.66	3512.58	A.G.	A.G.	A.G.
780.48	3471.75	A.G.	A.G.	A.G.

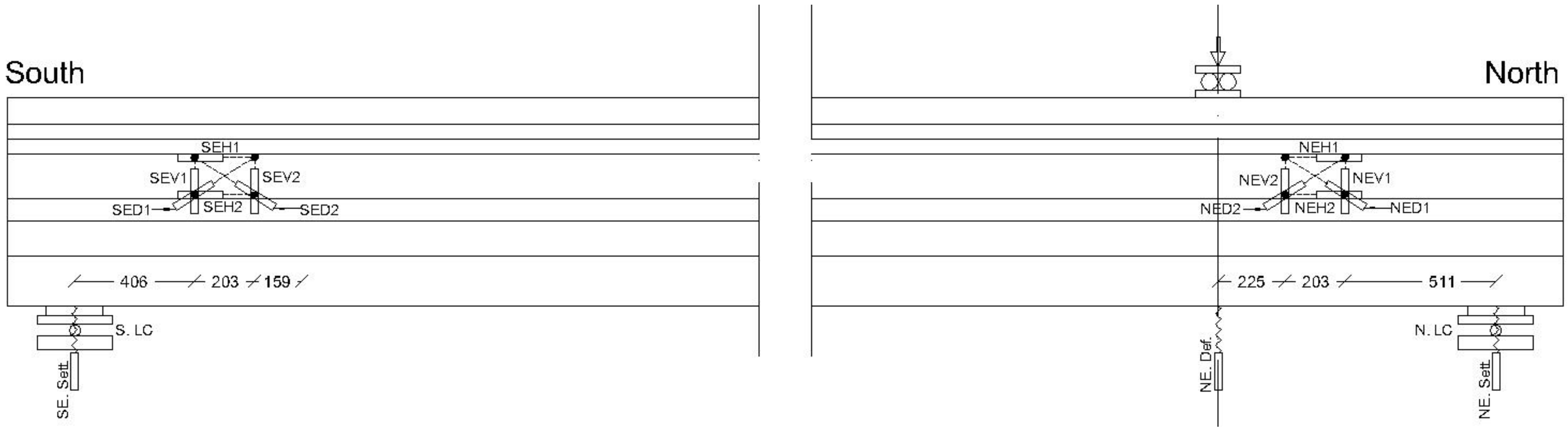
Experimental Data of Girder G2



West View

(All Dimensions are in mm)

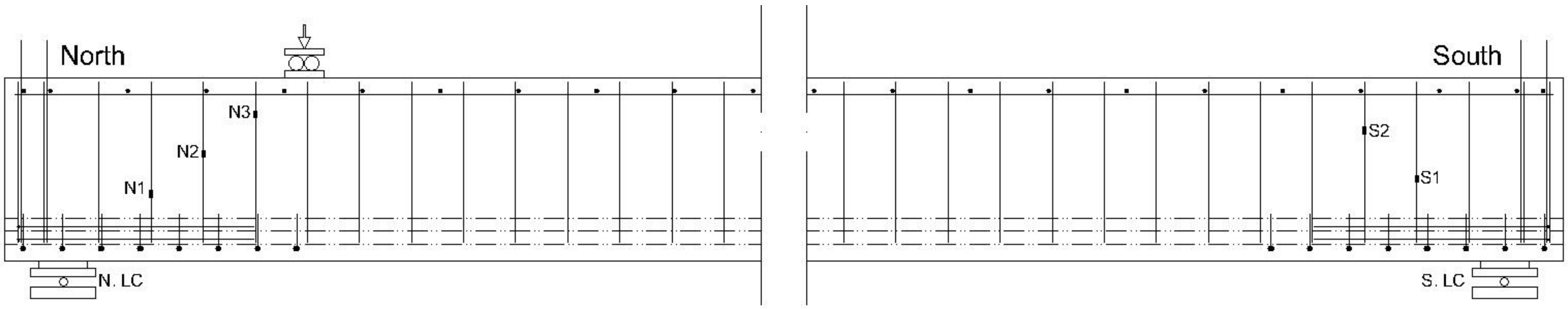
Fig. A.2.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G2-North End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.2.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G2-North End Testing (Labib 2012) (Cont'd)



West View

Fig. A.2.2 Layout of Strain Gauges on Transverse Reinforcement for Girder G2-North End Testing (Labib 2012)

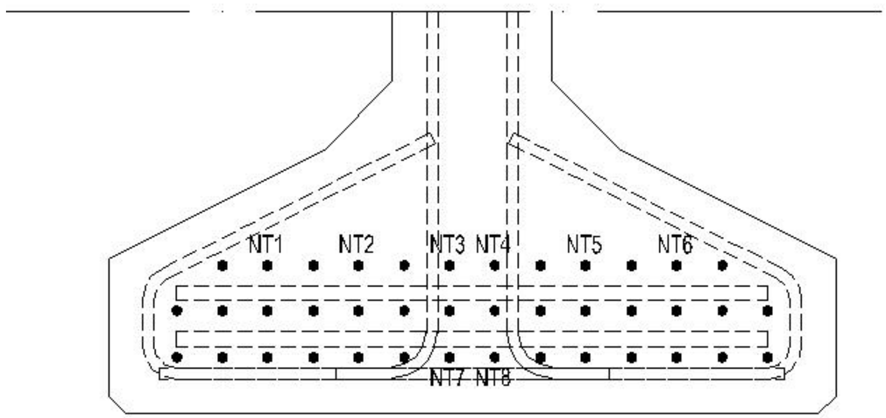


Fig. A.2.3 LVDTs Names on Selected Tendons of Girder G2-North End Testing (Labib 2012)

Table A.2.1 Measurements of Load and Deflection Relationships of Girder G2 – North End Testing (Labib 2012)

N. LC		S. LC		NW Def.		NE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
0.00	0.00	0.00	0.00	-0.001	-0.03	-0.001	-0.02	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
5.64	25.09	0.96	4.27	0.018	0.45	0.005	0.12	0.018	0.45	0.004	0.11	0.007	0.17	-0.001	-0.02
13.44	59.79	2.28	10.14	0.039	0.99	0.011	0.27	0.038	0.98	0.008	0.20	0.017	0.43	-0.006	-0.16
18.18	80.87	2.94	13.08	0.054	1.36	0.017	0.43	0.052	1.33	0.012	0.32	0.023	0.58	-0.010	-0.25
24.42	108.63	3.78	16.81	0.064	1.64	0.023	0.58	0.061	1.55	0.017	0.43	0.027	0.68	-0.011	-0.28
28.80	128.12	4.38	19.48	0.072	1.84	0.029	0.72	0.068	1.73	0.021	0.54	0.029	0.75	-0.012	-0.29
69.06	307.21	9.90	44.04	0.120	3.04	0.071	1.80	0.102	2.60	0.051	1.29	0.042	1.05	-0.012	-0.31
98.22	436.93	13.98	62.19	0.141	3.59	0.098	2.49	0.115	2.91	0.068	1.72	0.046	1.17	-0.012	-0.31
111.73	496.98	16.02	71.26	0.149	3.79	0.109	2.76	0.118	2.99	0.074	1.87	0.048	1.21	-0.012	-0.31
163.69	728.12	23.22	103.29	0.181	4.59	0.144	3.67	0.133	3.37	0.091	2.32	0.056	1.42	-0.009	-0.22
209.11	930.17	30.12	133.98	0.216	5.48	0.178	4.52	0.147	3.73	0.103	2.62	0.066	1.66	-0.004	-0.10
208.93	929.37	30.60	136.12	0.217	5.51	0.181	4.59	0.147	3.73	0.105	2.68	0.066	1.68	-0.004	-0.10
237.67	1057.22	34.74	154.53	0.236	6.00	0.198	5.03	0.155	3.95	0.111	2.81	0.072	1.82	-0.002	-0.06
271.09	1205.88	39.72	176.68	0.263	6.67	0.222	5.64	0.167	4.23	0.119	3.02	0.078	1.99	0.000	-0.01
256.45	1140.76	37.74	167.88	0.255	6.47	0.216	5.48	0.167	4.24	0.119	3.02	0.076	1.94	0.001	0.02
299.77	1333.47	43.92	195.37	0.281	7.15	0.239	6.08	0.174	4.43	0.124	3.15	0.083	2.10	0.001	0.04
338.84	1507.22	49.62	220.72	0.310	7.86	0.264	6.71	0.185	4.71	0.131	3.33	0.090	2.28	0.002	0.05
378.62	1684.18	55.56	247.14	0.340	8.63	0.291	7.38	0.198	5.02	0.138	3.51	0.097	2.46	0.003	0.07
407.96	1814.70	59.88	266.36	0.365	9.28	0.313	7.95	0.207	5.26	0.144	3.65	0.102	2.58	0.003	0.08
430.10	1913.19	63.30	281.57	0.388	9.85	0.333	8.46	0.215	5.46	0.149	3.77	0.106	2.69	0.003	0.08
457.22	2033.83	67.32	299.45	0.423	10.74	0.365	9.27	0.226	5.75	0.157	4.00	0.111	2.81	0.003	0.09
440.90	1961.23	64.98	289.05	0.453	11.50	0.398	10.10	0.235	5.96	0.171	4.34	0.110	2.79	0.004	0.09

Table A.2.2 Measurements of Tendons' slip at North End of Girder G2 – North End Testing (Labib 2012)

N. LC		NT1		NT2		NT3		NT4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
135.73	603.74	0.001	0.01	0.000	0.00	0.000	0.01	0.001	0.01
157.09	698.76	0.000	0.01	0.000	0.01	0.000	0.01	0.000	0.00
172.87	768.96	0.000	0.01	0.000	0.01	0.001	0.02	0.000	0.01
191.83	853.30	0.001	0.01	0.000	0.01	0.000	0.01	0.000	0.00
211.39	940.31	0.001	0.02	0.000	0.00	0.000	0.01	0.000	0.01
229.39	1020.38	0.002	0.05	0.000	0.01	0.001	0.02	0.000	0.01
246.67	1097.25	0.003	0.07	0.000	0.01	0.002	0.06	0.000	0.00
266.65	1186.13	0.003	0.09	0.000	0.01	0.004	0.11	0.000	0.01
251.41	1118.34	0.004	0.10	0.001	0.02	0.006	0.15	0.001	0.03
292.15	1299.57	0.004	0.11	0.001	0.03	0.008	0.19	0.005	0.13
311.30	1384.71	0.005	0.14	0.002	0.04	0.010	0.25	0.011	0.28
328.64	1461.85	0.006	0.15	0.002	0.06	0.011	0.29	0.015	0.38
346.46	1541.12	0.007	0.17	0.003	0.09	0.013	0.33	0.018	0.47
363.68	1617.72	0.007	0.19	0.004	0.11	0.015	0.37	0.022	0.56
381.92	1698.86	0.008	0.21	0.005	0.13	0.016	0.42	0.026	0.66
398.30	1771.73	0.009	0.23	0.006	0.16	0.019	0.48	0.030	0.77
411.02	1828.31	0.010	0.25	0.007	0.19	0.022	0.55	0.035	0.88
423.26	1882.76	0.013	0.32	0.009	0.22	0.023	0.59	0.038	0.96
435.62	1937.74	0.015	0.39	0.010	0.26	0.026	0.66	0.041	1.04
448.64	1995.66	0.018	0.45	0.012	0.30	0.029	0.73	0.045	1.14
457.22	2033.83	0.022	0.56	0.016	0.40	0.034	0.86	0.051	1.30
434.78	1934.01	0.046	1.16	0.035	0.90	0.076	1.94	0.083	2.10

Table A.2.2 Measurements of Tendons' slip at North End of Girder G2 – North End Testing (Labib 2012) (Cont'd)

N. LC		NT5		NT6		NT7		NT8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
135.73	603.74	0.000	0.00	-0.001	-0.02	0.001	0.02	0.001	0.03
157.09	698.76	0.000	0.00	-0.001	-0.01	0.000	0.00	0.001	0.03
172.87	768.96	0.000	0.00	-0.001	-0.02	0.000	0.00	0.001	0.03
191.83	853.30	0.000	0.00	-0.001	-0.02	0.001	0.01	0.001	0.03
211.39	940.31	0.000	0.00	0.000	-0.01	0.001	0.02	0.001	0.04
229.39	1020.38	0.000	0.00	0.000	0.00	0.000	0.00	0.001	0.03
246.67	1097.25	0.000	0.00	0.001	0.02	0.000	0.01	0.001	0.04
266.65	1186.13	0.000	0.01	0.001	0.04	0.000	0.01	0.001	0.03
251.41	1118.34	0.001	0.02	0.002	0.05	0.000	0.01	0.002	0.04
292.15	1299.57	0.001	0.03	0.003	0.08	0.000	0.01	0.002	0.05
311.30	1384.71	0.002	0.04	0.004	0.10	0.001	0.02	0.003	0.09
328.64	1461.85	0.002	0.05	0.005	0.12	0.001	0.02	0.004	0.11
346.46	1541.12	0.003	0.06	0.005	0.14	0.001	0.02	0.005	0.12
363.68	1617.72	0.003	0.08	0.007	0.17	0.000	0.01	0.005	0.14
381.92	1698.86	0.004	0.10	0.009	0.22	0.000	0.01	0.006	0.15
398.30	1771.73	0.005	0.12	0.011	0.28	0.001	0.03	0.007	0.18
411.02	1828.31	0.006	0.15	0.013	0.34	0.002	0.06	0.008	0.20
423.26	1882.76	0.007	0.17	0.016	0.40	0.003	0.08	0.009	0.22
435.62	1937.74	0.008	0.20	0.018	0.46	0.004	0.10	0.010	0.24
448.64	1995.66	0.009	0.23	0.021	0.54	0.007	0.18	0.011	0.29
457.22	2033.83	0.011	0.29	0.027	0.69	0.011	0.28	0.015	0.39
434.78	1934.01	0.026	0.65	0.047	1.21	0.031	0.79	0.037	0.93

Table A.2.3 Measurements of LVDTs for North Rosette Strains of Girder G2 – North End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
0.00	0.00	N.R.	0.000000	0.000000	N.R.	0.000000	0.000000
135.73	603.74	N.R.	-0.000021	-0.000021	N.R.	0.000050	0.000050
157.09	698.76	N.R.	-0.000004	-0.000004	N.R.	0.000074	0.000074
172.87	768.96	N.R.	-0.000045	-0.000045	N.R.	0.000108	0.000108
191.83	853.30	N.R.	-0.000035	-0.000035	N.R.	0.000105	0.000105
211.39	940.31	N.R.	-0.000118	-0.000118	N.R.	0.000910	0.000910
229.39	1020.38	N.R.	-0.000187	-0.000187	N.R.	0.001131	0.001131
246.67	1097.25	N.R.	-0.000308	-0.000308	N.R.	0.001471	0.001471
266.65	1186.13	N.R.	-0.000433	-0.000433	N.R.	0.001785	0.001785
251.41	1118.34	N.R.	-0.000509	-0.000509	N.R.	0.001967	0.001967
292.15	1299.57	N.R.	-0.000634	-0.000634	N.R.	0.002288	0.002288
311.30	1384.71	N.R.	-0.000953	-0.000953	N.R.	0.002640	0.002640
328.64	1461.85	N.R.	-0.000987	-0.000987	N.R.	0.002959	0.002959
346.46	1541.12	N.R.	-0.001171	-0.001171	N.R.	0.003306	0.003306
363.68	1617.72	N.R.	-0.001306	-0.001306	N.R.	0.003656	0.003656
381.92	1698.86	N.R.	-0.001507	-0.001507	N.R.	0.004054	0.004054
398.30	1771.73	N.R.	-0.001694	-0.001694	N.R.	0.004502	0.004502
411.02	1828.31	N.R.	-0.001739	-0.001739	N.R.	0.004880	0.004880
423.26	1882.76	N.R.	-0.001985	-0.001985	N.R.	0.005242	0.005242
435.62	1937.74	N.R.	-0.002165	-0.002165	N.R.	0.005645	0.005645
448.64	1995.66	N.R.	-0.002331	-0.002331	N.R.	0.006110	0.006110
457.22	2033.83	N.R.	-0.002321	-0.002321	N.R.	0.006785	0.006785
434.78	1934.01	N.R.	-0.004604	-0.004604	N.R.	0.010245	0.010245

Table A.2.3 Measurements of LVDTs for North Rosette Strains of Girder G2 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
0.00	0.00	N.R.	0.000007	0.000007	N.R.	0.000005	0.000005
135.73	603.74	N.R.	-0.000002	-0.000002	N.R.	0.000000	0.000000
157.09	698.76	N.R.	0.000072	0.000072	N.R.	-0.000005	-0.000005
172.87	768.96	N.R.	0.000075	0.000075	N.R.	0.000004	0.000004
191.83	853.30	N.R.	0.000080	0.000080	N.R.	0.000009	0.000009
211.39	940.31	N.R.	0.000608	0.000608	N.R.	0.000049	0.000049
229.39	1020.38	N.R.	0.000681	0.000681	N.R.	0.000045	0.000045
246.67	1097.25	N.R.	0.000905	0.000905	N.R.	0.000049	0.000049
266.65	1186.13	N.R.	0.001097	0.001097	N.R.	0.000040	0.000040
251.41	1118.34	N.R.	0.001228	0.001228	N.R.	0.000045	0.000045
292.15	1299.57	N.R.	0.001417	0.001417	N.R.	0.000049	0.000049
311.30	1384.71	N.R.	0.001616	0.001616	N.R.	0.000067	0.000067
328.64	1461.85	N.R.	0.001774	0.001774	N.R.	0.000063	0.000063
346.46	1541.12	N.R.	0.001955	0.001955	N.R.	0.000063	0.000063
363.68	1617.72	N.R.	0.002138	0.002138	N.R.	0.000058	0.000058
381.92	1698.86	N.R.	0.002290	0.002290	N.R.	0.000058	0.000058
398.30	1771.73	N.R.	0.002528	0.002528	N.R.	0.000054	0.000054
411.02	1828.31	N.R.	0.002789	0.002789	N.R.	0.000054	0.000054
423.26	1882.76	N.R.	0.002930	0.002930	N.R.	0.000049	0.000049
435.62	1937.74	N.R.	0.003178	0.003178	N.R.	0.000058	0.000058
448.64	1995.66	N.R.	0.003358	0.003358	N.R.	0.000072	0.000072
457.22	2033.83	N.R.	0.003761	0.003761	N.R.	0.000090	0.000090
434.78	1934.01	N.R.	0.005787	0.005787	N.R.	0.001209	0.001209

Table A.2.3 Measurements of LVDTs for North Rosette Strains of Girder G2 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
0.00	0.00	N.R.	0.000000	0.000000	N.R.	0.000000	0.000000
135.73	603.74	N.R.	0.000027	0.000027	N.R.	-0.000017	-0.000017
157.09	698.76	N.R.	0.000027	0.000027	N.R.	-0.000017	-0.000017
172.87	768.96	N.R.	0.000022	0.000022	N.R.	-0.000022	-0.000022
191.83	853.30	N.R.	0.000027	0.000027	N.R.	-0.000022	-0.000022
211.39	940.31	N.R.	0.000000	0.000000	N.R.	0.000278	0.000278
229.39	1020.38	N.R.	0.000000	0.000000	N.R.	0.000343	0.000343
246.67	1097.25	N.R.	-0.000027	-0.000027	N.R.	0.000841	0.000841
266.65	1186.13	N.R.	-0.000033	-0.000033	N.R.	0.000852	0.000852
251.41	1118.34	N.R.	-0.000011	-0.000011	N.R.	0.000852	0.000852
292.15	1299.57	N.R.	-0.000022	-0.000022	N.R.	0.000863	0.000863
311.30	1384.71	N.R.	-0.000066	-0.000066	N.R.	0.000917	0.000917
328.64	1461.85	N.R.	-0.000061	-0.000061	N.R.	0.000943	0.000943
346.46	1541.12	N.R.	-0.000050	-0.000050	N.R.	0.001147	0.001147
363.68	1617.72	N.R.	-0.000055	-0.000055	N.R.	0.001346	0.001346
381.92	1698.86	N.R.	-0.000044	-0.000044	N.R.	0.001539	0.001539
398.30	1771.73	N.R.	-0.000061	-0.000061	N.R.	0.001689	0.001689
411.02	1828.31	N.R.	-0.000066	-0.000066	N.R.	0.001861	0.001861
423.26	1882.76	N.R.	-0.000055	-0.000055	N.R.	0.002022	0.002022
435.62	1937.74	N.R.	-0.000077	-0.000077	N.R.	0.002236	0.002236
448.64	1995.66	N.R.	-0.000082	-0.000082	N.R.	0.002424	0.002424
457.22	2033.83	N.R.	-0.000148	-0.000148	N.R.	0.002987	0.002987
434.78	1934.01	N.R.	-0.001645	-0.001645	N.R.	0.005991	0.005991

Table A.2.4 Measurements of LVDTs for South Rosette Strains of Girder G2 – North End Testing (Labib 2012)

S. LC		SWD1	SED1	SD1 AVG	SWD2	SED2	SD2 AVG
kips	KN						
0.00	0.00	N.R.	-0.000004	-0.000004	N.R.	-0.000021	-0.000021
19.38	86.21	N.R.	0.000157	0.000157	N.R.	-0.000062	-0.000062
22.02	97.95	N.R.	0.000165	0.000165	N.R.	-0.000044	-0.000044
24.90	110.76	N.R.	0.000169	0.000169	N.R.	-0.000039	-0.000039
27.66	123.04	N.R.	0.000173	0.000173	N.R.	-0.000002	-0.000002
30.96	137.72	N.R.	0.000169	0.000169	N.R.	0.000000	0.000000
33.48	148.93	N.R.	0.000165	0.000165	N.R.	-0.000021	-0.000021
36.00	160.14	N.R.	0.000169	0.000169	N.R.	0.000000	0.000000
38.82	172.68	N.R.	0.000173	0.000173	N.R.	-0.000002	-0.000002
37.20	165.47	N.R.	0.000177	0.000177	N.R.	-0.000057	-0.000057
42.78	190.29	N.R.	0.000189	0.000189	N.R.	-0.000069	-0.000069
45.60	202.84	N.R.	0.000189	0.000189	N.R.	-0.000053	-0.000053
48.12	214.05	N.R.	0.000185	0.000185	N.R.	-0.000046	-0.000046
50.82	226.06	N.R.	0.000189	0.000189	N.R.	-0.000032	-0.000032
53.34	237.27	N.R.	0.000189	0.000189	N.R.	-0.000021	-0.000021
56.04	249.28	N.R.	0.000193	0.000193	N.R.	0.000000	0.000000
58.50	260.22	N.R.	0.000197	0.000197	N.R.	-0.000011	-0.000011
60.48	269.03	N.R.	0.000193	0.000193	N.R.	-0.000025	-0.000025
62.28	277.04	N.R.	0.000193	0.000193	N.R.	-0.000046	-0.000046
64.14	285.31	N.R.	0.000173	0.000173	N.R.	-0.000048	-0.000048
66.06	293.85	N.R.	0.000101	0.000101	N.R.	-0.000034	-0.000034
67.32	299.45	N.R.	0.000081	0.000081	N.R.	-0.000009	-0.000009
64.02	284.78	N.R.	0.000077	0.000077	N.R.	-0.000025	-0.000025

Table A.2.4 Measurements of LVDTs for South Rosette Strains of Girder G2 – North End Testing (Labib 2012) (Cont'd)

S. LC		SWV1	SEV1	SV1 AVG	SWV2	SEV2	SV2 AVG
kips	KN						
0.00	0.00	N.R.	-0.000004	-0.000004	N.R.	-0.000055	-0.000055
19.38	86.21	N.R.	-0.000026	-0.000026	N.R.	-0.000079	-0.000079
22.02	97.95	N.R.	-0.000035	-0.000035	N.R.	-0.000124	-0.000124
24.90	110.76	N.R.	-0.000026	-0.000026	N.R.	-0.000089	-0.000089
27.66	123.04	N.R.	-0.000035	-0.000035	N.R.	-0.000109	-0.000109
30.96	137.72	N.R.	-0.000030	-0.000030	N.R.	-0.000129	-0.000129
33.48	148.93	N.R.	-0.000035	-0.000035	N.R.	-0.000079	-0.000079
36.00	160.14	N.R.	-0.000030	-0.000030	N.R.	-0.000149	-0.000149
38.82	172.68	N.R.	-0.000035	-0.000035	N.R.	-0.000104	-0.000104
37.20	165.47	N.R.	-0.000030	-0.000030	N.R.	-0.000114	-0.000114
42.78	190.29	N.R.	-0.000035	-0.000035	N.R.	-0.000144	-0.000144
45.60	202.84	N.R.	-0.000030	-0.000030	N.R.	-0.000139	-0.000139
48.12	214.05	N.R.	-0.000030	-0.000030	N.R.	-0.000109	-0.000109
50.82	226.06	N.R.	-0.000022	-0.000022	N.R.	-0.000144	-0.000144
53.34	237.27	N.R.	-0.000030	-0.000030	N.R.	-0.000104	-0.000104
56.04	249.28	N.R.	-0.000035	-0.000035	N.R.	-0.000149	-0.000149
58.50	260.22	N.R.	-0.000035	-0.000035	N.R.	-0.000154	-0.000154
60.48	269.03	N.R.	-0.000039	-0.000039	N.R.	-0.000169	-0.000169
62.28	277.04	N.R.	-0.000035	-0.000035	N.R.	-0.000124	-0.000124
64.14	285.31	N.R.	-0.000030	-0.000030	N.R.	-0.000084	-0.000084
66.06	293.85	N.R.	-0.000022	-0.000022	N.R.	-0.000104	-0.000104
67.32	299.45	N.R.	-0.000013	-0.000013	N.R.	-0.000084	-0.000084
64.02	284.78	N.R.	-0.000013	-0.000013	N.R.	-0.000287	-0.000287

Table A.2.4 Measurements of LVDTs for South Rosette Strains of Girder G2 – North End Testing (Labib 2012) (Cont'd)

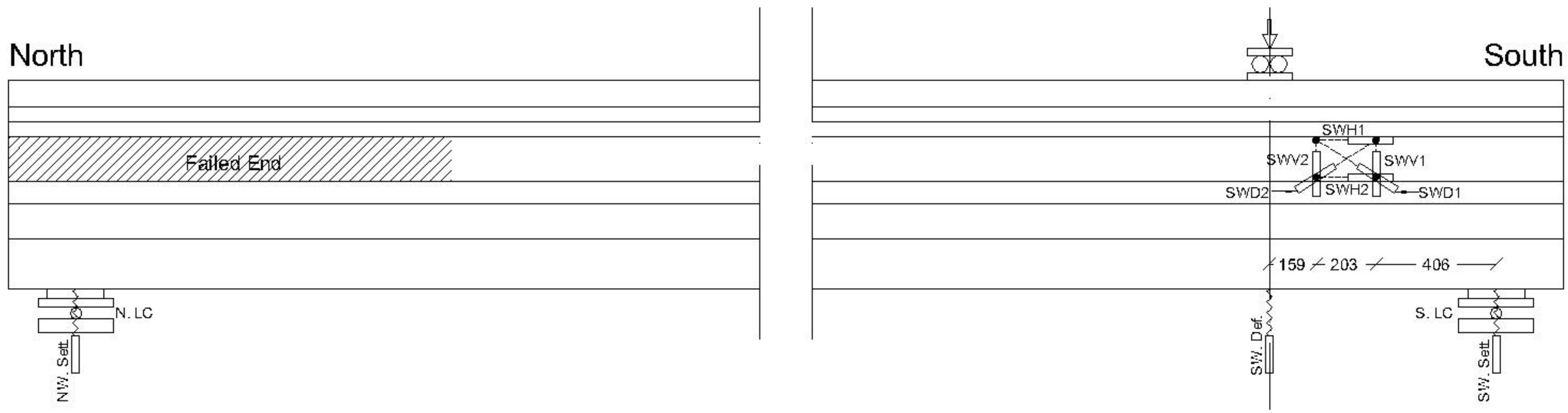
S. LC		SWH1	SEH1	SH1 AVG	SWH2	SEH2	SH2 AVG
kips	KN						
0.00	0.00	N.R.	-0.000006	-0.000006	N.R.	-0.000005	-0.000005
19.38	86.21	N.R.	-0.000011	-0.000011	N.R.	0.000026	0.000026
22.02	97.95	N.R.	0.000000	0.000000	N.R.	0.000026	0.000026
24.90	110.76	N.R.	-0.000017	-0.000017	N.R.	0.000031	0.000031
27.66	123.04	N.R.	-0.000011	-0.000011	N.R.	0.000000	0.000000
30.96	137.72	N.R.	-0.000011	-0.000011	N.R.	0.000041	0.000041
33.48	148.93	N.R.	-0.000017	-0.000017	N.R.	0.000031	0.000031
36.00	160.14	N.R.	-0.000006	-0.000006	N.R.	0.000036	0.000036
38.82	172.68	N.R.	-0.000006	-0.000006	N.R.	0.000036	0.000036
37.20	165.47	N.R.	-0.000011	-0.000011	N.R.	0.000041	0.000041
42.78	190.29	N.R.	-0.000011	-0.000011	N.R.	0.000036	0.000036
45.60	202.84	N.R.	-0.000006	-0.000006	N.R.	0.000036	0.000036
48.12	214.05	N.R.	0.000000	0.000000	N.R.	0.000036	0.000036
50.82	226.06	N.R.	-0.000006	-0.000006	N.R.	0.000041	0.000041
53.34	237.27	N.R.	-0.000006	-0.000006	N.R.	0.000041	0.000041
56.04	249.28	N.R.	-0.000006	-0.000006	N.R.	0.000041	0.000041
58.50	260.22	N.R.	-0.000006	-0.000006	N.R.	0.000051	0.000051
60.48	269.03	N.R.	-0.000006	-0.000006	N.R.	0.000036	0.000036
62.28	277.04	N.R.	-0.000006	-0.000006	N.R.	0.000046	0.000046
64.14	285.31	N.R.	0.000017	0.000017	N.R.	0.000046	0.000046
66.06	293.85	N.R.	0.000000	0.000000	N.R.	0.000051	0.000051
67.32	299.45	N.R.	0.000011	0.000011	N.R.	0.000036	0.000036
64.02	284.78	N.R.	0.000011	0.000011	N.R.	0.000036	0.000036

Table A.2.5 Measurements of North Strain Gauges on Transverse Steel Bars of Girder G2 – North End Testing (Labib 2012)

N. LC		N1	N2	N3
kips	KN			
0.00	0.00	0.000000	0.000015	0.000001
135.73	603.74	0.000029	0.000033	0.000011
157.09	698.76	0.000032	0.000045	0.000009
172.87	768.96	0.000036	0.000048	0.000035
191.83	853.30	0.000038	0.000047	0.000077
211.39	940.31	0.000042	0.000344	0.000388
229.39	1020.38	0.000043	0.000347	0.000395
246.67	1097.25	0.000042	0.000425	0.000543
266.65	1186.13	0.000045	0.000458	0.000583
251.41	1118.34	0.000057	0.000576	0.000849
292.15	1299.57	0.000063	0.000588	0.000834
311.30	1384.71	0.000065	0.000634	0.000942
328.64	1461.85	0.000072	0.000681	0.001060
346.46	1541.12	0.000083	0.000732	0.001200
363.68	1617.72	0.000117	0.000796	0.001317
381.92	1698.86	0.000161	0.000862	0.001458
398.30	1771.73	0.000226	0.000937	0.001618
411.02	1828.31	0.000381	0.001027	0.001785
423.26	1882.76	0.000505	0.001128	0.001900
435.62	1937.74	0.000653	0.001228	0.002002
448.64	1995.66	0.000870	0.001331	0.002107
457.22	2033.83	0.001198	0.001480	0.002211
434.78	1934.01	0.006090	0.004616	0.002447

Table A.2.6 Measurements of South Strain Gauges on Transverse Steel Bars of Girder G2 – North End Testing (Labib 2012)

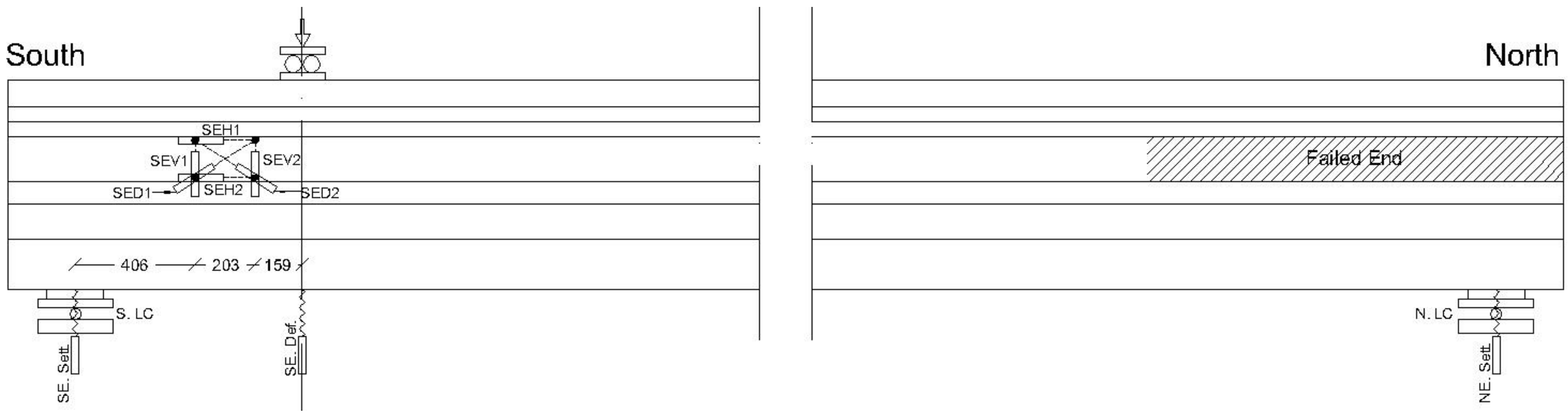
S. LC		S1	S2
kips	KN		
0.00	0.00	0.000000	0.000003
19.38	86.21	0.000000	0.000043
22.02	97.95	0.000000	0.000042
24.90	110.76	-0.002594	0.000013
27.66	123.04	-0.002597	0.000014
30.96	137.72	0.000000	0.000044
33.48	148.93	0.000000	0.000044
36.00	160.14	0.000000	0.000047
38.82	172.68	0.000000	0.000049
37.20	165.47	0.000000	0.000052
42.78	190.29	0.000000	0.000056
45.60	202.84	0.000000	0.000057
48.12	214.05	0.000000	0.000056
50.82	226.06	0.000000	0.000059
53.34	237.27	0.000000	0.000058
56.04	249.28	0.000000	0.000059
58.50	260.22	0.000000	0.000060
60.48	269.03	0.000000	0.000061
62.28	277.04	0.000000	0.000061
64.14	285.31	0.000000	0.000063
66.06	293.85	0.000000	0.000067
67.32	299.45	0.000000	0.000055
64.02	284.78	0.000000	0.000046



West View

(All Dimensions are in mm)

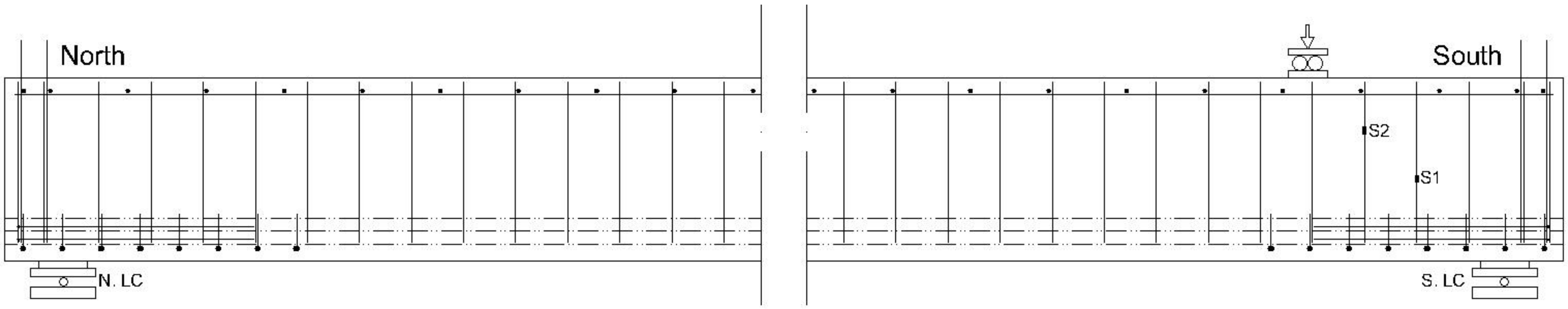
Fig. A.2.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G2-South End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.2.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder G2-South End Testing (Labib 2012) (Cont'd)



West View

Fig. A.2.5 Layout of Strain Gauges on Transverse Reinforcement for Girder G2-South End Testing (Labib 2012)

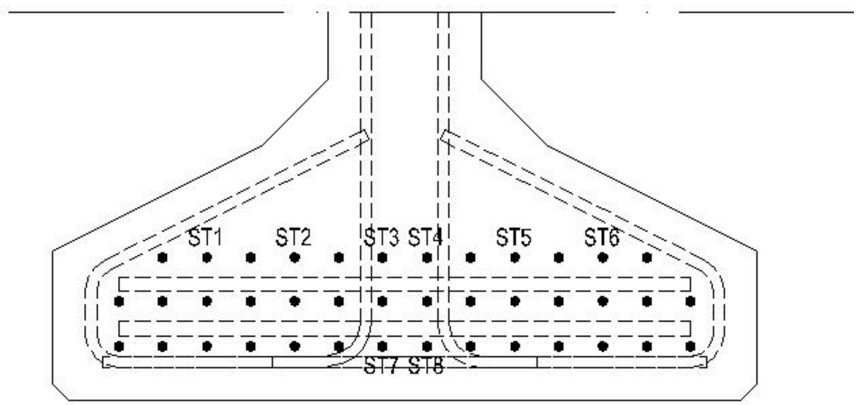


Fig. A.2.6 LVDTs Names on Selected Tendons of Girder G2-South End Testing (Labib 2012)

Table A.2.7 Measurements of Load and Deflection Relationships of Girder G2 – South End Testing (Labib 2012)

N. LC		S. LC		SW Def.		SE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0	0.00	0.000	0.00	0.000	0.01	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
7.20	32.01	60.06	267.16	0.004	0.10	0.076	1.92	-0.020	-0.50	0.044	1.11	0.001	0.03	0.050	1.28
11.13	49.50	92.88	413.15	0.024	0.61	0.098	2.49	-0.018	-0.45	0.050	1.27	0.012	0.31	0.063	1.61
14.49	64.46	120.96	538.06	0.041	1.05	0.115	2.93	-0.013	-0.32	0.055	1.39	0.023	0.58	0.073	1.86
14.38	63.95	120	533.79	0.041	1.05	0.116	2.95	-0.013	-0.32	0.055	1.40	0.023	0.58	0.074	1.88
16.63	73.99	138.84	617.59	0.052	1.32	0.125	3.17	-0.008	-0.22	0.057	1.45	0.028	0.70	0.078	1.98
20.75	92.31	173.22	770.52	0.072	1.84	0.141	3.58	-0.001	-0.02	0.059	1.51	0.039	0.99	0.084	2.14
24.96	111.05	208.38	926.92	0.092	2.34	0.155	3.95	0.007	0.19	0.061	1.56	0.049	1.25	0.089	2.26
28.05	124.76	234.12	1041.42	0.110	2.79	0.169	4.29	0.014	0.37	0.062	1.58	0.057	1.45	0.092	2.34
32.71	145.51	273.06	1214.63	0.132	3.35	0.185	4.70	0.024	0.60	0.063	1.60	0.067	1.70	0.096	2.44
37.40	166.36	312.18	1388.65	0.154	3.91	0.201	5.10	0.032	0.81	0.064	1.63	0.077	1.95	0.099	2.51
42.16	187.56	351.96	1565.60	0.176	4.46	0.218	5.53	0.040	1.01	0.065	1.65	0.085	2.16	0.102	2.59
46.88	208.53	391.32	1740.68	0.198	5.02	0.235	5.98	0.047	1.18	0.066	1.69	0.093	2.36	0.105	2.66
47.25	210.20	394.44	1754.56	0.204	5.18	0.241	6.13	0.048	1.22	0.068	1.71	0.096	2.43	0.107	2.71
50.47	224.49	421.26	1873.86	0.214	5.43	0.252	6.40	0.051	1.29	0.069	1.75	0.099	2.51	0.109	2.76
54.50	242.43	454.92	2023.59	0.233	5.92	0.269	6.84	0.056	1.42	0.070	1.79	0.106	2.69	0.111	2.83
57.08	253.90	476.46	2119.40	0.247	6.27	0.282	7.15	0.060	1.51	0.071	1.80	0.111	2.82	0.113	2.87
59.33	263.91	495.24	2202.94	0.259	6.58	0.292	7.41	0.062	1.59	0.071	1.80	0.116	2.95	0.113	2.88
60.07	267.21	501.42	2230.43	0.267	6.78	0.298	7.58	0.064	1.63	0.071	1.80	0.119	3.02	0.114	2.91
62.26	276.96	519.72	2311.83	0.283	7.18	0.312	7.94	0.067	1.70	0.071	1.80	0.125	3.18	0.116	2.96
61.88	275.26	516.54	2297.68	0.322	8.18	0.299	7.60	0.091	2.32	0.050	1.26	0.153	3.88	0.117	2.97
62.85	279.58	524.64	2333.72	0.346	8.78	0.310	7.88	0.099	2.52	0.043	1.09	0.164	4.17	0.115	2.93
61.12	271.87	510.18	2269.39	0.385	9.79	0.342	8.70	0.107	2.71	0.035	0.89	0.177	4.50	0.115	2.92

Table A.2.8 Measurements of Tendons' slip at South End of Girder G2 – South End Testing (Labib 2012)

S. LC		ST1		ST2		ST3		ST4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
5.76	25.62	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
20.34	90.48	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
31.38	139.59	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
46.50	206.84	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
68.52	304.79	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
110.46	491.35	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
120.24	534.85	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
141.18	628.00	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
184.74	821.76	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
219.06	974.43	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
267.96	1191.95	0.000	0.01	0.000	0.00	0.000	-0.01	0.000	0.00
317.52	1412.40	0.002	0.06	0.000	0.01	0.001	0.02	0.000	0.00
368.40	1638.72	0.004	0.09	0.002	0.05	0.002	0.06	0.003	0.07
401.88	1787.65	0.005	0.13	0.004	0.09	0.005	0.12	0.008	0.21
418.74	1862.65	0.005	0.14	0.004	0.10	0.006	0.16	0.010	0.25
460.38	2047.87	0.014	0.36	0.006	0.16	0.011	0.28	0.012	0.30
484.74	2156.23	0.015	0.37	0.008	0.20	0.015	0.39	0.013	0.34
493.86	2196.80	0.015	0.39	0.009	0.24	0.017	0.44	0.014	0.35
519.72	2311.83	0.018	0.44	0.012	0.30	0.029	0.73	0.015	0.39
519.00	2308.63	0.023	0.58	0.028	0.72	0.042	1.06	0.025	0.63
524.64	2333.72	0.032	0.80	0.030	0.77	0.050	1.27	0.030	0.77
504.66	2244.84	0.048	1.22	0.055	1.39	0.079	2.01	0.052	1.33

Table A.2.8 Measurements of Tendons' slip at South End of Girder G2 – South End Testing (Labib 2012) (Cont'd)

S. LC		ST5		ST6		ST7		ST8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
5.76	25.62	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
20.34	90.48	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
31.38	139.59	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
46.50	206.84	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
68.52	304.79	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
110.46	491.35	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
120.24	534.85	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
141.18	628.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
184.74	821.76	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
219.06	974.43	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
267.96	1191.95	0.000	0.00	0.001	0.02	0.000	0.01	0.000	0.00
317.52	1412.40	0.004	0.09	0.003	0.08	0.000	0.01	0.000	0.01
368.40	1638.72	0.006	0.14	0.005	0.12	0.000	0.01	0.003	0.08
401.88	1787.65	0.007	0.18	0.006	0.16	0.001	0.03	0.005	0.13
418.74	1862.65	0.008	0.19	0.007	0.17	0.001	0.03	0.005	0.14
460.38	2047.87	0.010	0.24	0.009	0.23	0.003	0.07	0.007	0.18
484.74	2156.23	0.011	0.28	0.011	0.28	0.004	0.10	0.009	0.23
493.86	2196.80	0.012	0.31	0.012	0.32	0.006	0.15	0.011	0.28
519.72	2311.83	0.015	0.37	0.016	0.42	0.014	0.34	0.016	0.41
519.00	2308.63	0.020	0.51	0.025	0.64	0.026	0.66	0.030	0.75
524.64	2333.72	0.023	0.57	0.031	0.79	0.033	0.84	0.038	0.95
504.66	2244.84	0.041	1.03	0.063	1.60	0.061	1.56	0.067	1.69

Table A.2.9 Measurements of LVDTs for South Rosette Strains of Girder G2 – South End Testing (Labib 2012)

S. LC		SWD1	SED1	SD1 AVG	SWD2	SED2	SD2 AVG
kips	KN						
0.00	0.00	N.R.	-0.000004	-0.000004	N.R.	0.000007	0.000007
5.76	25.62	N.R.	-0.000004	-0.000004	N.R.	-0.000030	-0.000030
20.34	90.48	N.R.	-0.000016	-0.000016	N.R.	-0.000023	-0.000023
31.38	139.59	N.R.	-0.000012	-0.000012	N.R.	0.000014	0.000014
46.50	206.84	N.R.	-0.000004	-0.000004	N.R.	-0.000039	-0.000039
68.52	304.79	N.R.	-0.000004	-0.000004	N.R.	-0.000034	-0.000034
110.46	491.35	N.R.	0.000004	0.000004	N.R.	0.000025	0.000025
120.24	534.85	N.R.	-0.000004	-0.000004	N.R.	-0.000011	-0.000011
141.18	628.00	N.R.	-0.000020	-0.000020	N.R.	-0.000034	-0.000034
184.74	821.76	N.R.	-0.000161	-0.000161	N.R.	0.000009	0.000009
219.06	974.43	N.R.	-0.000358	-0.000358	N.R.	0.000307	0.000307
267.96	1191.95	N.R.	-0.000620	-0.000620	N.R.	0.000862	0.000862
317.52	1412.40	N.R.	-0.000902	-0.000902	N.R.	0.001449	0.001449
368.40	1638.72	N.R.	-0.001281	-0.001281	N.R.	0.002083	0.002083
401.88	1787.65	N.R.	-0.001688	-0.001688	N.R.	0.002764	0.002764
418.74	1862.65	N.R.	-0.001809	-0.001809	N.R.	0.003041	0.003041
460.38	2047.87	N.R.	-0.002183	-0.002183	N.R.	0.003883	0.003883
484.74	2156.23	N.R.	-0.002449	-0.002449	N.R.	0.004501	0.004501
493.86	2196.80	N.R.	-0.002646	-0.002646	N.R.	0.005201	0.005201
519.72	2311.83	N.R.	-0.002856	-0.002856	N.R.	0.006278	0.006278
519.00	2308.63	N.R.	-0.002602	-0.002602	N.R.	0.008444	0.008444
524.64	2333.72	N.R.	-0.002227	-0.002227	N.R.	0.009471	0.009471
504.66	2244.84	N.R.	-0.001136	-0.001136	N.R.	0.013174	0.013174

Table A.2.9 Measurements of LVDTs for South Rosette Strains of Girder G2 – South End Testing (Labib 2012) (Cont'd)

S. LC		SWV1	SEV1	SV1 AVG	SWV2	SEV2	SV2 AVG
kips	KN						
0.00	0.00	N.R.	0.000000	0.000000	N.R.	-0.000045	-0.000045
5.76	25.62	N.R.	0.000004	0.000004	N.R.	-0.000074	-0.000074
20.34	90.48	N.R.	0.000000	0.000000	N.R.	-0.000015	-0.000015
31.38	139.59	N.R.	0.000000	0.000000	N.R.	-0.000064	-0.000064
46.50	206.84	N.R.	0.000000	0.000000	N.R.	-0.000079	-0.000079
68.52	304.79	N.R.	-0.000009	-0.000009	N.R.	-0.000040	-0.000040
110.46	491.35	N.R.	-0.000004	-0.000004	N.R.	-0.000030	-0.000030
120.24	534.85	N.R.	-0.000004	-0.000004	N.R.	-0.000094	-0.000094
141.18	628.00	N.R.	-0.000004	-0.000004	N.R.	-0.000045	-0.000045
184.74	821.76	N.R.	0.000004	0.000004	N.R.	-0.000069	-0.000069
219.06	974.43	N.R.	-0.000013	-0.000013	N.R.	-0.000248	-0.000248
267.96	1191.95	N.R.	0.000009	0.000009	N.R.	-0.000238	-0.000238
317.52	1412.40	N.R.	0.000022	0.000022	N.R.	-0.000486	-0.000486
368.40	1638.72	N.R.	0.000035	0.000035	N.R.	-0.000843	-0.000843
401.88	1787.65	N.R.	0.000143	0.000143	N.R.	-0.000976	-0.000976
418.74	1862.65	N.R.	0.000238	0.000238	N.R.	-0.001021	-0.001021
460.38	2047.87	N.R.	0.000950	0.000950	N.R.	-0.001175	-0.001175
484.74	2156.23	N.R.	0.001780	0.001780	N.R.	-0.001358	-0.001358
493.86	2196.80	N.R.	0.001788	0.001788	N.R.	-0.001457	-0.001457
519.72	2311.83	N.R.	0.003357	0.003357	N.R.	-0.002032	-0.002032
519.00	2308.63	N.R.	0.004005	0.004005	N.R.	-0.001626	-0.001626
524.64	2333.72	N.R.	0.004821	0.004821	N.R.	-0.001631	-0.001631
504.66	2244.84	N.R.	0.006744	0.006744	N.R.	-0.001616	-0.001616

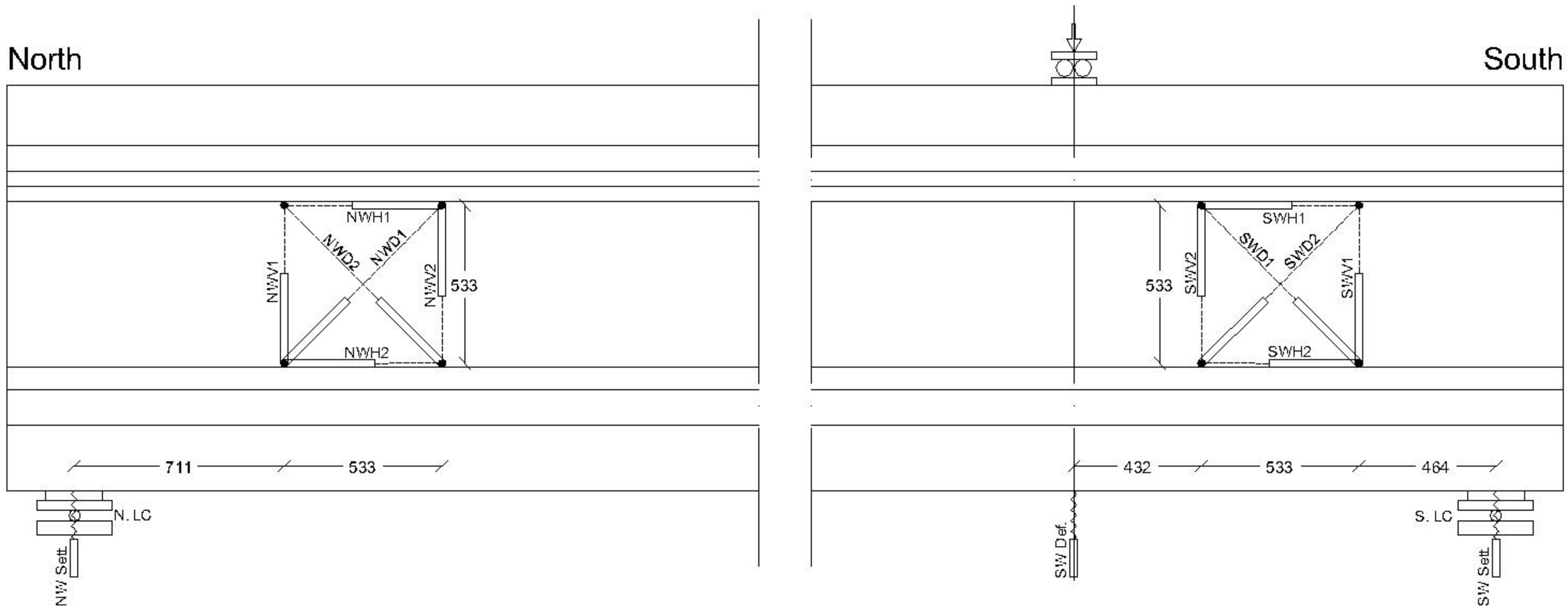
Table A.2.9 Measurements of LVDTs for South Rosette Strains of Girder G2 – South End Testing (Labib 2012) (Cont'd)

S. LC		SWH1	SEH1	SH1 AVG	SWH2	SEH2	SH2 AVG
kips	KN						
0.00	0.00	N.R.	0.000000	0.000000	N.R.	-0.000005	-0.000005
5.76	25.62	N.R.	0.000000	0.000000	N.R.	-0.000010	-0.000010
20.34	90.48	N.R.	0.000000	0.000000	N.R.	0.000000	0.000000
31.38	139.59	N.R.	0.000011	0.000011	N.R.	0.000000	0.000000
46.50	206.84	N.R.	0.000006	0.000006	N.R.	-0.000005	-0.000005
68.52	304.79	N.R.	0.000006	0.000006	N.R.	-0.000010	-0.000010
110.46	491.35	N.R.	0.000006	0.000006	N.R.	0.000000	0.000000
120.24	534.85	N.R.	0.000006	0.000006	N.R.	0.000000	0.000000
141.18	628.00	N.R.	-0.000006	-0.000006	N.R.	-0.000005	-0.000005
184.74	821.76	N.R.	0.000011	0.000011	N.R.	-0.000015	-0.000015
219.06	974.43	N.R.	0.000011	0.000011	N.R.	-0.000072	-0.000072
267.96	1191.95	N.R.	0.000006	0.000006	N.R.	-0.000067	-0.000067
317.52	1412.40	N.R.	0.000006	0.000006	N.R.	-0.000062	-0.000062
368.40	1638.72	N.R.	0.000000	0.000000	N.R.	-0.000159	-0.000159
401.88	1787.65	N.R.	0.000006	0.000006	N.R.	-0.000154	-0.000154
418.74	1862.65	N.R.	0.000011	0.000011	N.R.	-0.000164	-0.000164
460.38	2047.87	N.R.	0.000011	0.000011	N.R.	-0.000370	-0.000370
484.74	2156.23	N.R.	0.000006	0.000006	N.R.	-0.000596	-0.000596
493.86	2196.80	N.R.	0.000006	0.000006	N.R.	-0.000607	-0.000607
519.72	2311.83	N.R.	0.000198	0.000198	N.R.	-0.000941	-0.000941
519.00	2308.63	N.R.	0.003707	0.003707	N.R.	-0.000935	-0.000935
524.64	2333.72	N.R.	0.005436	0.005436	N.R.	-0.001100	-0.001100
504.66	2244.84	N.R.	0.010724	0.010724	N.R.	0.001362	0.001362

Table A.2.10 Measurements of South Strain Gauges on Transverse Steel Bars of Girder G2 – South End Testing (Labib 2012)

S. LC		S1	S2
kips	KN		
0.00	0.00	0.000001	0.000000
5.76	25.62	-0.000005	0.000004
20.34	90.48	-0.000014	0.000010
31.38	139.59	-0.000020	0.000012
46.50	206.84	-0.000023	0.000015
68.52	304.79	-0.000032	0.000016
110.46	491.35	-0.000051	0.000010
120.24	534.85	-0.000056	0.000008
141.18	628.00	-0.000063	0.000010
184.74	821.76	-0.000086	0.000021
219.06	974.43	-0.000166	0.000112
267.96	1191.95	-0.000157	0.000202
317.52	1412.40	-0.000121	0.000401
368.40	1638.72	-0.000028	0.000783
401.88	1787.65	0.000512	0.001637
418.74	1862.65	0.000651	0.001789
460.38	2047.87	0.001059	A.G.
484.74	2156.23	A.G.	A.G.
493.86	2196.80	A.G.	A.G.
519.72	2311.83	A.G.	A.G.
519.00	2308.63	A.G.	A.G.
524.64	2333.72	A.G.	A.G.
504.66	2244.84	A.G.	A.G.

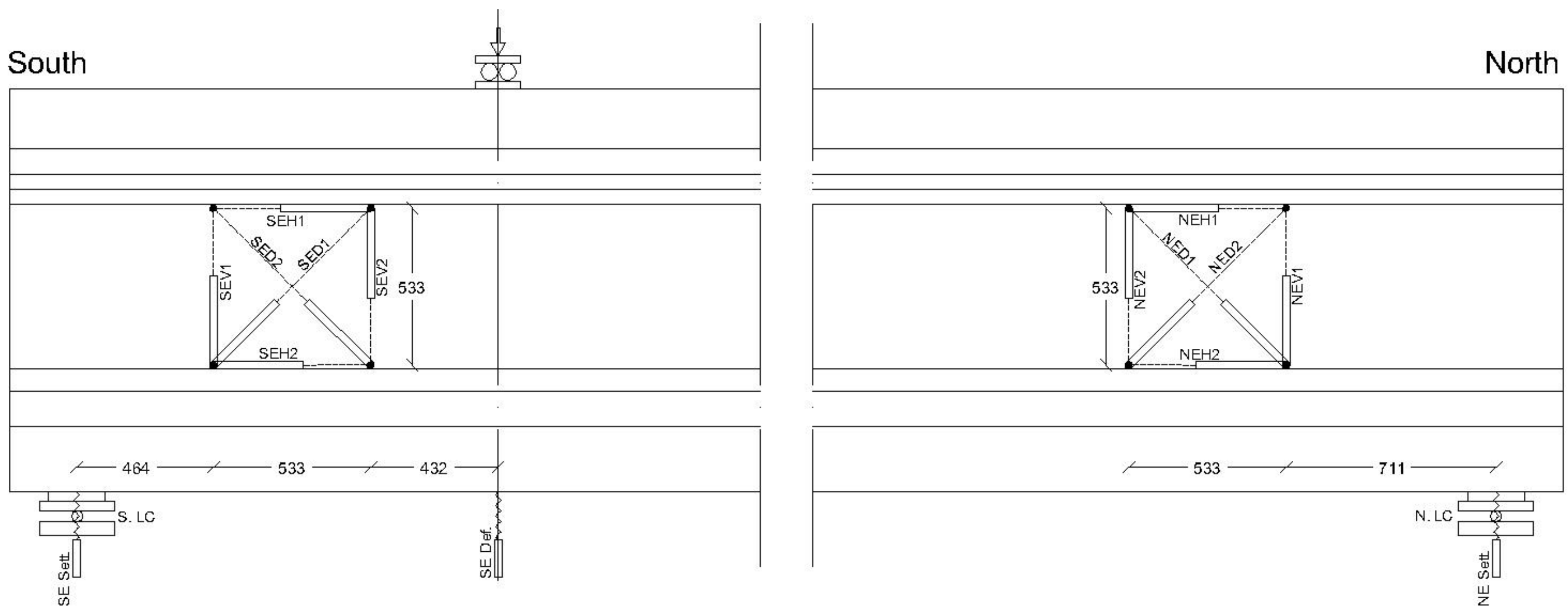
Experimental Data of Girder D1



West View

(All Dimensions are in mm)

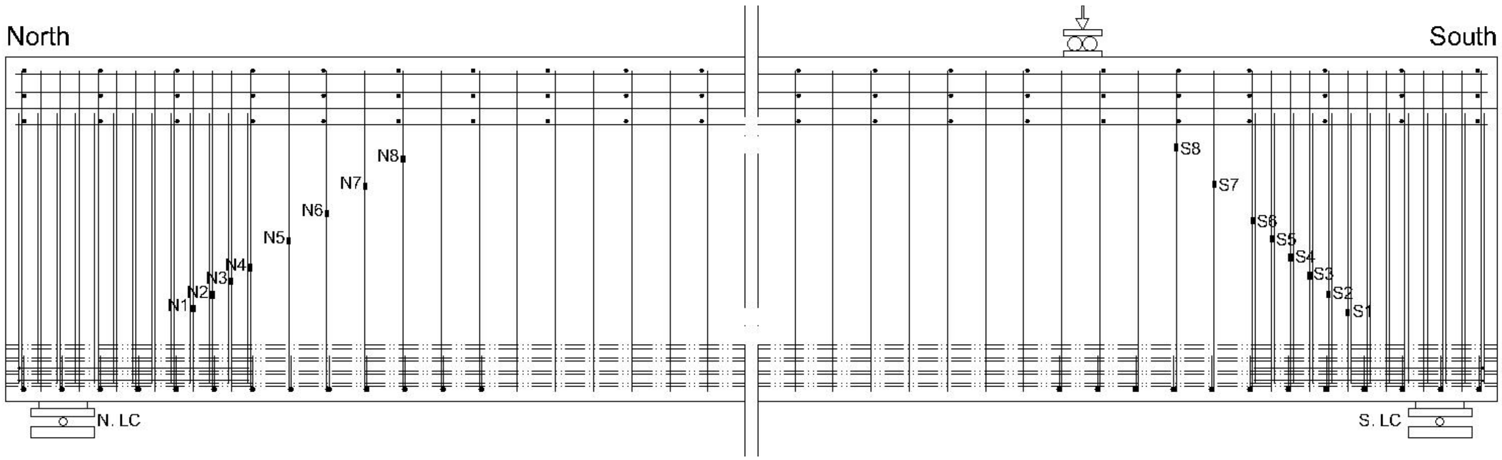
Fig. A.3.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D1-South End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.3.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D1-South End Testing (Labib 2012) (Cont'd)



West View

Fig. A.3.2 Layout of Strain Gauges on Transverse Reinforcement for Girder D1-South End Testing (Labib 2012)

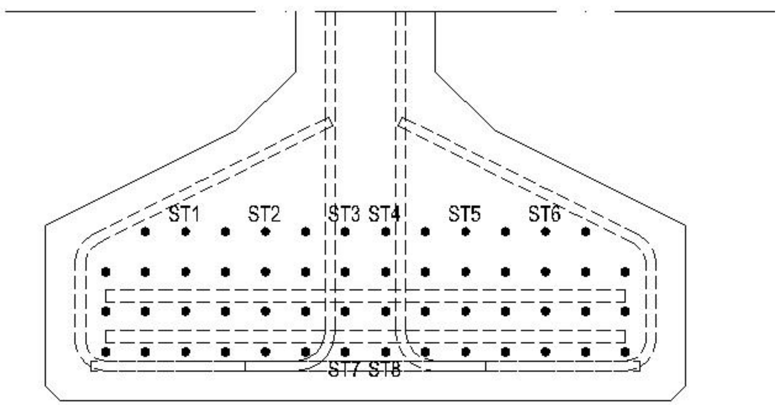


Fig. A.3.3 LVDTs Names on Selected Tendons of Girder D1-South End Testing (Labib 2012)

Table A.3.1 Measurements of Load and Deflection Relationships of Girder D1 – South End Testing (Labib 2012)

N. LC		S. LC		SW Def.		SE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.96	4.27	1.32	5.87	0.010	0.26	-0.006	-0.16	0.000	0.00	-0.009	-0.22	0.011	0.27	-0.008	-0.20
32.40	144.13	90.30	401.67	0.068	1.73	0.031	0.80	0.018	0.45	0.026	0.67	0.060	1.52	0.030	0.75
46.56	207.12	132.30	588.50	0.082	2.07	0.046	1.18	0.024	0.61	0.038	0.96	0.067	1.71	0.044	1.11
62.46	277.85	181.20	806.02	0.104	2.65	0.053	1.34	0.040	1.01	0.037	0.95	0.084	2.14	0.047	1.19
77.58	345.11	228.42	1016.06	0.128	3.25	0.057	1.45	0.056	1.42	0.034	0.85	0.102	2.59	0.046	1.16
87.12	387.55	258.42	1149.51	0.146	3.71	0.059	1.50	0.069	1.75	0.029	0.74	0.116	2.96	0.044	1.11
101.11	449.74	302.04	1343.54	0.164	4.16	0.070	1.79	0.077	1.96	0.033	0.83	0.128	3.24	0.050	1.26
114.79	510.59	343.50	1527.96	0.179	4.55	0.082	2.07	0.083	2.11	0.037	0.95	0.136	3.45	0.058	1.48
129.61	576.52	390.72	1738.01	0.196	4.98	0.095	2.41	0.089	2.27	0.043	1.09	0.145	3.68	0.068	1.74
143.29	637.37	432.90	1925.64	0.210	5.34	0.108	2.74	0.094	2.38	0.049	1.23	0.152	3.86	0.078	1.99
161.23	717.18	487.38	2167.97	0.230	5.83	0.126	3.19	0.099	2.50	0.056	1.42	0.161	4.09	0.092	2.34
169.09	752.14	511.62	2275.80	0.239	6.07	0.136	3.45	0.101	2.56	0.061	1.54	0.165	4.20	0.099	2.51
184.27	819.67	558.36	2483.71	0.258	6.55	0.153	3.89	0.105	2.66	0.066	1.67	0.173	4.40	0.110	2.80
202.03	898.67	613.08	2727.12	0.280	7.12	0.171	4.35	0.109	2.76	0.071	1.81	0.182	4.63	0.121	3.09
217.63	968.07	661.26	2941.43	0.300	7.61	0.188	4.78	0.112	2.85	0.076	1.94	0.191	4.85	0.133	3.37
236.29	1051.08	718.08	3194.18	0.323	8.20	0.209	5.30	0.116	2.96	0.082	2.09	0.201	5.10	0.146	3.71
249.49	1109.80	757.44	3369.26	0.342	8.68	0.225	5.71	0.120	3.04	0.087	2.21	0.209	5.31	0.158	4.01
257.89	1147.16	783.66	3485.89	0.352	8.94	0.234	5.94	0.121	3.08	0.090	2.27	0.213	5.41	0.164	4.17
258.43	1149.57	783.78	3486.43	0.359	9.12	0.241	6.13	0.122	3.11	0.092	2.33	0.217	5.51	0.170	4.32
249.01	1107.66	781.08	3474.42	0.355	9.02	0.240	6.11	0.121	3.07	0.092	2.34	0.216	5.50	0.172	4.38
262.69	1168.52	812.88	3615.87	0.365	9.28	0.247	6.27	0.123	3.12	0.094	2.38	0.219	5.57	0.175	4.44
274.33	1220.30	841.20	3741.84	0.379	9.62	0.259	6.57	0.125	3.18	0.096	2.44	0.224	5.70	0.182	4.62
297.67	1324.12	912.78	4060.25	0.418	10.61	0.291	7.39	0.130	3.29	0.101	2.57	0.236	6.00	0.202	5.13

Table A.3.2 Measurements of Tendons' slip at South End of Girder D1 – South End Testing (Labib 2012)

S. LC		ST1		ST2		ST3		ST4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.06	0.27	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	-0.01
66.84	297.32	0.000	0.01	0.000	0.00	0.000	0.00	0.000	0.00
111.60	496.42	0.000	0.00	0.000	0.00	0.000	0.00	0.000	-0.01
149.58	665.37	0.000	0.01	0.000	0.00	0.000	0.00	0.000	0.00
186.18	828.17	0.000	0.00	0.000	0.00	0.000	0.00	0.000	-0.01
230.04	1023.27	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
272.88	1213.83	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
314.16	1397.45	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
357.48	1590.15	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
398.88	1774.31	0.000	0.00	0.000	0.00	0.000	0.00	0.000	-0.01
446.52	1986.22	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
491.16	2184.79	0.000	0.00	0.000	0.01	0.001	0.02	0.000	0.00
535.08	2380.15	0.001	0.02	0.000	0.01	0.001	0.03	0.000	0.01
576.18	2562.98	0.001	0.02	0.000	0.01	0.001	0.03	0.000	0.01
620.52	2760.21	0.001	0.02	0.000	0.01	0.001	0.04	0.000	0.00
659.34	2932.89	0.001	0.03	0.001	0.01	0.002	0.04	0.000	0.01
703.26	3128.26	0.001	0.03	0.001	0.02	0.002	0.04	0.001	0.01
747.96	3327.09	0.001	0.03	0.000	0.01	0.001	0.04	0.000	0.01
788.52	3507.51	0.002	0.04	0.000	0.00	0.001	0.04	0.001	0.01
762.24	3390.61	0.002	0.05	0.000	0.01	0.002	0.04	0.000	0.01
821.64	3654.84	0.002	0.06	0.001	0.02	0.002	0.04	0.000	0.01
853.20	3795.22	0.003	0.07	0.002	0.06	0.002	0.06	0.000	0.01
912.78	4060.25	0.006	0.15	0.010	0.25	0.005	0.12	0.002	0.04

Table A.3.2 Measurements of Tendons' slip at South End of Girder D1 – South End Testing (Labib 2012) (Cont'd)

S. LC		ST5		ST6		ST7		ST8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.06	0.27	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	-0.01
66.84	297.32	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	-0.01
111.60	496.42	0.000	0.00	0.000	0.00	0.000	0.00	0.000	-0.01
149.58	665.37	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
186.18	828.17	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
230.04	1023.27	0.000	0.00	0.000	0.00	-0.001	-0.02	0.000	-0.01
272.88	1213.83	0.000	0.00	0.000	0.00	-0.001	-0.02	0.000	-0.01
314.16	1397.45	0.000	0.00	0.000	0.00	-0.001	-0.02	0.000	-0.01
357.48	1590.15	0.000	0.00	0.000	0.00	0.000	0.00	0.000	-0.01
398.88	1774.31	0.000	0.00	0.000	0.00	0.000	0.00	0.000	-0.01
446.52	1986.22	0.000	0.00	0.000	0.00	-0.001	-0.02	-0.001	-0.01
491.16	2184.79	0.000	0.00	0.000	0.00	-0.001	-0.02	0.000	-0.01
535.08	2380.15	0.000	0.00	0.000	0.00	0.000	0.01	0.000	-0.01
576.18	2562.98	0.000	0.01	0.000	0.00	0.002	0.04	0.000	0.00
620.52	2760.21	0.000	0.00	0.000	0.00	0.002	0.04	0.000	0.00
659.34	2932.89	0.000	0.01	0.000	0.01	0.002	0.04	0.001	0.02
703.26	3128.26	0.000	0.00	0.000	0.01	0.002	0.05	0.002	0.04
747.96	3327.09	0.001	0.02	0.000	0.01	0.003	0.06	0.002	0.06
788.52	3507.51	0.002	0.04	0.000	0.01	0.004	0.09	0.003	0.08
762.24	3390.61	0.002	0.05	0.001	0.01	0.004	0.09	0.003	0.09
821.64	3654.84	0.003	0.07	0.001	0.02	0.004	0.11	0.004	0.10
853.20	3795.22	0.003	0.08	0.001	0.03	0.004	0.11	0.004	0.10
912.78	4060.25	0.005	0.13	0.003	0.08	0.005	0.14	0.005	0.12

Table A.3.3 Measurements of LVDTs for South Rosette Strains of Girder D1 – South End Testing (Labib 2012)

S. LC		SED1	SWD1	SD1 AVG	SED2	SWD2	SD2 AVG
kips	KN						
0.06	0.27	-0.000001	0.000001	0.000000	-0.000006	0.000000	-0.000003
66.84	297.32	-0.000041	-0.000045	-0.000043	-0.000009	0.000022	0.000006
111.60	496.42	-0.000056	-0.000068	-0.000062	0.000009	0.000041	0.000025
149.58	665.37	-0.000087	-0.000095	-0.000091	0.000017	0.000060	0.000039
186.18	828.17	-0.000104	-0.000127	-0.000116	0.000045	0.000082	0.000064
230.04	1023.27	-0.000138	-0.000146	-0.000142	0.000083	0.000105	0.000094
272.88	1213.83	-0.000187	-0.000148	-0.000168	0.000152	0.000154	0.000153
314.16	1397.45	-0.000234	-0.000156	-0.000195	0.000230	0.000207	0.000219
357.48	1590.15	-0.000303	-0.000160	-0.000232	0.000317	0.000273	0.000295
398.88	1774.31	-0.000373	-0.000118	-0.000246	0.000427	0.000388	0.000408
446.52	1986.22	-0.000489	-0.000122	-0.000306	0.000547	0.000497	0.000522
491.16	2184.79	-0.000540	-0.000145	-0.000343	0.000699	0.000638	0.000669
535.08	2380.15	-0.000635	-0.000278	-0.000457	0.000843	0.000763	0.000803
576.18	2562.98	-0.000681	-0.000367	-0.000524	0.001005	0.000930	0.000968
620.52	2760.21	-0.000741	-0.000462	-0.000602	0.001170	0.001121	0.001146
659.34	2932.89	-0.000815	-0.000511	-0.000663	0.001319	0.001362	0.001341
703.26	3128.26	-0.000902	-0.000521	-0.000712	0.001494	0.001629	0.001562
747.96	3327.09	-0.000987	-0.000679	-0.000833	0.001727	0.001843	0.001785
788.52	3507.51	-0.001105	-0.000844	-0.000975	0.001949	0.002087	0.002018
762.24	3390.61	-0.001154	-0.000898	-0.001026	0.002039	0.002168	0.002104
821.64	3654.84	-0.001267	-0.001090	-0.001179	0.002139	0.002281	0.002210
853.20	3795.22	-0.001408	-0.001251	-0.001330	0.002328	0.002492	0.002410
912.78	4060.25	-0.001766	-0.001624	-0.001695	0.002877	0.003038	0.002958

Table A.3.3 Measurements of LVDTs for South Rosette Strains of Girder D1 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEV1	SWV1	SV1 AVG	SEV2	SWV2	SV2 AVG
kips	KN						
0.06	0.27	-0.000002	-0.000002	-0.000002	0.000024	0.000003	0.000014
66.84	297.32	0.000004	0.000041	0.000023	0.000022	-0.000003	0.000010
111.60	496.42	0.000004	0.000039	0.000022	0.000020	0.000004	0.000012
149.58	665.37	0.000000	0.000037	0.000019	0.000026	0.000007	0.000017
186.18	828.17	-0.000002	0.000042	0.000020	0.000026	0.000004	0.000015
230.04	1023.27	-0.000010	0.000040	0.000015	0.000016	0.000007	0.000012
272.88	1213.83	0.000044	-0.000030	0.000007	0.000018	0.000010	0.000014
314.16	1397.45	0.000079	-0.000029	0.000025	0.000154	0.000019	0.000087
357.48	1590.15	0.000125	-0.000033	0.000046	0.000179	0.000031	0.000105
398.88	1774.31	0.000196	-0.000030	0.000083	0.000257	0.000269	0.000263
446.52	1986.22	0.000181	0.000032	0.000107	0.000344	0.000404	0.000374
491.16	2184.79	0.000381	0.000116	0.000249	0.000507	0.000484	0.000496
535.08	2380.15	0.000513	0.000115	0.000314	0.000580	0.000517	0.000549
576.18	2562.98	0.000667	0.000115	0.000391	0.000694	0.000537	0.000616
620.52	2760.21	0.000817	0.000180	0.000499	0.000836	0.000561	0.000699
659.34	2932.89	0.000946	0.000399	0.000673	0.000936	0.000623	0.000780
703.26	3128.26	0.001071	0.000560	0.000816	0.001078	0.000732	0.000905
747.96	3327.09	0.001242	0.000629	0.000936	0.001230	0.000732	0.000981
788.52	3507.51	0.001388	0.000733	0.001061	0.001362	0.000732	0.001047
762.24	3390.61	0.001446	0.000784	0.001115	0.001411	0.000728	0.001070
821.64	3654.84	0.001521	0.000804	0.001163	0.001440	0.000730	0.001085
853.20	3795.22	0.001390	0.000902	0.001146	0.001547	0.000730	0.001139
912.78	4060.25	0.001828	0.001444	0.001636	0.001802	0.000981	0.001392

Table A.3.3 Measurements of LVDTs for South Rosette Strains of Girder D1 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEH1	SWH1	SH1 AVG	SEH2	SWH2	SH2 AVG
kips	KN						
0.06	0.27	0.000000	0.000000	0.000000	0.000002	-0.000002	0.000000
66.84	297.32	-0.000001	0.000002	0.000001	0.000000	0.000016	0.000008
111.60	496.42	-0.000001	-0.000032	-0.000017	-0.000002	0.000016	0.000007
149.58	665.37	-0.000058	-0.000083	-0.000071	-0.000002	0.000016	0.000007
186.18	828.17	-0.000058	-0.000129	-0.000094	0.000002	0.000018	0.000010
230.04	1023.27	-0.000060	-0.000192	-0.000126	-0.000002	0.000021	0.000010
272.88	1213.83	-0.000082	-0.000230	-0.000156	-0.000004	0.000031	0.000014
314.16	1397.45	-0.000116	-0.000272	-0.000194	-0.000002	0.000018	0.000008
357.48	1590.15	-0.000113	-0.000349	-0.000231	0.000000	0.000021	0.000011
398.88	1774.31	-0.000130	-0.000395	-0.000263	-0.000014	0.000018	0.000002
446.52	1986.22	-0.000130	-0.000434	-0.000282	-0.000056	0.000018	-0.000019
491.16	2184.79	-0.000153	-0.000446	-0.000300	-0.000206	0.000012	-0.000097
535.08	2380.15	-0.000151	-0.000476	-0.000314	-0.000337	0.000016	-0.000161
576.18	2562.98	-0.000154	-0.000484	-0.000319	-0.000427	0.000006	-0.000211
620.52	2760.21	-0.000162	-0.000504	-0.000333	-0.000562	-0.000039	-0.000301
659.34	2932.89	-0.000181	-0.000635	-0.000408	-0.000681	-0.000047	-0.000364
703.26	3128.26	-0.000195	-0.001170	-0.000683	-0.000831	-0.000062	-0.000447
747.96	3327.09	-0.000195	-0.001297	-0.000746	-0.000960	-0.000115	-0.000538
788.52	3507.51	-0.000204	-0.001349	-0.000777	-0.001121	-0.000146	-0.000634
762.24	3390.61	-0.000203	-0.001349	-0.000776	-0.001198	-0.000170	-0.000684
821.64	3654.84	-0.000198	-0.001385	-0.000792	-0.001312	-0.000181	-0.000747
853.20	3795.22	-0.000197	-0.001409	-0.000803	-0.001544	-0.000259	-0.000902
912.78	4060.25	-0.000208	-0.001464	-0.000836	-0.001933	-0.000369	-0.001151

Table A.3.4 Measurements of LVDTs for North Rosette Strains of Girder D1 – South End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
0.18	0.80	0.000002	0.000006	0.000004	0.000008	0.000000	0.000004
21.42	95.29	0.000036	-0.000006	0.000015	0.000002	0.000006	0.000004
39.60	176.16	0.000040	-0.000002	0.000019	0.000000	0.000014	0.000007
51.90	230.87	0.000046	-0.000016	0.000015	0.000020	0.000012	0.000016
63.66	283.19	0.000036	-0.000016	0.000010	0.000026	0.000026	0.000026
78.06	347.25	0.000036	-0.000020	0.000008	0.000020	0.000028	0.000024
91.74	408.10	0.000026	-0.000032	-0.000003	0.000042	0.000042	0.000042
105.19	467.89	0.000028	-0.000032	-0.000002	0.000054	0.000038	0.000046
118.87	528.74	0.000008	-0.000054	-0.000023	0.000054	0.000050	0.000052
132.79	590.66	-0.000008	-0.000048	-0.000028	0.000076	0.000058	0.000067
147.79	657.39	-0.000002	-0.000068	-0.000035	0.000082	0.000072	0.000077
162.49	722.78	-0.000018	-0.000076	-0.000047	0.000090	0.000076	0.000083
176.65	785.77	-0.000076	-0.000170	-0.000123	0.000198	0.000130	0.000164
189.85	844.49	-0.000082	-0.000178	-0.000130	0.000250	0.000204	0.000227
204.31	908.82	-0.000114	-0.000206	-0.000160	0.000368	0.000370	0.000369
216.85	964.60	-0.000114	-0.000204	-0.000159	0.000414	0.000404	0.000409
231.13	1028.12	-0.000114	-0.000204	-0.000159	0.000504	0.000482	0.000493
246.01	1094.32	-0.000124	-0.000208	-0.000166	0.000566	0.000548	0.000557
259.45	1154.10	-0.000124	-0.000224	-0.000174	0.000640	0.000610	0.000625
251.47	1118.61	-0.000042	-0.000214	-0.000128	0.000682	0.000640	0.000661
266.23	1184.26	-0.000046	-0.000226	-0.000136	0.000672	0.000640	0.000656
279.31	1242.45	-0.000070	-0.000262	-0.000166	0.000688	0.000670	0.000679
297.67	1324.12	-0.000116	-0.000274	-0.000195	0.000736	0.000734	0.000735

Table A.3.4 Measurements of LVDTs for North Rosette Strains of Girder D1 – South End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
0.18	0.80	0.000000	0.000000	0.000000	0.000000	-0.000004	-0.000002
21.42	95.29	0.000043	-0.000004	0.000020	-0.000006	0.000011	0.000003
39.60	176.16	0.000047	-0.000017	0.000015	-0.000003	0.000010	0.000004
51.90	230.87	0.000047	0.000000	0.000024	-0.000003	-0.000012	-0.000008
63.66	283.19	0.000047	0.000000	0.000024	-0.000002	-0.000015	-0.000009
78.06	347.25	0.000047	0.000004	0.000026	-0.000002	0.000006	0.000002
91.74	408.10	0.000035	0.000008	0.000022	-0.000001	0.000012	0.000006
105.19	467.89	0.000036	0.000004	0.000020	0.000000	-0.000003	-0.000002
118.87	528.74	0.000036	0.000008	0.000022	0.000002	0.000011	0.000007
132.79	590.66	0.000036	0.000017	0.000027	0.000002	0.000011	0.000007
147.79	657.39	0.000036	0.000004	0.000020	0.000002	-0.000002	0.000000
162.49	722.78	0.000038	0.000008	0.000023	0.000004	-0.000008	-0.000002
176.65	785.77	0.000009	0.000054	0.000032	0.000126	0.000015	0.000071
189.85	844.49	0.000045	0.000088	0.000067	0.000198	0.000133	0.000166
204.31	908.82	0.000093	0.000188	0.000141	0.000332	0.000291	0.000312
216.85	964.60	0.000136	0.000226	0.000181	0.000398	0.000355	0.000377
231.13	1028.12	0.000184	0.000271	0.000228	0.000488	0.000432	0.000460
246.01	1094.32	0.000220	0.000317	0.000269	0.000569	0.000522	0.000546
259.45	1154.10	0.000254	0.000384	0.000319	0.000648	0.000591	0.000620
251.47	1118.61	0.000172	0.000401	0.000287	0.000689	0.000646	0.000668
266.23	1184.26	0.000171	0.000418	0.000295	0.000678	0.000642	0.000660
279.31	1242.45	0.000166	0.000447	0.000307	0.000694	0.000682	0.000688
297.67	1324.12	0.000167	0.000493	0.000330	0.000753	0.000763	0.000758

Table A.3.4 Measurements of LVDTs for North Rosette Strains of Girder D1 – South End Testing (Labib 2012) (Cont'd)

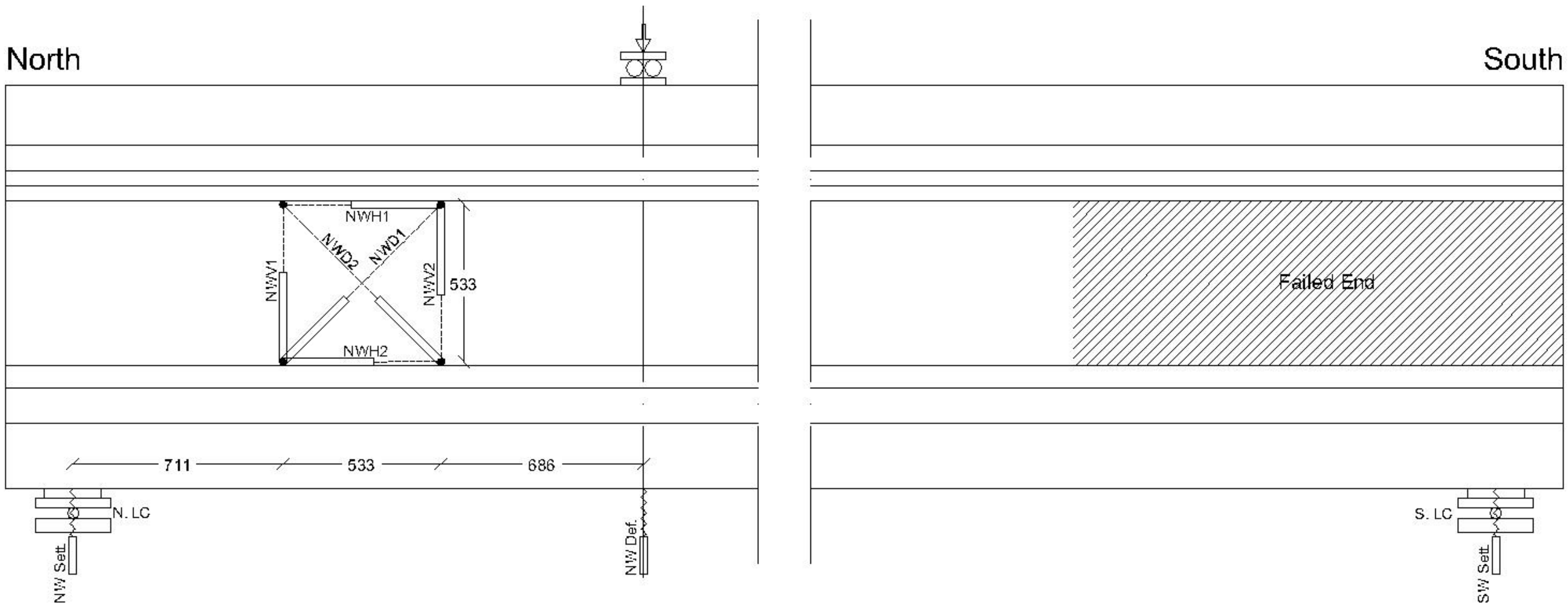
N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
0.18	0.80	0.000001	0.000000	0.000001	MF.	0.000000	0.000000
21.42	95.29	-0.000003	0.000001	-0.000001	MF.	0.000000	0.000000
39.60	176.16	-0.000004	0.000002	-0.000001	MF.	-0.000002	-0.000002
51.90	230.87	-0.000006	0.000004	-0.000001	MF.	-0.000002	-0.000002
63.66	283.19	-0.000005	0.000005	0.000000	MF.	-0.000002	-0.000002
78.06	347.25	-0.000005	0.000006	0.000001	MF.	-0.000003	-0.000003
91.74	408.10	-0.000008	0.000004	-0.000002	MF.	-0.000002	-0.000002
105.19	467.89	-0.000009	0.000009	0.000000	MF.	-0.000002	-0.000002
118.87	528.74	-0.000010	0.000008	-0.000001	MF.	-0.000002	-0.000002
132.79	590.66	-0.000009	0.000006	-0.000002	MF.	-0.000002	-0.000002
147.79	657.39	-0.000009	0.000002	-0.000004	MF.	-0.000002	-0.000002
162.49	722.78	-0.000002	-0.000006	-0.000004	MF.	-0.000003	-0.000003
176.65	785.77	-0.000017	-0.000071	-0.000044	MF.	-0.000002	-0.000002
189.85	844.49	-0.000034	-0.000098	-0.000066	MF.	0.000000	0.000000
204.31	908.82	-0.000047	-0.000106	-0.000077	MF.	-0.000032	-0.000032
216.85	964.60	-0.000052	-0.000122	-0.000087	MF.	-0.000032	-0.000032
231.13	1028.12	-0.000055	-0.000120	-0.000088	MF.	-0.000032	-0.000032
246.01	1094.32	-0.000056	-0.000131	-0.000094	MF.	-0.000032	-0.000032
259.45	1154.10	-0.000056	-0.000152	-0.000104	MF.	-0.000029	-0.000029
251.47	1118.61	-0.000059	-0.000156	-0.000108	MF.	-0.000031	-0.000031
266.23	1184.26	-0.000055	-0.000161	-0.000108	MF.	-0.000036	-0.000036
279.31	1242.45	-0.000070	-0.000184	-0.000127	MF.	-0.000050	-0.000050
297.67	1324.12	-0.000100	-0.000210	-0.000155	MF.	-0.000076	-0.000076

Table A.3.5 Measurements of South Strain Gauges on Transverse Steel Bars of Girder D1 – South End Testing (Labib 2012)

S. LC		S1	S2	S3	S4	S5	S6	S7	S8
kips	KN								
0.06	0.27	0.000006	0.000002	-0.000001	-0.000002	-0.000007	-0.000011	-0.000040	-0.000020
66.84	297.32	-0.000010	0.000000	0.000010	0.000008	0.000016	0.000067	0.000053	0.000007
111.60	496.42	-0.000016	-0.000001	0.000010	0.000017	0.000033	0.000097	0.000107	0.000044
149.58	665.37	-0.000019	-0.000001	0.000013	0.000027	0.000051	0.000121	0.000153	0.000073
186.18	828.17	-0.000018	-0.000003	0.000022	0.000038	0.000078	0.000147	0.000209	0.000106
230.04	1023.27	-0.000013	0.000012	0.000061	0.000084	0.000139	0.000204	0.000297	0.000169
272.88	1213.83	-0.000008	0.000066	0.000150	0.000166	0.000210	0.000296	0.000412	0.000265
314.16	1397.45	0.000020	0.000120	0.000241	0.000247	0.000287	0.000391	0.000532	0.000379
357.48	1590.15	0.000079	0.000163	0.000307	0.000294	0.000354	0.000486	0.000680	0.000527
398.88	1774.31	0.000119	0.000181	0.000383	0.000359	0.000425	0.000572	0.000814	0.000658
446.52	1986.22	0.000187	0.000271	0.000508	0.000446	0.000532	0.000683	0.000990	0.000843
491.16	2184.79	0.000225	0.000334	0.000594	0.000529	0.000633	0.000786	0.001163	0.001008
535.08	2380.15	0.000318	0.000435	0.000691	0.000583	0.000713	0.000867	0.001208	0.000962
576.18	2562.98	0.000384	0.000500	0.000763	0.000625	0.000760	0.000876	0.001185	0.000937
620.52	2760.21	0.000462	0.000560	0.000836	0.000672	0.000823	0.000913	0.001225	0.000981
659.34	2932.89	0.000518	0.000615	0.000903	0.000715	0.000890	0.000976	0.001338	0.001093
703.26	3128.26	0.000584	0.000693	0.000998	0.000757	0.000962	0.001014	0.001401	0.001257
747.96	3327.09	0.000634	0.000761	0.001087	0.000803	0.001040	0.001086	0.001495	0.001380
788.52	3507.51	0.000678	0.000827	0.001174	0.000847	0.001114	0.001161	0.001591	0.001496
762.24	3390.61	0.000672	0.000826	0.001160	0.000821	0.001096	0.001146	0.001566	0.001481
821.64	3654.84	0.000740	0.000908	0.001256	0.000903	0.001190	0.001233	0.001688	0.001611
853.20	3795.22	0.000797	0.000980	0.001334	0.000963	0.001267	0.001296	0.001808	0.001696
912.78	4060.25	0.000879	0.001139	0.001478	0.001100	0.001417	0.001414	0.002083	0.001950

Table A.3.6 Measurements of North Strain Gauges on Transverse Steel Bars of Girder D1 – South End Testing (Labib 2012)

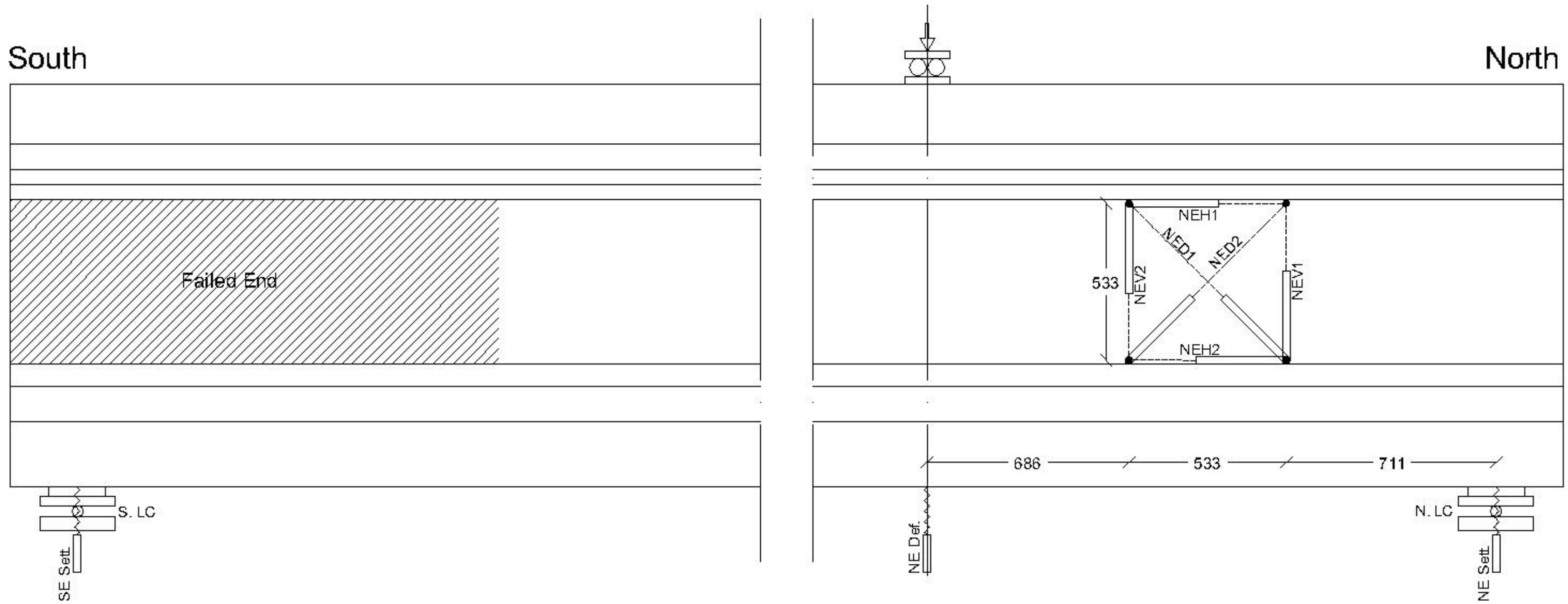
N. LC		N1	N2	N3	N4	N5	N6	N7	N8
kips	KN								
0.18	0.80	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
21.42	95.29	-0.000002	-0.000002	-0.000001	-0.000001	-0.000001	-0.000001	-0.000004	-0.000001
39.60	176.16	-0.000004	-0.000003	-0.000002	-0.000001	-0.000001	-0.000001	-0.000008	-0.000001
51.90	230.87	-0.000004	-0.000004	-0.000003	-0.000001	-0.000002	0.000000	-0.000012	-0.000001
63.66	283.19	-0.000005	-0.000005	-0.000005	0.000001	-0.000003	0.000001	-0.000017	0.000000
78.06	347.25	-0.000006	-0.000006	-0.000008	-0.000002	-0.000005	0.000004	-0.000021	-0.000004
91.74	408.10	-0.000018	-0.000018	-0.000001	0.000027	-0.000003	0.000005	-0.000024	-0.000003
105.19	467.89	-0.000021	-0.000020	-0.000003	0.000026	-0.000003	0.000005	-0.000028	-0.000003
118.87	528.74	-0.000020	-0.000018	-0.000001	-0.000003	0.000002	0.000000	-0.000027	0.000000
132.79	590.66	-0.000022	-0.000020	-0.000001	-0.000004	0.000002	0.000004	-0.000031	-0.000002
147.79	657.39	-0.000023	-0.000022	-0.000001	-0.000003	0.000004	0.000005	-0.000031	0.000000
162.49	722.78	-0.000014	-0.000013	0.000010	0.000008	0.000019	0.000024	-0.000018	0.000009
176.65	785.77	0.000073	0.000074	0.000048	0.000093	0.000013	0.000032	0.000312	0.000159
189.85	844.49	0.000065	0.000065	0.000042	0.000142	0.000005	0.000181	0.000531	0.000253
204.31	908.82	0.000106	0.000107	0.000132	0.000366	0.000357	0.000615	0.000788	0.000460
216.85	964.60	0.000151	0.000152	0.000190	0.000439	0.000475	0.000774	0.000858	0.000511
231.13	1028.12	0.000186	0.000187	0.000242	0.000511	0.000592	0.000855	0.000905	0.000567
246.01	1094.32	0.000223	0.000224	0.000290	0.000584	0.000697	0.000947	0.000976	0.000631
259.45	1154.10	0.000258	0.000260	0.000331	0.000655	0.000778	0.001002	0.001037	0.000701
251.47	1118.61	0.000326	0.000327	0.000335	0.000721	0.000772	0.001012	0.001024	0.000794
266.23	1184.26	0.000352	0.000353	0.000369	0.000759	0.000833	0.001074	0.001084	0.000836
279.31	1242.45	0.000383	0.000383	0.000401	0.000810	0.000889	0.001131	0.001144	0.000885
297.67	1324.12	0.000419	0.000419	0.000441	0.000868	0.000956	0.001200	0.001211	0.000940



West View

(All Dimensions are in mm)

Fig. A.3.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D1-North End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.3.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D1-North End Testing (Labib 2012) (Cont'd)

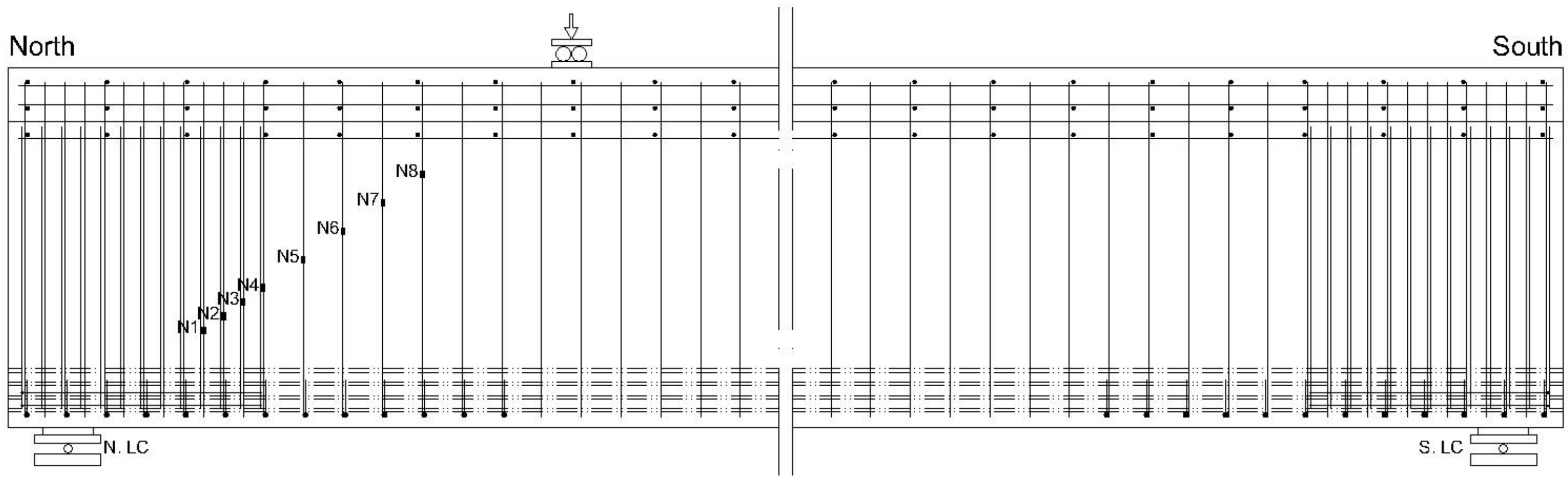


Fig. A.3.5 West View- Layout of Strain Gauges on Transverse Reinforcement for Girder D1-North End Testing (Labib 2012)

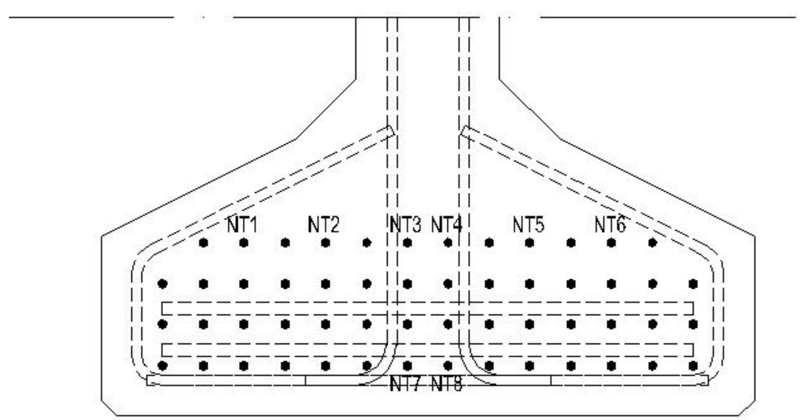


Fig. A.3.6 LVDTs Names on Selected Tendons of Girder D1-North End Testing (Labib 2012)

Table A.3.7 Measurements of Load and Deflection Relationships of Girder D1 – North End Testing (Labib 2012)

N. LC		S. LC		NW Def.		NE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
1.80	8.01	0.00	0.00	-0.001	-0.02	0.001	0.03	-0.004	-0.11	-0.008	-0.20	0.002	0.04	0.000	0.00
30.90	137.46	13.32	59.25	0.027	0.69	0.022	0.55	0.014	0.36	0.026	0.66	0.010	0.24	0.000	0.00
45.96	204.45	20.04	89.14	0.038	0.96	0.031	0.80	0.021	0.52	0.038	0.95	0.013	0.34	0.000	0.00
62.28	277.05	27.48	122.24	0.049	1.23	0.041	1.03	0.025	0.64	0.046	1.18	0.017	0.44	0.000	0.00
64.50	286.92	29.22	129.98	0.052	1.32	0.044	1.11	0.027	0.68	0.049	1.25	0.019	0.48	0.000	0.00
88.74	394.75	39.84	177.22	0.064	1.62	0.054	1.38	0.031	0.79	0.057	1.46	0.024	0.60	0.000	0.00
130.27	579.45	58.80	261.56	0.084	2.13	0.073	1.85	0.039	1.00	0.072	1.83	0.030	0.76	0.000	0.00
175.09	778.83	78.90	350.96	0.106	2.70	0.090	2.28	0.045	1.13	0.082	2.08	0.037	0.95	0.000	0.00
198.73	883.99	89.82	399.54	0.130	3.31	0.094	2.38	0.041	1.04	0.075	1.91	0.051	1.30	0.000	0.00
235.81	1048.94	106.80	475.07	0.153	3.90	0.102	2.59	0.041	1.04	0.075	1.91	0.061	1.55	0.000	0.00
281.65	1252.86	127.68	567.95	0.180	4.58	0.117	2.97	0.043	1.10	0.079	2.01	0.069	1.76	0.000	0.00
327.26	1455.71	148.38	660.03	0.208	5.27	0.135	3.43	0.048	1.22	0.088	2.23	0.075	1.91	0.000	0.00
369.68	1644.41	167.82	746.50	0.233	5.93	0.153	3.89	0.053	1.34	0.097	2.45	0.080	2.02	0.000	0.00
402.92	1792.28	183.18	814.83	0.254	6.46	0.168	4.27	0.056	1.43	0.103	2.62	0.082	2.10	0.000	0.00
450.44	2003.67	205.20	912.78	0.283	7.19	0.189	4.81	0.062	1.57	0.113	2.88	0.086	2.18	0.000	0.00
496.10	2206.78	226.44	1007.26	0.313	7.95	0.212	5.38	0.068	1.72	0.124	3.15	0.089	2.25	0.000	0.00
545.31	2425.65	249.06	1107.87	0.346	8.79	0.236	5.99	0.074	1.88	0.136	3.44	0.092	2.33	0.000	0.00
594.93	2646.38	269.04	1196.75	0.383	9.74	0.258	6.55	0.078	1.97	0.142	3.61	0.098	2.48	0.000	0.00
651.57	2898.34	294.90	1311.78	0.423	10.76	0.287	7.29	0.085	2.16	0.156	3.96	0.101	2.57	0.000	0.00
689.37	3066.49	312.18	1388.65	0.453	11.51	0.309	7.84	0.090	2.29	0.165	4.19	0.104	2.63	0.000	0.00
716.44	3186.87	324.48	1443.36	0.476	12.10	0.326	8.28	0.094	2.39	0.173	4.39	0.106	2.68	0.000	0.00
743.86	3308.84	336.96	1498.87	0.501	12.73	0.345	8.75	0.098	2.50	0.180	4.58	0.108	2.74	0.000	0.00
779.80	3468.72	353.10	1570.67	0.554	14.06	0.382	9.71	0.108	2.75	0.199	5.05	0.111	2.82	0.000	0.00

Table A.3.8 Measurements of Tendons' slip at North End of Girder D1 – North End Testing (Labib 2012)

N. LC		NT1		NT2		NT3		NT4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.01
40.98	182.30	-0.001	-0.02	-0.001	-0.01	0.000	0.01	0.001	0.01
58.68	261.03	-0.001	-0.02	-0.001	-0.02	0.000	0.01	0.000	0.00
79.32	352.85	-0.001	-0.02	-0.001	-0.01	0.000	0.00	0.000	0.00
113.11	503.12	-0.001	-0.02	-0.001	-0.02	0.000	0.00	0.000	0.00
149.05	663.00	-0.001	-0.01	-0.001	-0.02	0.000	0.00	0.000	0.00
184.09	818.87	-0.001	-0.02	-0.001	-0.01	0.000	0.01	0.000	0.01
214.45	953.92	0.000	-0.01	-0.001	-0.02	0.000	0.01	0.001	0.01
250.39	1113.80	-0.001	-0.02	-0.001	-0.01	0.000	0.01	0.000	0.01
286.69	1275.28	-0.001	-0.02	-0.001	-0.01	0.000	-0.01	0.000	0.00
323.30	1438.09	-0.001	-0.02	-0.001	-0.01	0.000	0.00	0.000	0.00
359.00	1596.90	-0.001	-0.02	-0.001	-0.01	0.000	0.00	0.000	0.00
395.78	1760.52	-0.001	-0.02	-0.001	-0.01	0.000	0.00	0.000	0.01
433.34	1927.60	-0.001	-0.03	-0.001	-0.02	0.000	0.00	0.000	0.01
471.80	2098.69	-0.001	-0.02	-0.001	-0.02	0.000	0.00	0.000	0.01
510.27	2269.77	-0.001	-0.03	-0.001	-0.02	0.000	0.01	0.000	0.01
549.81	2445.67	-0.001	-0.03	-0.001	-0.01	0.000	0.01	0.001	0.02
613.47	2728.85	-0.001	-0.02	-0.001	-0.01	0.000	0.00	0.001	0.02
657.27	2923.70	-0.001	-0.02	-0.001	-0.02	0.000	0.00	0.001	0.02
726.10	3229.84	0.000	0.00	-0.001	-0.01	0.000	0.01	0.001	0.03
750.58	3338.74	0.001	0.02	-0.001	-0.02	0.000	0.01	0.001	0.03
777.22	3457.24	0.003	0.06	-0.001	-0.02	0.001	0.02	0.001	0.03
779.80	3468.72	0.003	0.08	0.002	0.04	0.001	0.03	0.002	0.05

Table A.3.8 Measurements of Tendons' slip at North End of Girder D1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NT5		NT6		NT7		NT8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
40.98	182.30	-0.001	-0.03	-0.002	-0.04	0.002	0.06	-0.001	-0.02
58.68	261.03	-0.001	-0.03	-0.002	-0.05	0.002	0.06	0.000	-0.01
79.32	352.85	-0.001	-0.03	-0.002	-0.04	0.002	0.05	-0.001	-0.02
113.11	503.12	-0.001	-0.03	-0.002	-0.04	0.002	0.04	-0.001	-0.02
149.05	663.00	-0.001	-0.03	-0.002	-0.04	0.002	0.06	0.000	-0.01
184.09	818.87	-0.001	-0.03	-0.002	-0.04	0.002	0.05	-0.001	-0.02
214.45	953.92	-0.001	-0.03	-0.002	-0.04	0.002	0.06	0.000	-0.01
250.39	1113.80	-0.001	-0.03	-0.002	-0.04	0.003	0.07	0.000	-0.01
286.69	1275.28	-0.001	-0.03	-0.002	-0.05	0.002	0.05	-0.001	-0.02
323.30	1438.09	-0.001	-0.03	-0.002	-0.05	0.002	0.05	-0.001	-0.02
359.00	1596.90	-0.001	-0.03	-0.002	-0.05	0.003	0.07	-0.001	-0.02
395.78	1760.52	-0.001	-0.03	-0.002	-0.05	0.003	0.06	-0.001	-0.02
433.34	1927.60	-0.001	-0.03	-0.002	-0.05	0.003	0.09	0.000	-0.01
471.80	2098.69	-0.001	-0.03	-0.002	-0.05	0.004	0.09	0.000	-0.01
510.27	2269.77	-0.001	-0.03	-0.002	-0.05	0.005	0.13	0.001	0.03
549.81	2445.67	-0.001	-0.03	-0.002	-0.05	0.006	0.14	0.001	0.02
613.47	2728.85	-0.001	-0.03	-0.001	-0.01	0.009	0.23	0.005	0.14
657.27	2923.70	-0.001	-0.02	0.000	0.01	0.010	0.25	0.006	0.15
726.10	3229.84	-0.001	-0.02	0.002	0.06	0.011	0.27	0.006	0.16
750.58	3338.74	0.000	0.00	0.003	0.08	0.011	0.29	0.007	0.18
777.22	3457.24	0.002	0.04	0.005	0.13	0.012	0.30	0.007	0.18
779.80	3468.72	0.005	0.12	0.008	0.19	0.012	0.31	0.008	0.19

Table A.3.9 Measurements of LVDTs for North Rosette Strains of Girder D1 – North End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
0.00	0.00	0.000006	0.000012	0.000009	-0.000008	0.000002	-0.000003
40.98	182.30	-0.000048	-0.000032	-0.000040	0.000002	-0.000012	-0.000005
58.68	261.03	-0.000046	-0.000048	-0.000047	0.000012	0.000008	0.000010
79.32	352.85	-0.000046	-0.000064	-0.000055	0.000028	0.000036	0.000032
113.11	503.12	-0.000076	-0.000108	-0.000092	0.000056	0.000070	0.000063
149.05	663.00	-0.000094	-0.000166	-0.000130	0.000104	0.000106	0.000105
184.09	818.87	-0.000156	-0.000228	-0.000192	0.000144	0.000158	0.000151
214.45	953.92	-0.000204	-0.000262	-0.000233	0.000164	0.000212	0.000188
250.39	1113.80	-0.000282	-0.000304	-0.000293	0.000218	0.000290	0.000254
286.69	1275.28	-0.000276	-0.000362	-0.000319	0.000314	0.000354	0.000334
323.30	1438.09	-0.000296	-0.000392	-0.000344	0.000416	0.000462	0.000439
359.00	1596.90	-0.000324	-0.000438	-0.000381	0.000512	0.000546	0.000529
395.78	1760.52	-0.000332	-0.000502	-0.000417	0.000628	0.000616	0.000622
433.34	1927.60	-0.000340	-0.000574	-0.000457	0.000784	0.000758	0.000771
471.80	2098.69	-0.000398	-0.000616	-0.000507	0.000938	0.000916	0.000927
510.27	2269.77	-0.000432	-0.000720	-0.000576	0.001102	0.001096	0.001099
549.81	2445.67	-0.000526	-0.000834	-0.000680	0.001266	0.001284	0.001275
613.47	2728.85	-0.000630	-0.001008	-0.000819	0.001588	0.001610	0.001599
657.27	2923.70	-0.000772	-0.001140	-0.000956	0.001880	0.001894	0.001887
726.10	3229.84	-0.000936	-0.001396	-0.001166	0.002380	0.002386	0.002383
750.58	3338.74	-0.001066	-0.001510	-0.001288	0.002594	0.002612	0.002603
777.22	3457.24	-0.001172	-0.001686	-0.001429	0.002994	0.003046	0.003020
779.80	3468.72	-0.001374	-0.001866	-0.001620	0.003296	0.003330	0.003313

Table A.3.9 Measurements of LVDTs for North Rosette Strains of Girder D1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
0.00	0.00	-0.000001	-0.000008	-0.000005	0.000000	0.000004	0.000002
40.98	182.30	0.000002	-0.000004	-0.000001	-0.000009	-0.000007	-0.000008
58.68	261.03	0.000004	0.000004	0.000004	-0.000008	-0.000007	-0.000008
79.32	352.85	0.000005	0.000008	0.000007	-0.000009	0.000014	0.000003
113.11	503.12	0.000006	0.000033	0.000020	-0.000007	0.000022	0.000008
149.05	663.00	0.000021	0.000059	0.000040	0.000033	0.000021	0.000027
184.09	818.87	0.000026	0.000104	0.000065	0.000046	0.000037	0.000042
214.45	953.92	0.000025	0.000167	0.000096	0.000043	0.000088	0.000066
250.39	1113.80	0.000022	0.000213	0.000118	0.000076	0.000140	0.000108
286.69	1275.28	0.000062	0.000272	0.000167	0.000173	0.000193	0.000183
323.30	1438.09	0.000114	0.000338	0.000226	0.000259	0.000279	0.000269
359.00	1596.90	0.000178	0.000388	0.000283	0.000374	0.000337	0.000356
395.78	1760.52	0.000253	0.000455	0.000354	0.000598	0.000440	0.000519
433.34	1927.60	0.000387	0.000585	0.000486	0.000832	0.000553	0.000693
471.80	2098.69	0.000452	0.000731	0.000592	0.001040	0.000697	0.000869
510.27	2269.77	0.000502	0.000890	0.000696	0.001241	0.000834	0.001038
549.81	2445.67	0.000548	0.001027	0.000788	0.001440	0.000986	0.001213
613.47	2728.85	0.000680	0.001257	0.000969	0.001738	0.001244	0.001491
657.27	2923.70	0.000803	0.001453	0.001128	0.002024	0.001486	0.001755
726.10	3229.84	0.001144	0.001792	0.001468	0.002443	0.001890	0.002167
750.58	3338.74	0.001334	0.001963	0.001649	0.002619	0.002077	0.002348
777.22	3457.24	0.001719	0.002405	0.002062	0.003047	0.002357	0.002702
779.80	3468.72	0.001959	0.002556	0.002258	0.003272	0.002562	0.002917

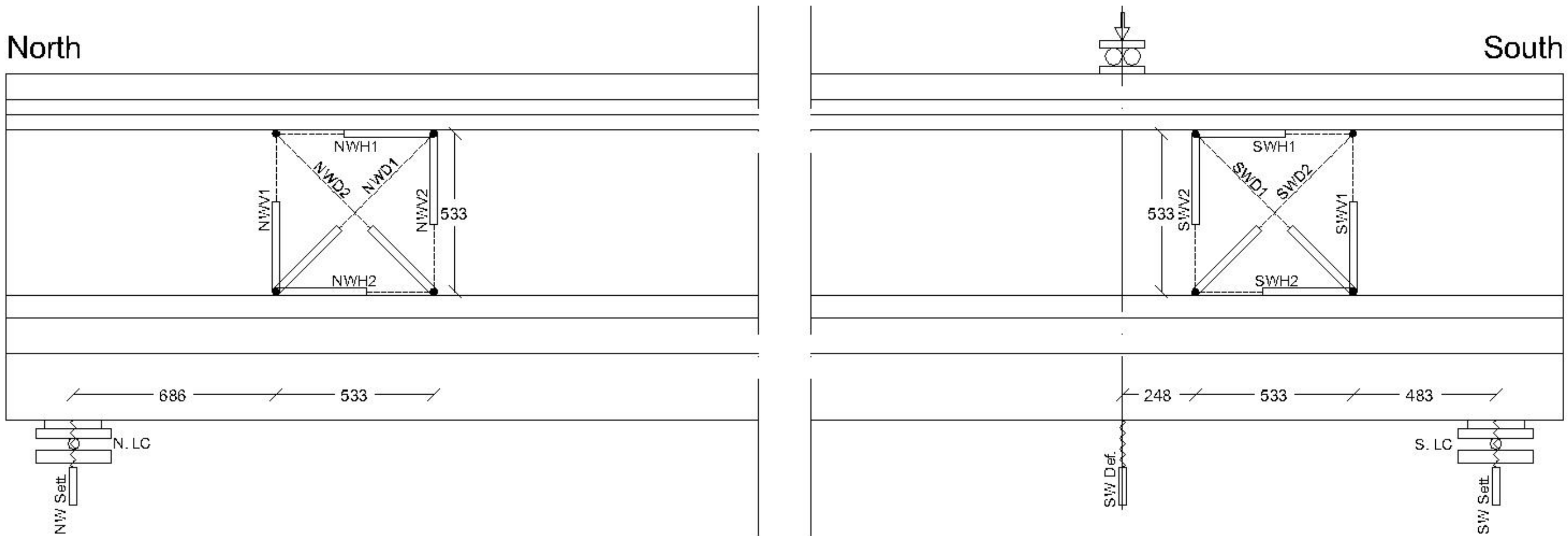
Table A.3.9 Measurements of LVDTs for North Rosette Strains of Girder D1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
0.00	0.00	-0.000001	-0.000003	-0.000002	0.000002	-0.000002	0.000000
40.98	182.30	0.000008	-0.000042	-0.000017	0.000001	-0.000003	-0.000001
58.68	261.03	0.000005	-0.000053	-0.000024	0.000002	-0.000003	0.000000
79.32	352.85	0.000001	-0.000075	-0.000037	0.000005	-0.000002	0.000002
113.11	503.12	0.000002	-0.000101	-0.000050	0.000006	-0.000005	0.000001
149.05	663.00	0.000025	-0.000126	-0.000051	0.000010	-0.000009	0.000001
184.09	818.87	0.000012	-0.000166	-0.000077	0.000010	-0.000027	-0.000009
214.45	953.92	-0.000006	-0.000189	-0.000098	0.000007	-0.000052	-0.000023
250.39	1113.80	-0.000017	-0.000213	-0.000115	-0.000003	-0.000078	-0.000041
286.69	1275.28	-0.000056	-0.000262	-0.000159	-0.000013	-0.000112	-0.000063
323.30	1438.09	-0.000072	-0.000257	-0.000165	-0.000015	-0.000134	-0.000075
359.00	1596.90	-0.000102	-0.000297	-0.000200	-0.000011	-0.000135	-0.000073
395.78	1760.52	-0.000224	-0.000380	-0.000302	-0.000015	-0.000164	-0.000090
433.34	1927.60	-0.000269	-0.000398	-0.000334	-0.000014	-0.000226	-0.000120
471.80	2098.69	-0.000312	-0.000430	-0.000371	-0.000032	-0.000286	-0.000159
510.27	2269.77	-0.000348	-0.000464	-0.000406	-0.000035	-0.000372	-0.000204
549.81	2445.67	-0.000393	-0.000491	-0.000442	-0.000035	-0.000479	-0.000257
613.47	2728.85	-0.000352	-0.000566	-0.000459	-0.000022	-0.000662	-0.000342
657.27	2923.70	-0.000388	-0.000609	-0.000499	-0.000098	-0.000765	-0.000432
726.10	3229.84	-0.000369	-0.000694	-0.000532	-0.000218	-0.000916	-0.000567
750.58	3338.74	-0.000345	-0.000741	-0.000543	-0.000364	-0.000976	-0.000670
777.22	3457.24	-0.000371	-0.000788	-0.000580	-0.000612	-0.001137	-0.000875
779.80	3468.72	-0.000400	-0.000792	-0.000596	-0.000891	-0.001238	-0.001065

Table A.3.10 Measurements of North Strain Gauges on Transverse Steel Bars of Girder D1 – North End Testing (Labib 2012)

N. LC		N1	N2	N3	N4	N5	N6	N7	N8
kips	KN								
0.00	0.00	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	-0.000007
40.98	182.30	0.000009	0.000010	0.000011	0.000008	0.000009	0.000007	-0.000003	-0.000006
58.68	261.03	0.000011	0.000011	0.000013	0.000009	0.000012	0.000006	0.000012	0.000005
79.32	352.85	0.000013	0.000013	0.000017	0.000014	0.000015	0.000010	0.000034	0.000018
113.11	503.12	0.000025	0.000025	0.000029	0.000030	0.000032	0.000042	0.000088	0.000048
149.05	663.00	0.000051	0.000051	0.000073	0.000083	0.000195	0.000133	0.000190	0.000219
184.09	818.87	0.000083	0.000083	0.000115	0.000164	0.000289	0.000245	0.000281	0.000295
214.45	953.92	0.000114	0.000114	0.000148	0.000241	0.000369	0.000344	0.000350	0.000366
250.39	1113.80	0.000149	0.000149	0.000192	0.000319	0.000454	0.000411	0.000439	0.000462
286.69	1275.28	0.000188	0.000189	0.000231	0.000393	0.000544	0.000499	0.000527	0.000531
323.30	1438.09	0.000251	0.000251	0.000284	0.000479	0.000664	0.000591	0.000630	0.000627
359.00	1596.90	0.000307	0.000307	0.000346	0.000570	0.000773	0.000697	0.000762	0.000716
395.78	1760.52	0.000363	0.000363	0.000402	0.000651	0.000870	0.000806	0.000970	0.000863
433.34	1927.60	0.000437	0.000437	0.000467	0.000727	0.000977	0.000941	0.001147	0.000990
471.80	2098.69	0.000502	0.000502	0.000535	0.000812	0.001080	0.001133	0.001320	0.001077
510.27	2269.77	0.000558	0.000558	0.000594	0.000876	0.001186	0.001297	0.001502	0.001222
549.81	2445.67	0.000637	0.000637	0.000667	0.000942	0.001321	0.001478	0.001710	0.001389
613.47	2728.85	0.000784	0.000784	0.000792	0.001104	0.001593	0.001758	0.002098	0.001626
657.27	2923.70	0.000884	0.000884	0.000882	0.001251	0.001841	0.001932	0.002152	0.001769
726.10	3229.84	0.001061	0.001061	0.001022	0.001490	0.002203	A.G.	0.002752	A.G.
750.58	3338.74	0.001143	0.001143	0.001090	0.001659	0.002355	A.G.	0.003060	A.G.
777.22	3457.24	0.001264	0.001264	0.001189	0.001856	A.G.	A.G.	A.G.	A.G.
779.80	3468.72	0.001367	0.001368	0.001228	0.001964	A.G.	A.G.	A.G.	A.G.

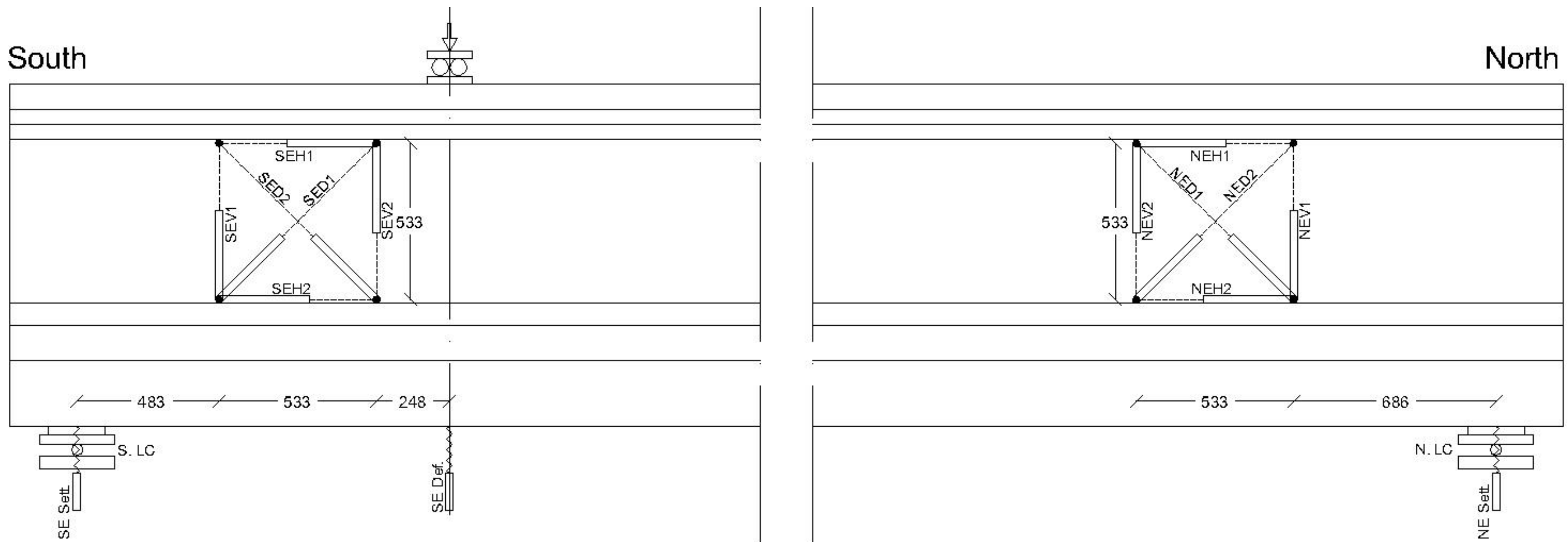
Experimental Data of Girder D2



West View

(All Dimensions are in mm)

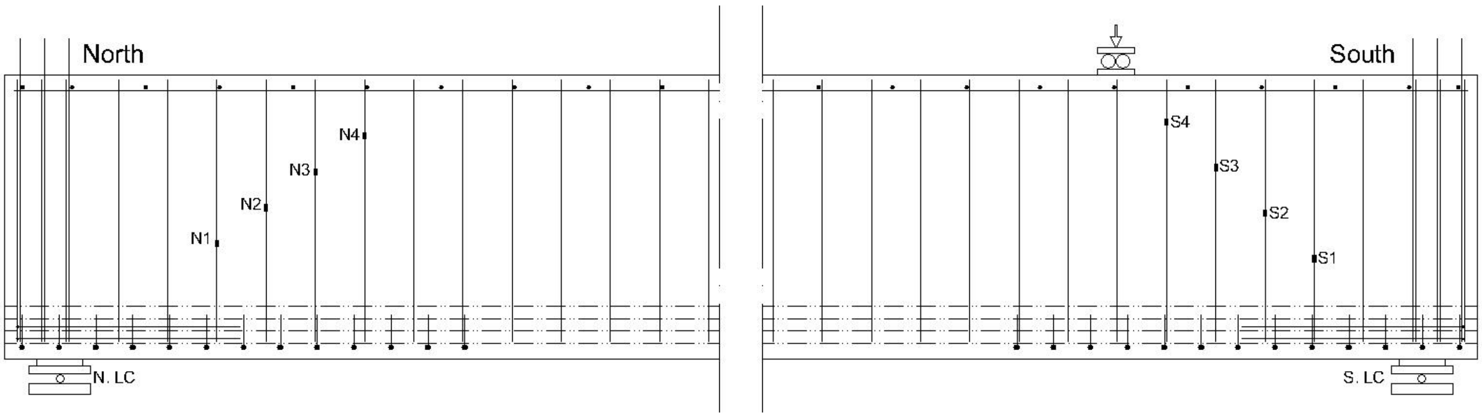
Fig. A.4.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D2-South End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.4.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D2-South End Testing (Labib 2012) (Cont'd)



West View

Fig. A.4.2 Layout of Strain Gauges on Transverse Reinforcement for Girder D2-South End Testing (Labib 2012)

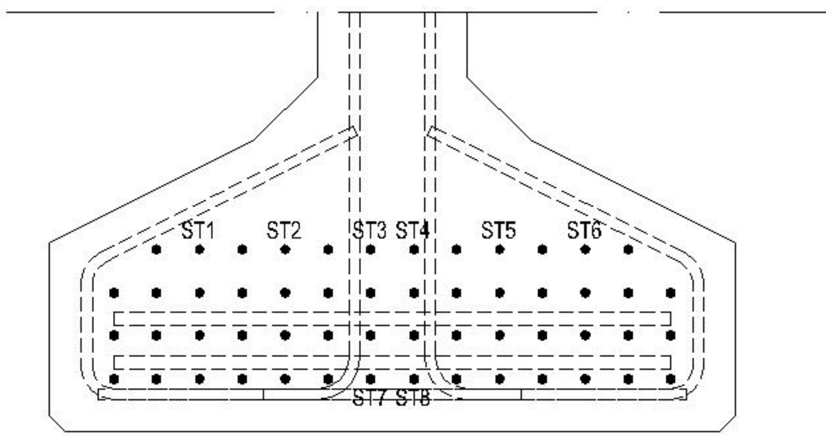


Fig. A.4.3 LVDTs Names on Selected Tendons of Girder D2-South End Testing (Labib 2012)

Table A.4.1 Measurements of Load and Deflection Relationships of Girder D2 – South End Testing (Labib 2012)

N. LC		S. LC		SW Def.		SE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
40.53	180.29	141.72	630.40	0.075	1.90	0.118	3.01	0.009	0.23	0.022	0.55	0.040	1.01	0.094	2.38
55.32	246.09	193.44	860.46	0.100	2.54	0.149	3.77	0.011	0.29	0.035	0.89	0.050	1.28	0.110	2.80
68.02	302.58	237.84	1057.97	0.120	3.04	0.171	4.34	0.013	0.33	0.043	1.08	0.058	1.48	0.121	3.08
83.41	371.05	291.66	1297.37	0.143	3.63	0.193	4.91	0.015	0.39	0.049	1.25	0.067	1.71	0.131	3.32
95.98	426.92	335.58	1492.73	0.167	4.25	0.215	5.47	0.017	0.44	0.052	1.33	0.075	1.91	0.136	3.45
112.04	498.37	391.74	1742.55	0.194	4.93	0.240	6.09	0.019	0.49	0.056	1.42	0.084	2.13	0.143	3.63
109.09	485.24	381.42	1696.64	0.197	5.00	0.242	6.16	0.020	0.50	0.056	1.43	0.085	2.16	0.144	3.66
112.59	500.81	393.66	1751.09	0.201	5.10	0.246	6.24	0.020	0.50	0.057	1.44	0.086	2.19	0.144	3.66
120.45	535.77	421.14	1873.32	0.212	5.39	0.257	6.52	0.020	0.52	0.057	1.44	0.090	2.28	0.147	3.73
127.52	567.22	445.86	1983.28	0.223	5.67	0.268	6.80	0.021	0.53	0.059	1.49	0.093	2.36	0.151	3.83
134.35	597.60	469.74	2089.51	0.234	5.95	0.279	7.09	0.022	0.55	0.060	1.52	0.096	2.44	0.154	3.91
140.57	625.31	491.52	2186.39	0.245	6.21	0.289	7.35	0.022	0.56	0.061	1.56	0.099	2.52	0.157	3.99
147.39	655.61	515.34	2292.35	0.256	6.50	0.301	7.65	0.023	0.58	0.062	1.58	0.102	2.60	0.161	4.08
153.91	684.62	538.14	2393.77	0.268	6.79	0.313	7.94	0.023	0.59	0.064	1.62	0.106	2.68	0.164	4.17
159.91	711.33	559.14	2487.18	0.279	7.09	0.324	8.23	0.024	0.61	0.065	1.64	0.108	2.75	0.167	4.25
165.46	735.99	578.52	2573.39	0.290	7.37	0.335	8.52	0.024	0.62	0.065	1.66	0.111	2.83	0.170	4.33
171.22	761.64	598.68	2663.06	0.303	7.70	0.349	8.86	0.025	0.63	0.066	1.68	0.115	2.91	0.173	4.40
177.04	787.51	619.02	2753.54	0.316	8.03	0.362	9.20	0.025	0.64	0.067	1.71	0.117	2.98	0.177	4.49
182.31	810.95	637.44	2835.47	0.329	8.35	0.376	9.55	0.025	0.64	0.069	1.74	0.120	3.05	0.180	4.57
186.67	830.33	652.68	2903.27	0.344	8.73	0.391	9.92	0.026	0.65	0.069	1.74	0.124	3.15	0.182	4.63
192.69	857.13	673.74	2996.95	0.369	9.36	0.417	10.59	0.026	0.66	0.069	1.75	0.129	3.29	0.188	4.78
192.48	856.21	673.02	2993.74	0.371	9.42	0.419	10.65	0.026	0.66	0.069	1.75	0.130	3.30	0.189	4.80

Table A.4.2 Measurements of Tendons' slip at South End of Girder D2 – South End Testing (Labib 2012)

S. LC		ST1		ST2		ST3		ST4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.18	0.80	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
12.42	55.25	0.000	0.00	0.000	0.01	0.001	0.01	0.000	0.01
21.60	96.08	0.000	0.00	0.000	0.00	0.001	0.01	0.000	0.01
57.36	255.15	0.000	0.00	0.000	0.01	0.000	0.01	0.001	0.01
115.50	513.77	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
176.22	783.87	0.000	0.00	0.000	0.01	0.001	0.01	0.000	0.01
235.44	1047.29	0.000	0.00	0.000	0.01	0.000	0.01	0.001	0.02
298.62	1328.33	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
359.88	1600.83	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
393.84	1751.89	0.000	0.00	0.000	0.01	0.001	0.03	0.001	0.03
399.78	1778.31	0.000	0.00	0.000	0.01	0.001	0.03	0.001	0.04
431.34	1918.70	0.001	0.01	0.000	0.01	0.001	0.03	0.007	0.17
459.84	2045.47	0.001	0.03	0.001	0.01	0.001	0.03	0.011	0.28
486.36	2163.44	0.002	0.05	0.000	0.01	0.002	0.05	0.015	0.39
513.66	2284.87	0.003	0.07	0.001	0.02	0.003	0.09	0.019	0.48
540.60	2404.71	0.003	0.08	0.004	0.11	0.007	0.18	0.022	0.56
566.94	2521.87	0.004	0.11	0.009	0.23	0.010	0.25	0.025	0.64
589.08	2620.36	0.006	0.16	0.013	0.34	0.013	0.34	0.029	0.73
613.38	2728.45	0.008	0.21	0.017	0.43	0.016	0.41	0.032	0.81
636.72	2832.27	0.011	0.28	0.021	0.53	0.020	0.50	0.036	0.92
657.06	2922.75	0.015	0.39	0.027	0.69	0.026	0.65	0.044	1.13
673.74	2996.95	0.021	0.53	0.036	0.92	0.036	0.91	0.055	1.39
630.00	2802.38	0.465	11.82	0.203	5.16	0.478	12.14	0.493	12.52

Table A.4.2 Measurements of Tendons' slip at South End of Girder D2 – South End Testing (Labib 2012) (Cont'd)

S. LC		ST5		ST6		ST7		ST8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.18	0.80	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
12.42	55.25	0.000	0.01	0.000	0.00	-0.001	-0.02	-0.001	-0.02
21.60	96.08	0.000	0.01	0.000	0.00	-0.001	-0.02	-0.001	-0.03
57.36	255.15	0.001	0.02	0.000	0.01	0.000	-0.01	0.000	-0.01
115.50	513.77	0.001	0.02	0.000	0.00	-0.001	-0.02	-0.001	-0.02
176.22	783.87	0.002	0.04	0.000	0.00	-0.001	-0.02	-0.001	-0.03
235.44	1047.29	0.002	0.04	0.000	0.00	-0.001	-0.02	-0.001	-0.02
298.62	1328.33	0.002	0.04	0.000	0.01	-0.001	-0.02	-0.001	-0.03
359.88	1600.83	0.001	0.04	0.000	0.01	-0.001	-0.02	-0.001	-0.02
393.84	1751.89	0.001	0.04	0.001	0.02	0.000	-0.01	-0.001	-0.01
399.78	1778.31	0.002	0.04	0.001	0.02	-0.001	-0.03	-0.001	-0.03
431.34	1918.70	0.002	0.04	0.001	0.03	-0.001	-0.02	-0.001	-0.03
459.84	2045.47	0.002	0.04	0.002	0.05	-0.001	-0.02	0.000	0.00
486.36	2163.44	0.002	0.04	0.003	0.07	0.000	-0.01	0.000	0.01
513.66	2284.87	0.002	0.05	0.003	0.08	0.000	-0.01	0.001	0.03
540.60	2404.71	0.003	0.08	0.004	0.10	0.000	-0.01	0.002	0.04
566.94	2521.87	0.005	0.13	0.005	0.13	0.000	0.00	0.002	0.05
589.08	2620.36	0.007	0.18	0.007	0.17	0.001	0.02	0.002	0.06
613.38	2728.45	0.009	0.24	0.009	0.23	0.001	0.03	0.003	0.06
636.72	2832.27	0.012	0.30	0.012	0.30	0.002	0.04	0.003	0.08
657.06	2922.75	0.015	0.39	0.016	0.40	0.003	0.07	0.004	0.11
673.74	2996.95	0.019	0.49	0.022	0.55	0.005	0.13	0.007	0.17
630.00	2802.38	0.279	7.08	0.500	12.71	0.474	12.04	0.516	13.10

Table A.4.3 Measurements of LVDTs for South Rosette Strains of Girder D2 – South End Testing (Labib 2012)

S. LC		SED1	SWD1	SD1 AVG	SED2	SWD2	SD2 AVG
kips	KN						
0.18	0.80	0.000003	-0.000001	0.000001	0.000013	-0.000001	0.000006
12.42	55.25	-0.000002	0.000001	-0.000001	-0.000015	0.000000	-0.000008
21.60	96.08	-0.000014	0.000000	-0.000007	-0.000010	0.000003	-0.000004
57.36	255.15	-0.000052	-0.000021	-0.000037	-0.000015	0.000002	-0.000007
115.50	513.77	-0.000113	-0.000067	-0.000090	0.000006	0.000016	0.000011
176.22	783.87	-0.000174	-0.000119	-0.000147	0.000037	0.000042	0.000039
235.44	1047.29	-0.000221	-0.000183	-0.000202	0.000063	0.000071	0.000067
298.62	1328.33	-0.000281	-0.000240	-0.000261	0.000102	0.000122	0.000112
359.88	1600.83	-0.000302	-0.000357	-0.000330	0.000464	0.000524	0.000494
393.84	1751.89	-0.000524	-0.000382	-0.000453	0.000943	0.000942	0.000943
399.78	1778.31	-0.000524	-0.000382	-0.000453	0.000958	0.000957	0.000958
431.34	1918.70	-0.000614	-0.000436	-0.000525	0.001163	0.001138	0.001151
459.84	2045.47	-0.000708	-0.000488	-0.000598	0.001349	0.001320	0.001335
486.36	2163.44	-0.000803	-0.000539	-0.000671	0.001543	0.001500	0.001522
513.66	2284.87	-0.000901	-0.000605	-0.000753	0.001754	0.001702	0.001728
540.60	2404.71	-0.001016	-0.000702	-0.000859	0.001968	0.001931	0.001950
566.94	2521.87	-0.001147	-0.000934	-0.001041	0.002217	0.002156	0.002187
589.08	2620.36	-0.001266	-0.001234	-0.001250	0.002510	0.002409	0.002460
613.38	2728.45	-0.001382	-0.001532	-0.001457	0.002805	0.002656	0.002731
636.72	2832.27	-0.001479	-0.001873	-0.001676	0.003154	0.003007	0.003081
657.06	2922.75	-0.001569	-0.002055	-0.001812	0.003597	0.003482	0.003540
673.74	2996.95	-0.001859	-0.002323	-0.002091	0.004249	0.004092	0.004171
630.00	2802.38	-0.002774	-0.002648	-0.002711	0.005428	0.005348	0.005388

Table A.4.3 Measurements of LVDTs for South Rosette Strains of Girder D2 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEV1	SWV1	SV1 AVG	SEV2	SWV2	SV2 AVG
kips	KN						
0.18	0.80	0.000004	0.000000	0.000002	MF.	-0.000007	-0.000007
12.42	55.25	0.000002	0.000000	0.000001	MF.	-0.000006	-0.000006
21.60	96.08	-0.000004	-0.000001	-0.000003	MF.	-0.000006	-0.000006
57.36	255.15	-0.000015	-0.000002	-0.000009	MF.	0.000001	0.000001
115.50	513.77	-0.000027	-0.000002	-0.000015	MF.	0.000017	0.000017
176.22	783.87	-0.000040	-0.000004	-0.000022	MF.	0.000034	0.000034
235.44	1047.29	-0.000048	-0.000002	-0.000025	MF.	0.000035	0.000035
298.62	1328.33	-0.000050	-0.000002	-0.000026	MF.	0.000041	0.000041
359.88	1600.83	0.000125	0.000039	0.000082	MF.	0.000442	0.000442
393.84	1751.89	0.000579	0.000745	0.000662	MF.	0.000606	0.000606
399.78	1778.31	0.000635	0.000797	0.000716	MF.	0.000598	0.000598
431.34	1918.70	0.000861	0.001061	0.000961	MF.	0.000595	0.000595
459.84	2045.47	0.001061	0.001358	0.001210	MF.	0.000625	0.000625
486.36	2163.44	0.001281	0.001635	0.001458	MF.	0.000646	0.000646
513.66	2284.87	0.001504	0.001908	0.001706	MF.	0.000682	0.000682
540.60	2404.71	0.001723	0.002218	0.001971	MF.	0.000741	0.000741
566.94	2521.87	0.001973	0.002506	0.002240	MF.	0.000852	0.000852
589.08	2620.36	0.002286	0.002792	0.002539	MF.	0.000923	0.000923
613.38	2728.45	0.002607	0.003102	0.002855	MF.	0.001020	0.001020
636.72	2832.27	0.003015	0.003502	0.003259	MF.	0.001452	0.001452
657.06	2922.75	0.003947	0.004119	0.004033	MF.	0.002185	0.002185
673.74	2996.95	0.004547	0.004950	0.004749	MF.	0.002824	0.002824
630.00	2802.38	0.005762	0.006609	0.006186	MF.	0.004862	0.004862

Table A.4.3 Measurements of LVDTs for South Rosette Strains of Girder D2 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEH1	SWH1	SH1 AVG	SEH2	SWH2	SH2 AVG
kips	KN						
0.18	0.80	0.000000	0.000004	0.000002	0.000000	0.000000	0.000000
12.42	55.25	0.000000	0.000006	0.000003	0.000002	0.000000	0.000001
21.60	96.08	0.000000	0.000004	0.000002	0.000002	0.000000	0.000001
57.36	255.15	-0.000025	-0.000002	-0.000014	0.000002	-0.000006	-0.000002
115.50	513.77	-0.000050	-0.000014	-0.000032	0.000000	-0.000020	-0.000010
176.22	783.87	-0.000073	-0.000049	-0.000061	0.000000	-0.000032	-0.000016
235.44	1047.29	-0.000088	-0.000085	-0.000087	-0.000004	-0.000037	-0.000020
298.62	1328.33	-0.000108	-0.000121	-0.000115	-0.000004	-0.000039	-0.000021
359.88	1600.83	-0.000110	-0.000167	-0.000139	-0.000006	0.000078	0.000036
393.84	1751.89	0.000008	-0.000167	-0.000080	-0.000006	-0.000026	-0.000016
399.78	1778.31	0.000019	-0.000161	-0.000071	-0.000008	-0.000041	-0.000025
431.34	1918.70	0.000088	-0.000141	-0.000027	-0.000008	-0.000071	-0.000040
459.84	2045.47	0.000148	-0.000073	0.000037	-0.000010	-0.000121	-0.000065
486.36	2163.44	0.000212	0.000008	0.000110	-0.000014	-0.000172	-0.000093
513.66	2284.87	0.000285	0.000058	0.000172	-0.000016	-0.000215	-0.000116
540.60	2404.71	0.000354	0.000111	0.000233	-0.000016	-0.000262	-0.000139
566.94	2521.87	0.000454	0.000121	0.000288	-0.000018	-0.000318	-0.000168
589.08	2620.36	0.000586	0.000137	0.000362	-0.000020	-0.000379	-0.000200
613.38	2728.45	0.000722	0.000151	0.000437	-0.000022	-0.000431	-0.000227
636.72	2832.27	0.000914	0.000195	0.000555	-0.000022	-0.000490	-0.000256
657.06	2922.75	0.001121	0.000369	0.000745	-0.000024	-0.000570	-0.000297
673.74	2996.95	0.001443	0.000861	0.001152	-0.000026	-0.000632	-0.000329
630.00	2802.38	0.001680	0.001679	0.001680	-0.000026	-0.001561	-0.000793

Table A.4.4 Measurements of LVDTs for North Rosette Strains of Girder D2 – South End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
0.05	0.23	0.000003	0.000009	0.000006	0.000000	0.000006	0.000003
3.55	15.80	0.000000	-0.000011	-0.000006	-0.000001	0.000028	0.000013
6.18	27.48	0.000000	-0.000011	-0.000006	-0.000001	-0.000017	-0.000009
16.40	72.97	-0.000003	-0.000005	-0.000004	0.000001	-0.000008	-0.000004
33.03	146.94	-0.000011	-0.000008	-0.000010	0.000000	-0.000011	-0.000006
50.40	224.19	-0.000020	-0.000011	-0.000016	0.000000	0.000008	0.000004
67.34	299.52	-0.000037	0.000003	-0.000017	0.000001	0.000025	0.000013
85.41	379.90	-0.000045	-0.000005	-0.000025	0.000001	0.000023	0.000012
102.93	457.84	-0.000059	-0.000031	-0.000045	0.000003	0.000011	0.000007
112.64	501.04	-0.000068	-0.000051	-0.000060	0.000005	0.000025	0.000015
114.34	508.60	-0.000068	-0.000040	-0.000054	0.000003	0.000028	0.000015
123.36	548.75	-0.000073	-0.000054	-0.000064	0.000005	0.000028	0.000016
131.51	585.00	-0.000079	-0.000060	-0.000070	0.000007	0.000008	0.000007
139.10	618.74	-0.000085	-0.000074	-0.000080	0.000007	-0.000006	0.000000
146.91	653.47	-0.000090	-0.000077	-0.000084	0.000009	-0.000006	0.000001
154.61	687.75	-0.000099	-0.000094	-0.000097	0.000016	0.000014	0.000015
162.14	721.26	-0.000104	-0.000094	-0.000099	0.000016	0.000023	0.000020
168.48	749.42	-0.000110	-0.000114	-0.000112	0.000023	0.000023	0.000023
175.43	780.34	-0.000116	-0.000112	-0.000114	0.000022	-0.000003	0.000009
182.10	810.03	-0.000121	-0.000123	-0.000122	0.000027	-0.000006	0.000010
187.92	835.91	-0.000127	-0.000117	-0.000122	0.000032	-0.000017	0.000008
192.69	857.13	-0.000147	-0.000134	-0.000141	0.000031	-0.000006	0.000012
180.18	801.48	-0.000158	-0.000189	-0.000174	0.000043	-0.000031	0.000006

Table A.4.4 Measurements of LVDTs for North Rosette Strains of Girder D2 – South End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
0.05	0.23	0.000001	-0.000006	-0.000003	0.000000	-0.000001	-0.000001
3.55	15.80	0.000000	-0.000013	-0.000007	-0.000002	-0.000003	-0.000003
6.18	27.48	0.000009	-0.000007	0.000001	-0.000004	-0.000003	-0.000004
16.40	72.97	0.000009	-0.000013	-0.000002	-0.000004	-0.000001	-0.000003
33.03	146.94	0.000000	0.000002	0.000001	-0.000003	-0.000001	-0.000002
50.40	224.19	0.000008	-0.000018	-0.000005	-0.000003	0.000008	0.000002
67.34	299.52	0.000009	-0.000002	0.000003	-0.000002	0.000019	0.000008
85.41	379.90	0.000009	-0.000015	-0.000003	-0.000003	0.000026	0.000011
102.93	457.84	0.000007	0.000006	0.000007	-0.000002	0.000026	0.000012
112.64	501.04	-0.000002	-0.000013	-0.000007	-0.000002	0.000028	0.000013
114.34	508.60	-0.000001	0.000000	0.000000	-0.000002	0.000026	0.000012
123.36	548.75	-0.000001	-0.000006	-0.000004	-0.000002	0.000030	0.000014
131.51	585.00	0.000001	-0.000004	-0.000001	-0.000002	0.000029	0.000013
139.10	618.74	0.000001	0.000003	0.000002	-0.000002	0.000030	0.000014
146.91	653.47	-0.000001	-0.000015	-0.000008	-0.000002	0.000030	0.000014
154.61	687.75	0.000000	0.000005	0.000003	-0.000002	0.000032	0.000015
162.14	721.26	0.000001	-0.000002	-0.000001	-0.000001	0.000028	0.000013
168.48	749.42	0.000000	-0.000004	-0.000002	-0.000002	0.000032	0.000015
175.43	780.34	0.000001	0.000002	0.000001	-0.000002	0.000037	0.000017
182.10	810.03	-0.000001	0.000003	0.000001	-0.000002	0.000038	0.000018
187.92	835.91	-0.000002	-0.000004	-0.000003	-0.000002	0.000039	0.000018
192.69	857.13	-0.000001	-0.000007	-0.000004	-0.000055	0.000035	-0.000010
180.18	801.48	-0.000025	-0.000019	-0.000022	-0.000036	0.000013	-0.000012

Table A.4.4 Measurements of LVDTs for North Rosette Strains of Girder D2 – South End Testing (Labib 2012) (Cont'd)

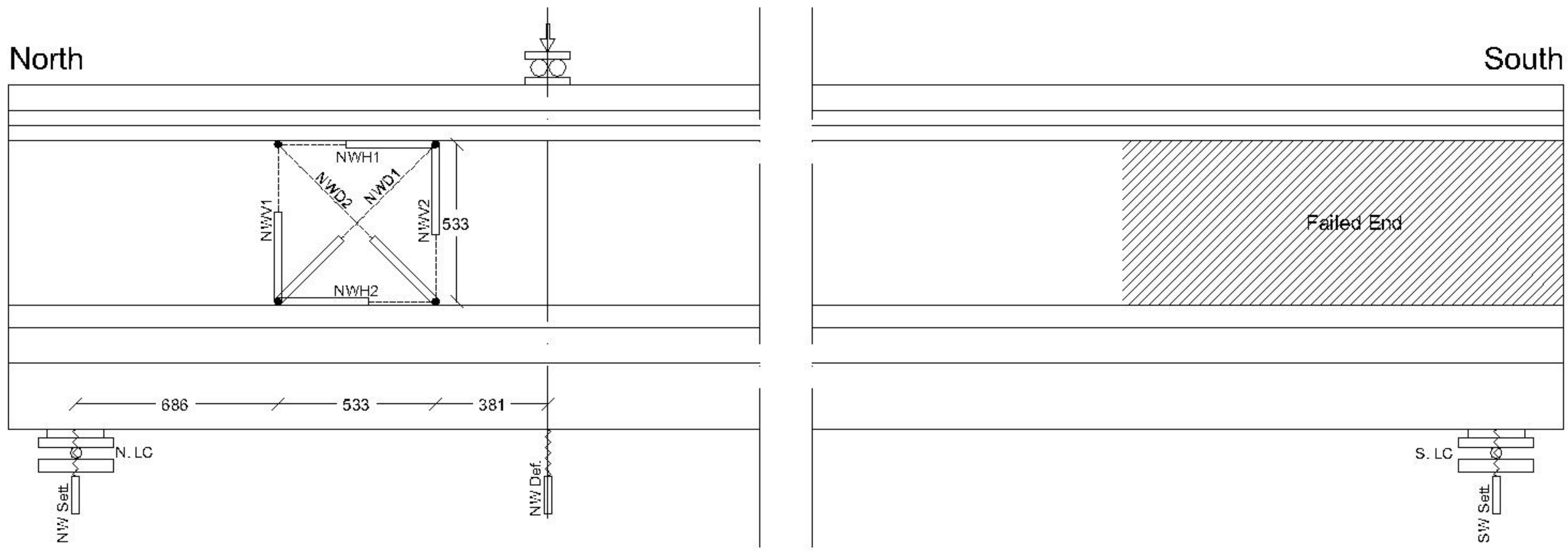
N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
0.05	0.23	-0.000004	-0.000002	-0.000003	0.000004	0.000001	0.000003
3.55	15.80	0.000008	0.000001	0.000005	0.000000	0.000003	0.000002
6.18	27.48	0.000008	0.000002	0.000005	0.000004	0.000004	0.000004
16.40	72.97	0.000008	0.000003	0.000006	-0.000004	0.000007	0.000001
33.03	146.94	-0.000004	0.000002	-0.000001	-0.000004	0.000010	0.000003
50.40	224.19	-0.000011	0.000000	-0.000005	-0.000004	0.000011	0.000003
67.34	299.52	-0.000019	0.000001	-0.000009	0.000000	0.000015	0.000007
85.41	379.90	-0.000035	-0.000005	-0.000020	-0.000004	0.000014	0.000005
102.93	457.84	-0.000051	-0.000016	-0.000033	-0.000004	0.000010	0.000003
112.64	501.04	-0.000059	-0.000035	-0.000047	0.000000	0.000009	0.000005
114.34	508.60	-0.000055	-0.000035	-0.000045	0.000000	0.000007	0.000004
123.36	548.75	-0.000063	-0.000037	-0.000050	0.000000	0.000008	0.000004
131.51	585.00	-0.000063	-0.000037	-0.000050	0.000004	0.000007	0.000006
139.10	618.74	-0.000075	-0.000053	-0.000064	0.000000	0.000003	0.000002
146.91	653.47	-0.000079	-0.000054	-0.000067	-0.000008	0.000006	-0.000001
154.61	687.75	-0.000087	-0.000064	-0.000076	-0.000008	0.000003	-0.000003
162.14	721.26	-0.000087	-0.000063	-0.000075	-0.000004	0.000004	0.000000
168.48	749.42	-0.000087	-0.000071	-0.000079	0.000004	0.000001	0.000003
175.43	780.34	-0.000091	-0.000073	-0.000082	0.000000	0.000002	0.000001
182.10	810.03	-0.000103	-0.000075	-0.000089	0.000004	0.000001	0.000003
187.92	835.91	-0.000099	-0.000074	-0.000087	0.000000	0.000001	0.000000
192.69	857.13	-0.000115	-0.000090	-0.000103	0.000000	-0.000004	-0.000002
180.18	801.48	-0.000126	-0.000146	-0.000136	0.000004	-0.000004	0.000000

Table A.4.5 Measurements of South Strain Gauges on Transverse Steel Bars of Girder D2 – South End Testing (Labib 2012)

S. LC		S1	S2	S3	S4
kips	KN				
0.18	0.80	0.000006	0.000002	0.000000	0.000006
12.42	55.25	0.000007	0.000005	-0.000024	0.000009
21.60	96.08	0.000010	0.000007	-0.000035	0.000007
57.36	255.15	0.000015	0.000009	-0.000041	0.000000
115.50	513.77	0.000019	0.000013	-0.000052	-0.000021
176.22	783.87	A.G.	0.000018	-0.000066	-0.000039
235.44	1047.29	A.G.	0.000023	-0.000079	-0.000014
298.62	1328.33	A.G.	0.000029	-0.000086	0.000012
359.88	1600.83	A.G.	0.001071	0.000080	0.000053
393.84	1751.89	A.G.	0.001407	0.000131	0.000315
399.78	1778.31	A.G.	0.001340	0.000121	0.000348
431.34	1918.70	A.G.	0.001371	0.000106	0.000458
459.84	2045.47	A.G.	0.001417	0.000093	0.000586
486.36	2163.44	A.G.	0.001488	0.000078	0.000710
513.66	2284.87	A.G.	0.001538	0.000060	0.000803
540.60	2404.71	A.G.	0.001642	0.000044	0.000911
566.94	2521.87	A.G.	0.001791	0.000130	0.001194
589.08	2620.36	A.G.	0.002195	0.000690	0.001539
613.38	2728.45	A.G.	0.002559	A.G.	0.001925
636.72	2832.27	A.G.	0.003040	A.G.	A.G.
657.06	2922.75	A.G.	0.003129	A.G.	A.G.
673.74	2996.95	A.G.	0.003165	A.G.	A.G.
630.00	2802.38	A.G.	0.004321	A.G.	A.G.

Table A.4.6 Measurements of North Strain Gauges on Transverse Steel Bars of Girder D2 – South End Testing (Labib 2012)

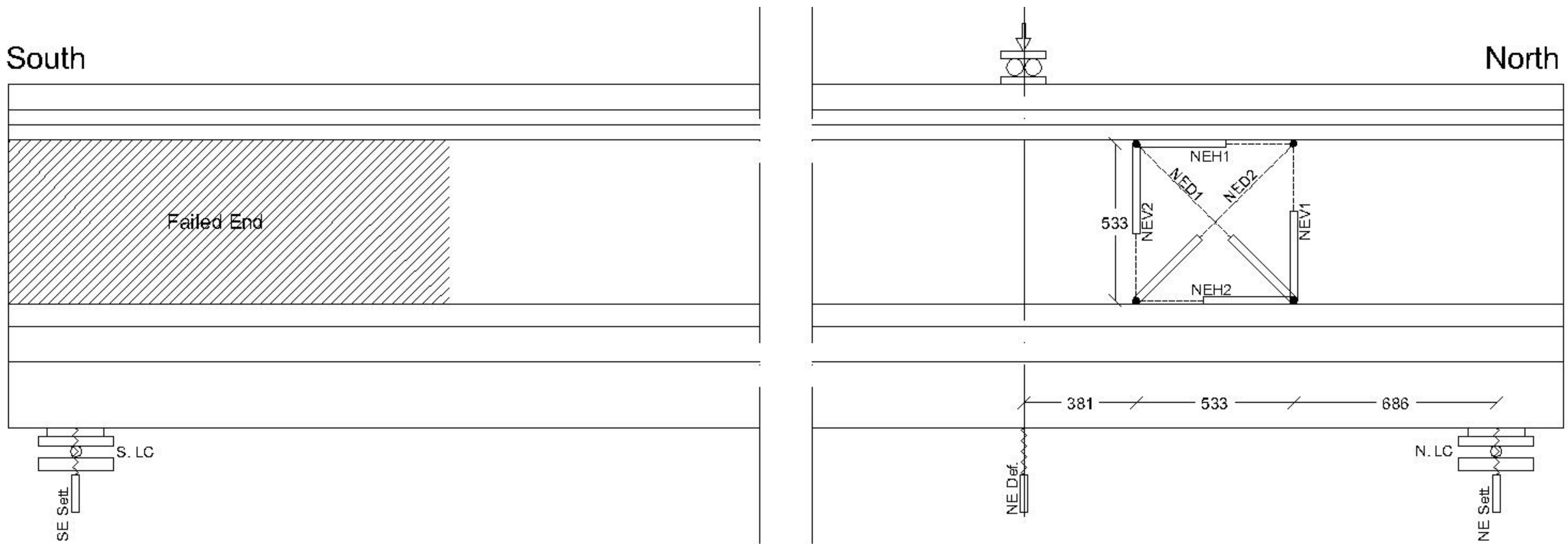
N. LC		N1	N2	N3	N4
kips	KN				
0.05	0.23	0.000027	-0.000010	0.000011	0.000009
3.55	15.80	-0.000016	0.000023	0.000006	0.000015
6.18	27.48	-0.000015	0.000025	0.000007	0.000008
16.40	72.97	-0.000015	0.000027	0.000009	0.000010
33.03	146.94	-0.000016	0.000026	0.000011	0.000011
50.40	224.19	-0.000015	0.000028	0.000017	0.000015
67.34	299.52	-0.000016	0.000027	0.000019	0.000018
85.41	379.90	-0.000017	0.000027	0.000022	0.000021
102.93	457.84	-0.000017	0.000027	0.000026	0.000024
112.64	501.04	-0.000019	0.000026	0.000028	0.000026
114.34	508.60	-0.000018	0.000027	0.000029	0.000027
123.36	548.75	-0.000019	0.000028	0.000031	0.000029
131.51	585.00	-0.000018	0.000029	0.000034	0.000032
139.10	618.74	-0.000018	0.000029	0.000035	0.000033
146.91	653.47	-0.000019	0.000029	0.000036	0.000035
154.61	687.75	-0.000019	0.000029	0.000038	0.000037
162.14	721.26	-0.000020	0.000030	0.000040	0.000038
168.48	749.42	-0.000022	0.000029	0.000041	0.000039
175.43	780.34	-0.000022	0.000030	0.000043	0.000041
182.10	810.03	-0.000023	0.000029	0.000044	0.000042
187.92	835.91	-0.000023	0.000030	0.000045	0.000044
192.69	857.13	-0.000023	0.000032	0.000047	0.000045
180.18	801.48	-0.000023	0.000032	0.000047	0.000045



West View

(All Dimensions are in mm)

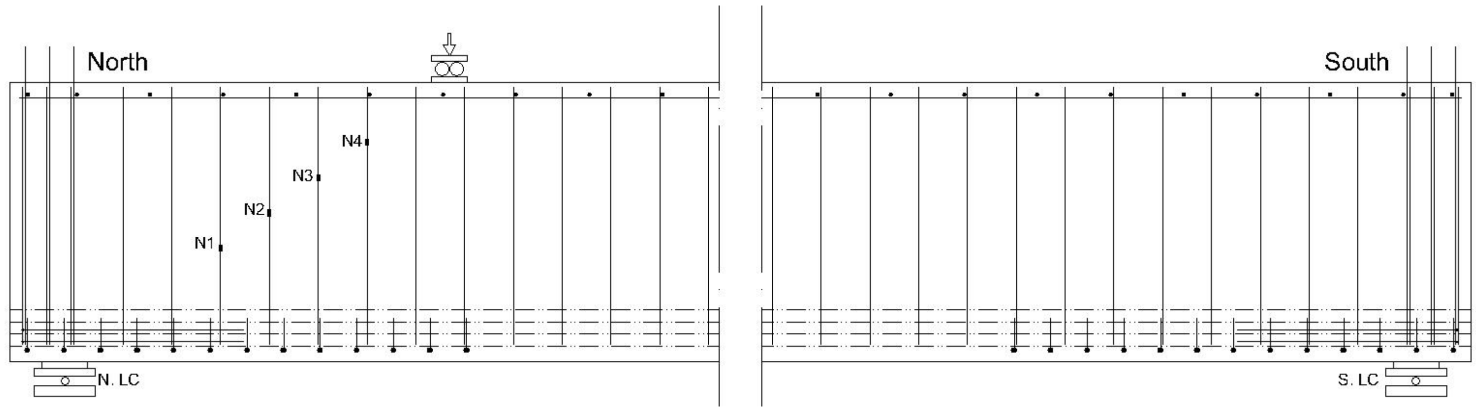
Fig. A.4.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D2-North End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.4.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder D2-North End Testing (Labib 2012) (Cont'd)



West View

Fig. A.4.5 Layout of Strain Gauges on Transverse Reinforcement for Girder D2-North End Testing (Labib 2012)

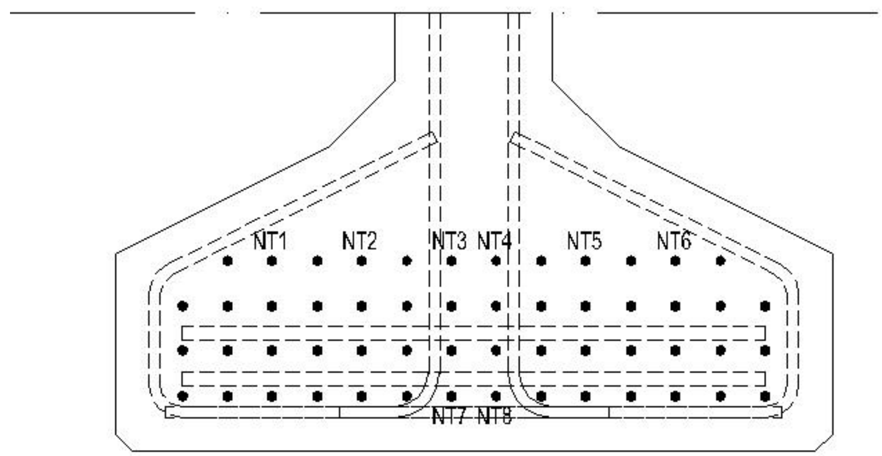


Fig. A.4.6 LVDTs Names on Selected Tendons of Girder D2-North End Testing (Labib 2012)

Table A.4.7 Measurements of Load and Deflection Relationships of Girder D2 – North End Testing (Labib 2012)

N. LC		S. LC		NW Def.		NE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	1.50	6.67	0.005	0.13	0.010	0.27	0.001	0.02	0.012	0.31	-0.001	-0.03	0.003	0.07
140.17	623.49	49.38	219.65	0.080	2.04	0.120	3.05	0.015	0.37	0.075	1.91	0.014	0.35	0.047	1.20
193.27	859.71	68.40	304.26	0.105	2.66	0.151	3.82	0.017	0.43	0.085	2.16	0.021	0.53	0.056	1.43
238.75	1062.02	84.72	376.85	0.126	3.21	0.175	4.44	0.019	0.49	0.093	2.35	0.027	0.68	0.062	1.58
276.79	1231.24	98.58	438.51	0.159	4.03	0.209	5.30	0.022	0.55	0.099	2.51	0.033	0.83	0.066	1.67
330.20	1468.79	117.84	524.18	0.191	4.86	0.243	6.17	0.025	0.63	0.108	2.75	0.039	1.00	0.069	1.76
339.92	1512.03	121.38	539.93	0.203	5.15	0.257	6.53	0.026	0.66	0.111	2.82	0.041	1.05	0.071	1.80
345.02	1534.71	125.28	557.27	0.205	5.21	0.257	6.53	0.026	0.66	0.111	2.82	0.042	1.06	0.071	1.81
367.70	1635.60	133.26	592.77	0.218	5.53	0.272	6.90	0.027	0.69	0.114	2.90	0.044	1.12	0.073	1.86
388.64	1728.75	140.70	625.86	0.230	5.85	0.285	7.25	0.028	0.71	0.118	3.00	0.046	1.17	0.075	1.90
407.90	1814.43	147.66	656.82	0.243	6.16	0.299	7.59	0.029	0.74	0.121	3.07	0.048	1.23	0.076	1.93
426.68	1897.97	154.38	686.72	0.255	6.48	0.312	7.92	0.030	0.77	0.124	3.16	0.050	1.28	0.077	1.96
444.56	1977.51	160.98	716.07	0.268	6.81	0.326	8.28	0.032	0.80	0.128	3.26	0.052	1.33	0.078	1.99
464.30	2065.32	168.18	748.10	0.282	7.15	0.340	8.63	0.033	0.83	0.131	3.33	0.055	1.39	0.079	2.00
484.10	2153.40	175.38	780.13	0.296	7.52	0.355	9.01	0.034	0.86	0.134	3.40	0.057	1.45	0.080	2.03
500.67	2227.07	181.44	807.09	0.308	7.83	0.367	9.32	0.035	0.89	0.137	3.49	0.059	1.50	0.081	2.05
519.21	2309.54	188.28	837.51	0.324	8.22	0.382	9.70	0.036	0.92	0.141	3.57	0.061	1.55	0.081	2.07
536.31	2385.61	194.52	865.27	0.339	8.61	0.398	10.10	0.037	0.95	0.143	3.64	0.063	1.60	0.082	2.09
550.59	2449.14	199.80	888.75	0.354	9.00	0.414	10.52	0.038	0.98	0.147	3.72	0.065	1.64	0.083	2.10
562.23	2500.92	204.06	907.70	0.369	9.37	0.430	10.93	0.039	1.00	0.150	3.81	0.066	1.67	0.083	2.10
568.95	2530.81	206.94	920.52	0.388	9.85	0.452	11.48	0.041	1.03	0.156	3.97	0.067	1.69	0.083	2.11
578.67	2574.05	210.54	936.53	0.403	10.24	0.469	11.92	0.042	1.06	0.159	4.04	0.067	1.71	0.084	2.13
558.21	2483.03	204.00	907.44	0.413	10.50	0.477	12.12	0.042	1.06	0.159	4.04	0.068	1.72	0.084	2.13

Table A.4.8 Measurements of Tendons' slip at North End of Girder D2 – North End Testing (Labib 2012)

N. LC		NT1		NT2		NT3		NT4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.06	0.27	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
-4.74	-21.09	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
4.86	21.62	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
15.96	71.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
23.94	106.50	0.000	0.00	0.000	0.00	0.001	0.01	0.000	0.01
61.98	275.71	0.000	0.01	0.000	0.00	0.000	0.00	0.000	0.00
135.19	601.34	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
208.63	928.03	0.000	0.01	0.000	0.00	0.000	0.00	0.000	0.00
275.89	1227.24	0.001	0.01	0.000	0.00	0.000	0.01	0.001	0.02
331.40	1474.13	0.001	0.03	0.000	0.00	0.017	0.43	0.001	0.02
324.92	1445.30	0.002	0.05	0.000	0.00	0.022	0.56	0.001	0.02
362.36	1611.85	0.002	0.05	0.000	0.01	0.024	0.61	0.001	0.02
391.34	1740.77	0.003	0.08	0.001	0.02	0.027	0.70	0.001	0.02
415.70	1849.13	0.005	0.12	0.002	0.05	0.031	0.79	0.001	0.02
443.78	1974.04	0.006	0.14	0.003	0.08	0.034	0.86	0.001	0.03
469.04	2086.41	0.007	0.19	0.006	0.14	0.038	0.96	0.005	0.14
492.32	2189.97	0.009	0.23	0.008	0.20	0.041	1.03	0.009	0.23
518.85	2307.94	0.012	0.30	0.011	0.28	0.044	1.12	0.013	0.34
541.71	2409.63	0.016	0.40	0.014	0.37	0.049	1.25	0.019	0.47
558.51	2484.37	0.020	0.52	0.018	0.46	0.056	1.42	0.024	0.60
569.97	2535.35	0.027	0.68	0.024	0.60	0.069	1.74	0.029	0.74
578.67	2574.05	0.031	0.80	0.027	0.69	0.077	1.95	0.033	0.83
577.95	2570.84	0.032	0.81	0.027	0.69	0.078	1.97	0.033	0.83

Table A.4.8 Measurements of Tendons' slip at North End of Girder D2 – North End Testing (Labib 2012) (Cont'd)

N. LC		NT5		NT6		NT7		NT8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.06	0.27	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
-4.74	-21.09	0.000	0.01	0.000	0.00	0.000	0.00	0.000	0.00
4.86	21.62	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.01
15.96	71.00	0.000	0.00	0.000	0.01	0.000	0.00	0.000	0.00
23.94	106.50	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.01
61.98	275.71	0.000	0.01	0.000	0.01	0.000	0.00	0.000	0.00
135.19	601.34	0.000	0.00	0.000	0.01	0.000	0.00	0.000	0.00
208.63	928.03	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.01
275.89	1227.24	0.000	0.01	0.000	0.01	0.000	-0.01	0.000	0.00
331.40	1474.13	0.000	0.00	0.000	0.01	0.001	0.03	0.001	0.03
324.92	1445.30	0.000	0.01	0.001	0.03	0.001	0.04	0.002	0.05
362.36	1611.85	0.000	0.01	0.002	0.04	0.001	0.04	0.002	0.06
391.34	1740.77	0.000	0.01	0.003	0.06	0.002	0.05	0.004	0.10
415.70	1849.13	0.001	0.02	0.004	0.10	0.002	0.06	0.005	0.13
443.78	1974.04	0.002	0.05	0.005	0.14	0.003	0.08	0.007	0.17
469.04	2086.41	0.003	0.07	0.007	0.18	0.004	0.09	0.008	0.21
492.32	2189.97	0.005	0.11	0.010	0.24	0.004	0.11	0.010	0.25
518.85	2307.94	0.007	0.18	0.014	0.35	0.005	0.14	0.012	0.31
541.71	2409.63	0.009	0.24	0.020	0.51	0.006	0.15	0.015	0.39
558.51	2484.37	0.012	0.31	0.026	0.65	0.007	0.18	0.020	0.50
569.97	2535.35	0.017	0.42	0.032	0.81	0.010	0.26	0.023	0.59
578.67	2574.05	0.019	0.48	0.035	0.90	0.011	0.29	0.025	0.62
577.95	2570.84	0.019	0.48	0.035	0.90	0.011	0.29	0.024	0.62

Table A.4.9 Measurements of LVDTs for North Rosette Strains of Girder D2 – North End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
0.06	0.27	0.000000	0.000006	0.000003	-0.000001	-0.000014	-0.000008
-4.74	-21.09	0.000003	0.000006	0.000005	0.000003	-0.000008	-0.000003
4.86	21.62	-0.000006	-0.000011	-0.000009	0.000003	0.000006	0.000005
15.96	71.00	-0.000006	-0.000009	-0.000008	0.000021	-0.000017	0.000002
23.94	106.50	-0.000008	-0.000006	-0.000007	0.000014	-0.000020	-0.000003
61.98	275.71	-0.000031	-0.000043	-0.000037	0.000023	0.000008	0.000016
135.19	601.34	-0.000087	-0.000109	-0.000098	0.000053	-0.000034	0.000010
208.63	928.03	-0.000133	-0.000166	-0.000150	0.000091	-0.000011	0.000040
275.89	1227.24	-0.000099	-0.000416	-0.000258	0.000772	0.000588	0.000680
331.40	1474.13	-0.000048	-0.000379	-0.000214	0.001296	0.001024	0.001160
324.92	1445.30	-0.000008	-0.000310	-0.000159	0.001486	0.001225	0.001356
362.36	1611.85	-0.000008	-0.000315	-0.000162	0.001627	0.001377	0.001502
391.34	1740.77	-0.000006	-0.000324	-0.000165	0.001882	0.001612	0.001747
415.70	1849.13	0.000000	-0.000304	-0.000152	0.002125	0.001866	0.001996
443.78	1974.04	0.000008	-0.000298	-0.000145	0.002411	0.002186	0.002299
469.04	2086.41	0.000011	-0.000301	-0.000145	0.002718	0.002475	0.002597
492.32	2189.97	0.000011	-0.000298	-0.000144	0.003000	0.002800	0.002900
518.85	2307.94	0.000008	-0.000267	-0.000130	0.003333	0.003105	0.003219
541.71	2409.63	0.000020	-0.000232	-0.000106	0.003778	0.003592	0.003685
558.51	2484.37	0.000054	-0.000209	-0.000078	0.004209	0.004061	0.004135
569.97	2535.35	0.000423	0.000284	0.000354	0.004994	0.004861	0.004928
578.67	2574.05	0.000567	0.000410	0.000489	0.005370	0.005303	0.005337
577.95	2570.84	0.000606	0.000453	0.000530	0.005447	0.005407	0.005427

Table A.4.9 Measurements of LVDTs for North Rosette Strains of Girder D2 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
Kips	KN						
0.06	0.27	-0.000001	-0.000010	-0.000006	0.000000	0.000000	0.000000
-4.74	-21.09	-0.000001	0.000012	0.000006	0.000000	-0.000010	-0.000005
4.86	21.62	-0.000001	-0.000001	-0.000001	0.000000	-0.000008	-0.000004
15.96	71.00	0.000000	0.000016	0.000008	0.000001	0.000003	0.000002
23.94	106.50	-0.000001	0.000006	0.000003	-0.000001	-0.000004	-0.000003
61.98	275.71	-0.000002	-0.000006	-0.000004	0.000010	-0.000004	0.000003
135.19	601.34	-0.000002	-0.000001	-0.000002	0.000017	-0.000007	0.000005
208.63	928.03	-0.000001	0.000001	0.000000	0.000031	-0.000014	0.000009
275.89	1227.24	0.001001	0.000948	0.000975	0.000843	0.000036	0.000440
331.40	1474.13	0.001765	0.001737	0.001751	0.001471	0.000593	0.001032
324.92	1445.30	0.002041	0.002034	0.002038	0.001698	0.000806	0.001252
362.36	1611.85	0.002235	0.002256	0.002246	0.001873	0.000975	0.001424
391.34	1740.77	0.002592	0.002671	0.002632	0.002163	0.001243	0.001703
415.70	1849.13	0.002932	0.003047	0.002990	0.002437	0.001500	0.001969
443.78	1974.04	0.003334	0.003479	0.003407	0.002752	0.001793	0.002273
469.04	2086.41	0.003768	0.003948	0.003858	0.003076	0.002114	0.002595
492.32	2189.97	0.004154	0.004367	0.004261	0.003380	0.002407	0.002894
518.85	2307.94	0.004614	0.004851	0.004733	0.003725	0.002752	0.003239
541.71	2409.63	0.005297	0.005578	0.005438	0.004249	0.003279	0.003764
558.51	2484.37	0.005884	0.006165	0.006025	0.004780	0.003799	0.004290
569.97	2535.35	0.007216	0.007685	0.007451	0.006152	0.004912	0.005532
578.67	2574.05	0.007938	0.008371	0.008155	0.006684	0.005110	0.005897
577.95	2570.84	0.008090	0.008549	0.008320	0.006891	0.005012	0.005952

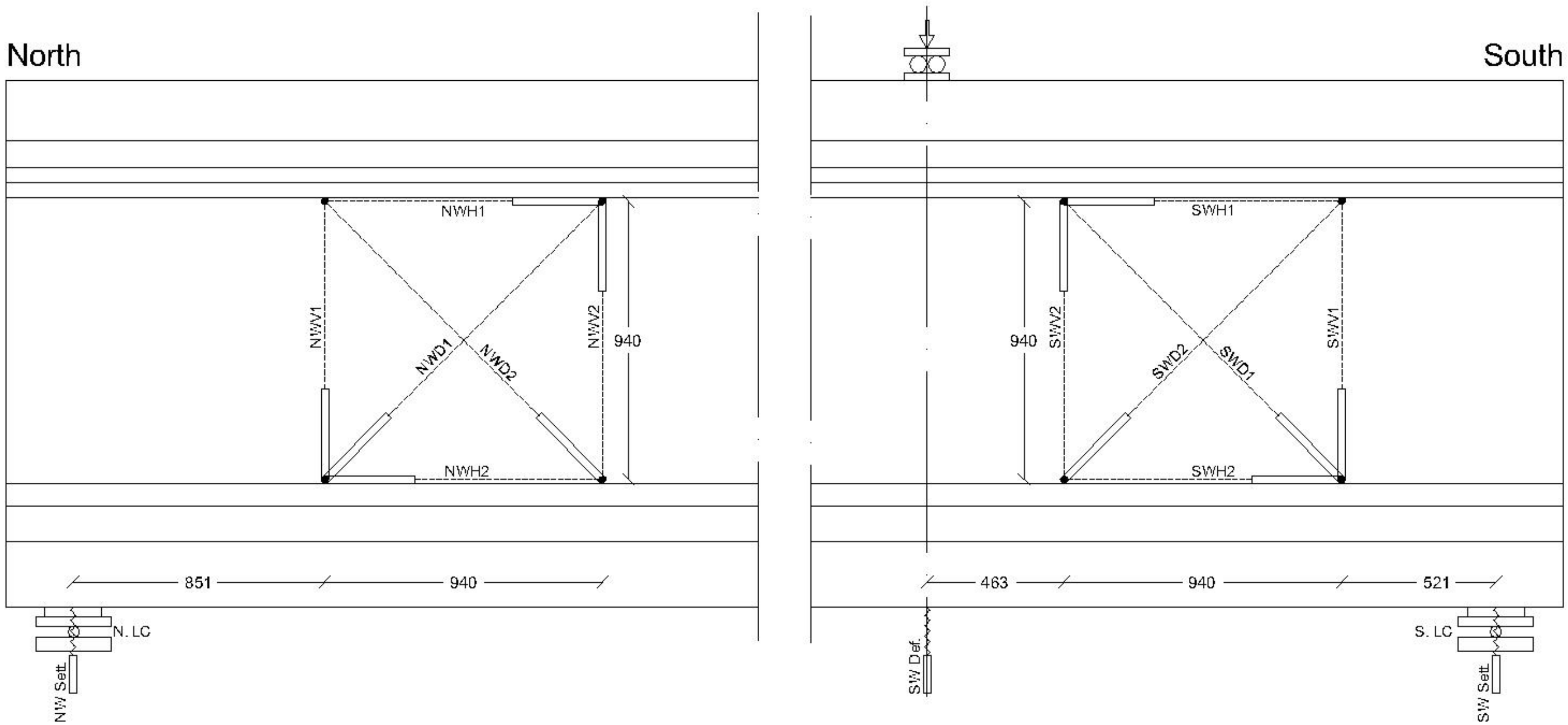
Table A.4.9 Measurements of LVDTs for North Rosette Strains of Girder D2 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
Kips	KN						
0.06	0.27	-0.000004	0.000001	-0.000002	0.000000	MF.	0.000000
-4.74	-21.09	0.000008	-0.000002	0.000003	0.000000	MF.	0.000000
4.86	21.62	0.000000	0.000002	0.000001	0.000000	MF.	0.000000
15.96	71.00	0.000012	0.000001	0.000007	-0.000004	MF.	-0.000004
23.94	106.50	0.000008	-0.000001	0.000004	0.000000	MF.	0.000000
61.98	275.71	-0.000016	-0.000002	-0.000009	0.000000	MF.	0.000000
135.19	601.34	-0.000063	-0.000061	-0.000062	0.000004	MF.	0.000004
208.63	928.03	-0.000095	-0.000104	-0.000100	0.000000	MF.	0.000000
275.89	1227.24	-0.000135	-0.000134	-0.000135	0.000004	MF.	0.000004
331.40	1474.13	-0.000214	-0.000221	-0.000218	-0.000035	MF.	-0.000035
324.92	1445.30	-0.000242	-0.000247	-0.000245	-0.000062	MF.	-0.000062
362.36	1611.85	-0.000246	-0.000258	-0.000252	-0.000066	MF.	-0.000066
391.34	1740.77	-0.000286	-0.000302	-0.000294	-0.000102	MF.	-0.000102
415.70	1849.13	-0.000325	-0.000340	-0.000333	-0.000137	MF.	-0.000137
443.78	1974.04	-0.000353	-0.000374	-0.000364	-0.000180	MF.	-0.000180
469.04	2086.41	-0.000381	-0.000399	-0.000390	-0.000223	MF.	-0.000223
492.32	2189.97	-0.000409	-0.000426	-0.000418	-0.000258	MF.	-0.000258
518.85	2307.94	-0.000436	-0.000458	-0.000447	-0.000301	MF.	-0.000301
541.71	2409.63	-0.000520	-0.000518	-0.000519	-0.000399	MF.	-0.000399
558.51	2484.37	-0.000587	-0.000606	-0.000597	-0.000415	MF.	-0.000415
569.97	2535.35	-0.000650	0.000000	-0.000717	-0.000509	MF.	-0.000509
578.67	2574.05	-0.000690	0.000000	-0.000757	-0.000583	MF.	-0.000583
577.95	2570.84	-0.000746	0.000000	-0.000813	-0.000607	MF.	-0.000607

Table A.4.10 Measurements of North Strain Gauges on Transverse Steel Bars of Girder D2 – North End Testing (Labib 2012)

N. LC		N1	N2	N3	N4
kips	KN				
0.06	0.27	-0.000001	-0.000001	-0.000003	-0.000002
-4.74	-21.09	0.000000	0.000001	-0.000007	0.000000
4.86	21.62	0.000002	0.000003	-0.000010	0.000001
15.96	71.00	0.000004	0.000005	-0.000012	0.000004
23.94	106.50	0.000024	0.000025	-0.000101	0.000076
61.98	275.71	0.000009	0.000010	-0.000003	0.000006
135.19	601.34	0.000010	0.000012	-0.000005	0.000014
208.63	928.03	0.000013	0.000015	-0.000030	0.000034
275.89	1227.24	0.000047	0.000050	-0.000272	0.000211
331.40	1474.13	0.001776	0.001827	0.001917	0.002347
324.92	1445.30	A.G.	A.G.	A.G.	A.G.
362.36	1611.85	A.G.	A.G.	A.G.	A.G.
391.34	1740.77	A.G.	A.G.	A.G.	A.G.
415.70	1849.13	A.G.	A.G.	A.G.	A.G.
443.78	1974.04	A.G.	A.G.	A.G.	A.G.
469.04	2086.41	A.G.	A.G.	A.G.	A.G.
492.32	2189.97	A.G.	A.G.	A.G.	A.G.
518.85	2307.94	A.G.	A.G.	A.G.	A.G.
541.71	2409.63	A.G.	A.G.	A.G.	A.G.
558.51	2484.37	A.G.	A.G.	A.G.	A.G.
569.97	2535.35	A.G.	A.G.	A.G.	A.G.
578.67	2574.05	A.G.	A.G.	A.G.	A.G.
577.95	2570.84	A.G.	A.G.	A.G.	A.G.

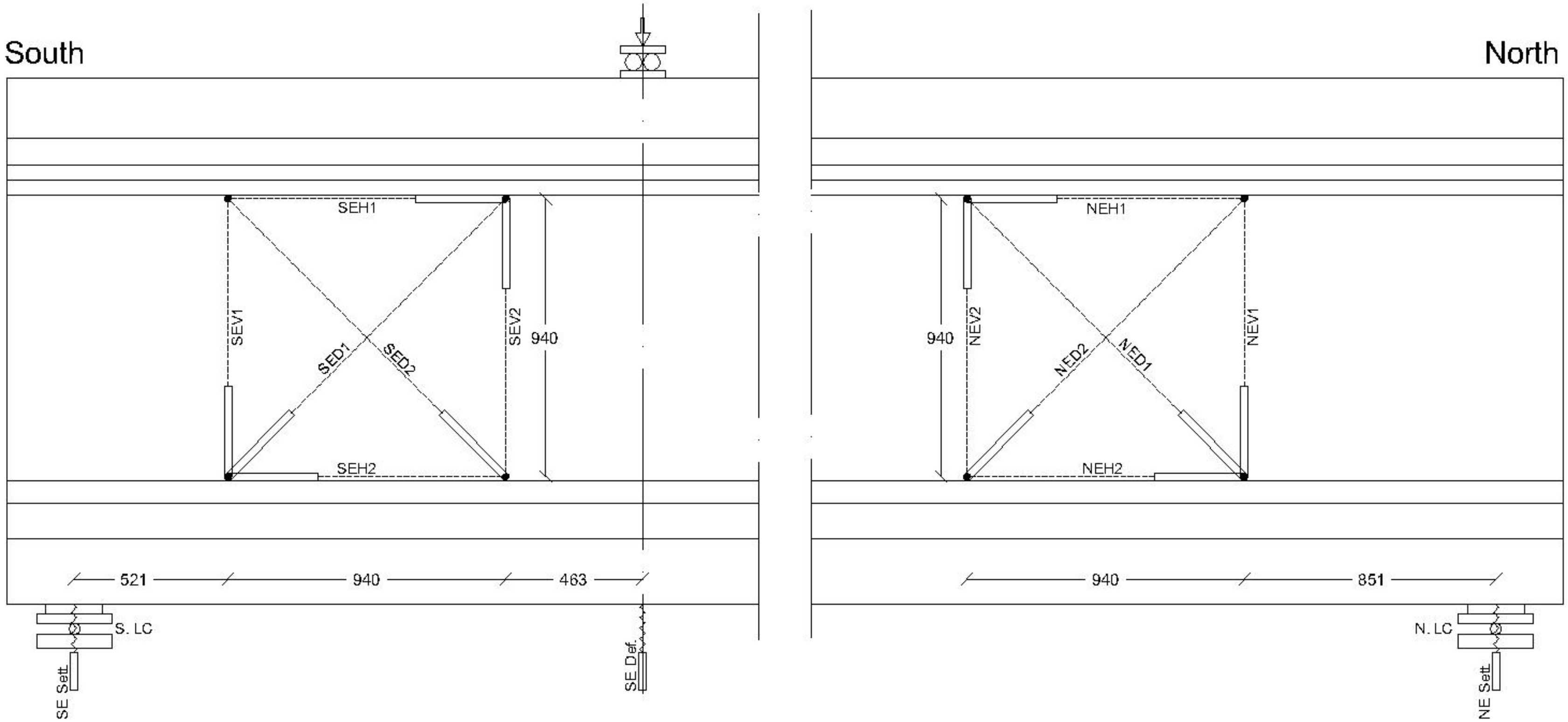
Experimental Data of Girder E1



West View

(All Dimensions are in mm)

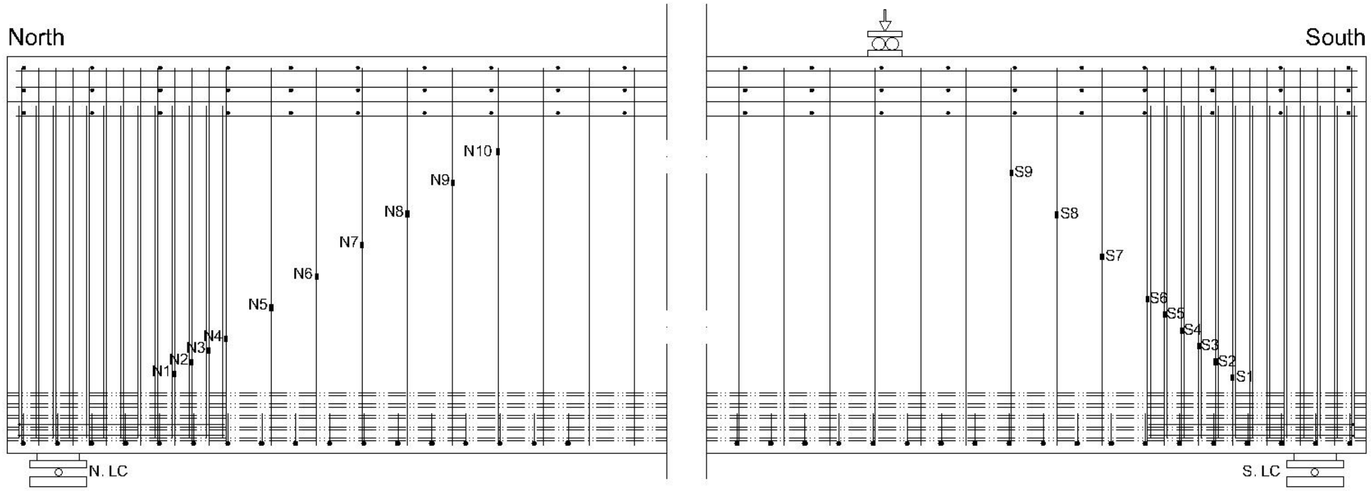
Fig. A.5.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder E1-South End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.5.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder E1-South End Testing (Labib 2012) (Cont'd)



West View

Fig. A.5.2 Layout of Strain Gauges on Transverse Reinforcement for Girder E1-South End Testing (Labib 2012)

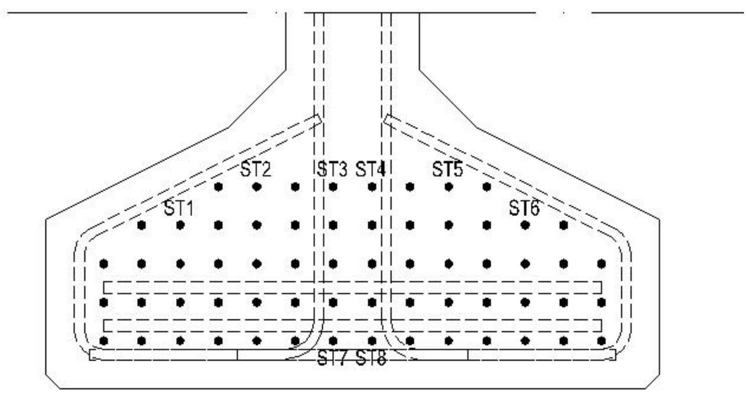


Fig. A.5.3 LVDTs Names on Selected Tendons of Girder E1-South End Testing (Labib 2012)

Table A.5.1 Measurements of Load and Deflection Relationships of Girder E1 – South End Testing (Labib 2012)

N. LC		S. LC		SW Def.		SE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
-1.50	-6.67	0.36	1.60	0.036	0.92	0.017	0.44	0.011	0.27	-0.009	-0.22	0.046	1.17	0.024	0.61
4.56	20.28	16.56	73.66	0.048	1.22	0.026	0.67	0.020	0.50	-0.003	-0.08	0.056	1.42	0.028	0.72
17.64	78.47	44.88	199.64	0.069	1.74	0.043	1.10	0.036	0.93	0.010	0.25	0.071	1.81	0.039	0.99
19.20	85.41	48.24	214.58	0.073	1.86	0.047	1.19	0.041	1.03	0.013	0.33	0.075	1.89	0.042	1.07
26.04	115.84	62.70	278.90	0.081	2.05	0.054	1.38	0.046	1.17	0.018	0.45	0.080	2.03	0.045	1.15
57.60	256.23	130.68	581.29	0.114	2.90	0.085	2.17	0.065	1.66	0.033	0.83	0.104	2.65	0.065	1.65
91.98	409.17	205.38	913.58	0.145	3.68	0.108	2.75	0.083	2.12	0.041	1.03	0.123	3.13	0.076	1.92
112.57	500.72	249.78	1111.08	0.166	4.22	0.120	3.04	0.096	2.44	0.043	1.09	0.135	3.43	0.079	2.00
142.75	634.97	315.78	1404.66	0.189	4.81	0.139	3.54	0.107	2.72	0.048	1.21	0.145	3.69	0.084	2.15
178.09	792.18	392.88	1747.62	0.217	5.50	0.164	4.17	0.118	3.00	0.054	1.37	0.156	3.96	0.092	2.35
202.03	898.67	444.72	1978.21	0.234	5.95	0.180	4.57	0.125	3.18	0.058	1.48	0.163	4.14	0.097	2.46
236.95	1054.01	520.44	2315.03	0.260	6.61	0.203	5.16	0.135	3.42	0.064	1.62	0.172	4.38	0.104	2.64
261.67	1163.98	574.08	2553.64	0.286	7.27	0.229	5.82	0.140	3.56	0.069	1.75	0.179	4.56	0.112	2.84
275.95	1227.50	604.68	2689.75	0.300	7.61	0.242	6.14	0.144	3.66	0.071	1.80	0.184	4.67	0.114	2.90
313.64	1395.12	686.16	3052.19	0.333	8.45	0.272	6.90	0.153	3.88	0.076	1.92	0.195	4.96	0.122	3.11
314.66	1399.66	688.68	3063.40	0.339	8.61	0.278	7.07	0.156	3.96	0.077	1.95	0.199	5.04	0.125	3.16
304.52	1354.55	679.08	3020.70	0.334	8.50	0.273	6.95	0.156	3.96	0.077	1.95	0.197	5.01	0.125	3.16
323.66	1439.69	712.92	3171.23	0.345	8.77	0.283	7.19	0.157	3.99	0.077	1.96	0.201	5.09	0.126	3.20
341.18	1517.63	743.88	3308.94	0.360	9.15	0.296	7.51	0.161	4.10	0.079	2.00	0.206	5.24	0.129	3.27
348.80	1551.53	766.62	3410.10	0.371	9.43	0.306	7.77	0.164	4.16	0.080	2.04	0.211	5.35	0.133	3.37
361.28	1607.05	788.82	3508.85	0.383	9.72	0.316	8.03	0.166	4.23	0.080	2.04	0.215	5.47	0.135	3.42
379.40	1687.65	829.02	3687.67	0.401	10.18	0.334	8.47	0.170	4.32	0.082	2.09	0.222	5.63	0.140	3.57
393.56	1750.64	853.74	3797.63	0.416	10.57	0.347	8.81	0.174	4.41	0.084	2.12	0.227	5.76	0.144	3.65

Table A.5.2 Measurements of Tendons' slip at South End of Girder E1 – South End Testing (Labib 2012)

S. LC		ST1		ST2		ST3		ST4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
-0.06	-0.27	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
22.56	100.35	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
48.48	215.65	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
80.28	357.10	0.000	0.00	0.000	0.00	0.001	0.01	0.000	0.01
124.68	554.60	0.000	0.00	0.000	0.00	0.001	0.02	0.000	0.01
175.92	782.53	0.000	0.00	0.000	0.00	0.001	0.02	0.000	0.00
221.40	984.84	0.000	0.00	0.000	0.00	0.001	0.01	0.000	0.00
266.10	1183.67	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
314.64	1399.59	0.000	0.00	0.000	0.00	0.000	0.01	0.000	0.00
364.62	1621.91	0.000	0.00	0.000	0.00	0.001	0.02	0.000	0.01
414.84	1845.30	0.000	0.00	0.000	0.00	0.001	0.03	0.000	0.01
464.88	2067.89	0.000	0.00	0.000	0.00	0.001	0.02	0.000	0.00
518.52	2306.49	0.000	0.00	0.000	0.00	0.001	0.02	0.000	0.01
569.82	2534.69	0.000	0.01	0.000	0.00	0.001	0.04	0.000	0.01
620.40	2759.68	0.000	0.00	0.000	0.00	0.002	0.05	0.001	0.01
673.68	2996.68	0.000	0.01	0.000	0.00	0.002	0.05	0.000	0.01
674.70	3001.22	0.001	0.02	0.000	0.01	0.002	0.05	0.000	0.01
711.24	3163.75	0.001	0.02	0.000	0.01	0.003	0.07	0.001	0.01
738.18	3283.59	0.001	0.03	0.001	0.02	0.003	0.07	0.001	0.01
769.26	3421.84	0.001	0.03	0.001	0.03	0.003	0.07	0.001	0.02
802.20	3568.36	0.001	0.04	0.002	0.06	0.002	0.06	0.001	0.02
839.16	3732.77	0.002	0.04	0.003	0.08	0.005	0.12	0.001	0.02
853.74	3797.63	0.002	0.04	0.004	0.10	0.006	0.15	0.001	0.02

Table A.5.2 Measurements of Tendons' slip at South End of Girder E1 – South End Testing (Labib 2012) (Cont'd)

S. LC		ST5		ST6		ST7		ST8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
-0.06	-0.27	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
22.56	100.35	0.000	-0.01	0.000	-0.01	0.000	0.01	-0.001	-0.02
48.48	215.65	0.000	0.00	0.000	-0.01	0.001	0.03	0.000	0.01
80.28	357.10	0.000	0.00	0.000	-0.01	0.001	0.02	0.000	0.00
124.68	554.60	0.000	0.00	0.000	-0.01	0.001	0.02	0.000	0.00
175.92	782.53	0.000	0.00	0.000	-0.01	0.001	0.02	-0.001	-0.01
221.40	984.84	0.000	-0.01	0.000	-0.01	0.001	0.02	-0.001	-0.02
266.10	1183.67	0.000	0.00	0.000	-0.01	0.002	0.05	0.000	0.00
314.64	1399.59	0.000	0.00	0.000	-0.01	0.000	0.00	-0.001	-0.03
364.62	1621.91	0.000	0.00	0.000	-0.01	0.000	0.00	-0.001	-0.02
414.84	1845.30	0.000	0.00	0.000	0.00	0.001	0.01	0.000	-0.01
464.88	2067.89	0.000	0.00	0.000	-0.01	0.000	0.00	-0.001	-0.03
518.52	2306.49	0.000	0.00	0.000	-0.01	0.000	0.00	-0.001	-0.03
569.82	2534.69	0.000	0.00	0.000	0.00	0.002	0.05	0.000	0.01
620.40	2759.68	0.000	0.00	0.000	0.00	0.001	0.03	0.000	0.00
673.68	2996.68	0.000	0.00	0.000	0.00	0.002	0.04	0.000	0.01
674.70	3001.22	0.000	0.00	0.000	0.00	0.003	0.07	0.001	0.03
711.24	3163.75	0.000	0.00	0.000	0.00	0.003	0.07	0.001	0.03
738.18	3283.59	0.000	0.01	0.000	0.00	0.003	0.07	0.002	0.04
769.26	3421.84	0.000	0.00	0.000	0.01	0.003	0.07	0.002	0.05
802.20	3568.36	0.000	0.01	0.000	0.01	0.004	0.09	0.002	0.06
839.16	3732.77	0.001	0.02	0.001	0.01	0.003	0.09	0.002	0.06
853.74	3797.63	0.001	0.03	0.001	0.02	0.003	0.09	0.003	0.08

Table A.5.3 Measurements of LVDTs for South Rosette Strains of Girder E1 – South End Testing (Labib 2012)

S. LC		SED1	SWD1	SD1 AVG	SED2	SWD2	SD2 AVG
kips	KN						
-0.06	-0.27	0.000006	0.000001	0.000003	-0.000002	0.000000	-0.000001
22.56	100.35	-0.000002	-0.000016	-0.000009	0.000007	-0.000006	0.000001
48.48	215.65	-0.000013	-0.000032	-0.000023	0.000022	0.000001	0.000011
80.28	357.10	-0.000032	-0.000051	-0.000041	0.000036	0.000009	0.000023
124.68	554.60	-0.000057	-0.000077	-0.000067	0.000057	0.000025	0.000041
175.92	782.53	-0.000086	-0.000110	-0.000098	0.000086	0.000039	0.000062
221.40	984.84	-0.000115	-0.000141	-0.000128	0.000114	0.000054	0.000084
266.10	1183.67	-0.000186	-0.000171	-0.000179	0.000179	0.000091	0.000135
314.64	1399.59	-0.000217	-0.000222	-0.000220	0.000253	0.000141	0.000197
364.62	1621.91	-0.000261	-0.000279	-0.000270	0.000339	0.000222	0.000280
414.84	1845.30	-0.000309	-0.000337	-0.000323	0.000413	0.000292	0.000352
464.88	2067.89	-0.000360	-0.000401	-0.000381	0.000495	0.000362	0.000428
518.52	2306.49	-0.000417	-0.000466	-0.000442	0.000587	0.000449	0.000518
569.82	2534.69	-0.000465	-0.000591	-0.000528	0.000750	0.000579	0.000665
620.40	2759.68	-0.000519	-0.000681	-0.000600	0.000856	0.000681	0.000768
673.68	2996.68	-0.000587	-0.000786	-0.000686	0.001001	0.000813	0.000907
674.70	3001.22	-0.000618	-0.000844	-0.000731	0.001064	0.000876	0.000970
711.24	3163.75	-0.000645	-0.000876	-0.000761	0.001104	0.000905	0.001004
738.18	3283.59	-0.000679	-0.000933	-0.000806	0.001176	0.000976	0.001076
769.26	3421.84	-0.000740	-0.001039	-0.000889	0.001295	0.001074	0.001184
802.20	3568.36	-0.000797	-0.001134	-0.000965	0.001393	0.001152	0.001272
839.16	3732.77	-0.000902	-0.001278	-0.001090	0.001586	0.001342	0.001464
853.74	3797.63	-0.000927	-0.001313	-0.001120	0.001631	0.001384	0.001507

Table A.5.3 Measurements of LVDTs for South Rosette Strains of Girder E1 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEV1	SWV1	SV1 AVG	SEV2	SWV2	SV2 AVG
kips	KN						
-0.06	-0.27	0.000007	0.000001	0.000004	-0.000002	0.000002	0.000000
22.56	100.35	0.000023	-0.000002	0.000011	0.000011	-0.000031	-0.000010
48.48	215.65	0.000027	-0.000005	0.000011	0.000010	-0.000039	-0.000015
80.28	357.10	0.000028	-0.000007	0.000011	0.000011	-0.000048	-0.000018
124.68	554.60	0.000031	-0.000026	0.000003	0.000025	-0.000060	-0.000018
175.92	782.53	0.000041	-0.000043	-0.000001	0.000032	-0.000086	-0.000027
221.40	984.84	0.000048	-0.000073	-0.000012	0.000047	-0.000107	-0.000030
266.10	1183.67	0.000082	-0.000100	-0.000009	0.000138	-0.000176	-0.000019
314.64	1399.59	0.000119	-0.000100	0.000009	0.000218	-0.000251	-0.000016
364.62	1621.91	0.000167	-0.000102	0.000032	0.000268	-0.000204	0.000032
414.84	1845.30	0.000202	-0.000102	0.000050	0.000311	-0.000166	0.000072
464.88	2067.89	0.000236	-0.000102	0.000067	0.000355	-0.000129	0.000113
518.52	2306.49	0.000296	-0.000077	0.000110	0.000402	-0.000101	0.000150
569.82	2534.69	0.000447	0.000004	0.000226	0.000504	-0.000048	0.000228
620.40	2759.68	0.000529	0.000016	0.000272	0.000573	0.000003	0.000288
673.68	2996.68	0.000631	0.000046	0.000338	0.000650	0.000049	0.000350
674.70	3001.22	0.000684	0.000053	0.000369	0.000682	0.000080	0.000381
711.24	3163.75	0.000700	0.000056	0.000378	0.000695	0.000078	0.000387
738.18	3283.59	0.000743	0.000076	0.000410	0.000740	0.000111	0.000425
769.26	3421.84	0.000804	0.000149	0.000476	0.000809	0.000162	0.000486
802.20	3568.36	0.000860	0.000149	0.000505	0.000858	0.000175	0.000517
839.16	3732.77	0.000990	0.000237	0.000614	0.000967	0.000183	0.000575
853.74	3797.63	0.001016	0.000243	0.000629	0.000987	0.000192	0.000590

Table A.5.3 Measurements of LVDTs for South Rosette Strains of Girder E1 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEH1	SWH1	SH1 AVG	SEH2	SWH2	SH2AVG
kips	KN						
-0.06	-0.27	-0.000001	0.000003	0.000001	-0.000001	0.000000	-0.000001
22.56	100.35	0.000003	0.000001	0.000002	0.000001	-0.000005	-0.000002
48.48	215.65	0.000003	-0.000002	0.000000	0.000000	-0.000003	-0.000002
80.28	357.10	0.000003	-0.000001	0.000001	0.000002	-0.000003	-0.000001
124.68	554.60	0.000002	0.000000	0.000001	-0.000001	-0.000003	-0.000002
175.92	782.53	0.000000	0.000001	0.000001	0.000001	-0.000002	-0.000001
221.40	984.84	-0.000012	-0.000001	-0.000007	0.000000	-0.000002	-0.000001
266.10	1183.67	-0.000054	0.000005	-0.000025	0.000000	-0.000002	-0.000001
314.64	1399.59	-0.000089	0.000001	-0.000044	0.000001	-0.000007	-0.000003
364.62	1621.91	-0.000108	0.000000	-0.000054	0.000001	-0.000013	-0.000006
414.84	1845.30	-0.000131	-0.000001	-0.000066	0.000000	-0.000022	-0.000011
464.88	2067.89	-0.000146	-0.000002	-0.000074	0.000000	-0.000034	-0.000017
518.52	2306.49	-0.000167	-0.000003	-0.000085	0.000001	-0.000049	-0.000024
569.82	2534.69	-0.000193	0.000002	-0.000095	0.000000	-0.000122	-0.000061
620.40	2759.68	-0.000212	-0.000001	-0.000106	0.000000	-0.000156	-0.000078
673.68	2996.68	-0.000226	-0.000001	-0.000114	0.000001	-0.000185	-0.000092
674.70	3001.22	-0.000238	-0.000002	-0.000120	0.000001	-0.000229	-0.000114
711.24	3163.75	-0.000244	-0.000001	-0.000123	0.000000	-0.000238	-0.000119
738.18	3283.59	-0.000250	-0.000002	-0.000126	0.000001	-0.000267	-0.000133
769.26	3421.84	-0.000274	-0.000001	-0.000138	0.000001	-0.000339	-0.000169
802.20	3568.36	-0.000278	0.000000	-0.000139	0.000001	-0.000382	-0.000190
839.16	3732.77	-0.000308	0.000000	-0.000154	0.000001	-0.000448	-0.000224
853.74	3797.63	-0.000309	0.000000	-0.000155	0.000000	-0.000468	-0.000234

Table A.5.4 Measurements of LVDTs for North Rosette Strains of Girder E1 – South End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
-0.06	-0.27	0.000003	0.000003	0.000003	-0.000003	0.000001	-0.000001
6.96	30.96	0.000016	0.000026	0.000021	0.000031	0.000019	0.000025
19.14	85.14	0.000011	0.000023	0.000017	0.000026	0.000019	0.000023
34.20	152.14	0.000012	0.000018	0.000015	0.000024	0.000017	0.000020
54.90	244.22	-0.000003	0.000009	0.000003	0.000034	0.000022	0.000028
78.54	349.38	-0.000019	-0.000005	-0.000012	0.000048	0.000035	0.000041
99.48	442.53	-0.000027	-0.000011	-0.000019	0.000053	0.000035	0.000044
120.13	534.35	-0.000039	-0.000020	-0.000030	0.000062	0.000043	0.000053
142.39	633.37	-0.000050	-0.000031	-0.000040	0.000067	0.000060	0.000064
165.19	734.79	-0.000054	-0.000042	-0.000048	0.000078	0.000068	0.000073
188.17	837.02	-0.000076	-0.000053	-0.000065	0.000089	0.000077	0.000083
211.39	940.31	-0.000089	-0.000069	-0.000079	0.000104	0.000096	0.000100
236.05	1050.01	-0.000095	-0.000078	-0.000087	0.000119	0.000104	0.000112
259.63	1154.91	-0.000149	-0.000062	-0.000106	0.000274	0.000347	0.000310
283.15	1259.53	-0.000187	-0.000074	-0.000131	0.000339	0.000425	0.000382
307.76	1368.96	-0.000207	-0.000096	-0.000152	0.000463	0.000564	0.000514
308.30	1371.37	-0.000232	-0.000098	-0.000165	0.000540	0.000633	0.000587
322.76	1435.69	-0.000226	-0.000106	-0.000166	0.000536	0.000637	0.000586
338.12	1504.02	-0.000235	-0.000106	-0.000170	0.000591	0.000703	0.000647
350.48	1559.00	-0.000246	-0.000101	-0.000174	0.000669	0.000820	0.000744
364.10	1619.59	-0.000276	-0.000112	-0.000194	0.000717	0.000867	0.000792
385.28	1713.81	-0.000285	-0.000127	-0.000206	0.000805	0.000963	0.000884
393.56	1750.64	-0.000296	-0.000129	-0.000213	0.000839	0.000994	0.000917

Table A.5.4 Measurements of LVDTs for North Rosette Strains of Girder E1 – South End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
-0.06	-0.27	0.000000	0.000001	0.000001	0.000000	0.000002	0.000001
6.96	30.96	0.000018	0.000008	0.000013	0.000043	0.000033	0.000038
19.14	85.14	0.000018	0.000007	0.000012	0.000043	0.000033	0.000038
34.20	152.14	0.000018	0.000007	0.000012	0.000042	0.000041	0.000042
54.90	244.22	0.000018	0.000007	0.000012	0.000042	0.000041	0.000041
78.54	349.38	0.000001	0.000005	0.000003	0.000040	0.000035	0.000037
99.48	442.53	0.000001	0.000003	0.000002	0.000040	0.000032	0.000036
120.13	534.35	-0.000003	0.000009	0.000003	0.000041	0.000027	0.000034
142.39	633.37	-0.000006	0.000018	0.000006	0.000041	0.000033	0.000037
165.19	734.79	-0.000006	0.000020	0.000007	0.000041	0.000032	0.000037
188.17	837.02	-0.000007	0.000020	0.000007	0.000041	0.000036	0.000038
211.39	940.31	-0.000010	0.000024	0.000007	0.000041	0.000032	0.000036
236.05	1050.01	-0.000010	0.000026	0.000008	0.000041	0.000040	0.000041
259.63	1154.91	0.000031	0.000175	0.000103	0.000211	0.000398	0.000305
283.15	1259.53	0.000050	0.000217	0.000133	0.000306	0.000508	0.000407
307.76	1368.96	0.000120	0.000328	0.000224	0.000423	0.000633	0.000528
308.30	1371.37	0.000166	0.000375	0.000271	0.000493	0.000734	0.000613
322.76	1435.69	0.000166	0.000379	0.000273	0.000498	0.000728	0.000613
338.12	1504.02	0.000179	0.000418	0.000299	0.000565	0.000812	0.000689
350.48	1559.00	0.000211	0.000480	0.000345	0.000680	0.000925	0.000803
364.10	1619.59	0.000233	0.000506	0.000370	0.000715	0.000982	0.000848
385.28	1713.81	0.000280	0.000558	0.000419	0.000818	0.001099	0.000958
393.56	1750.64	0.000300	0.000577	0.000438	0.000856	0.001149	0.001003

Table A.5.4 Measurements of LVDTs for North Rosette Strains of Girder E1 – South End Testing (Labib 2012) (Cont'd)

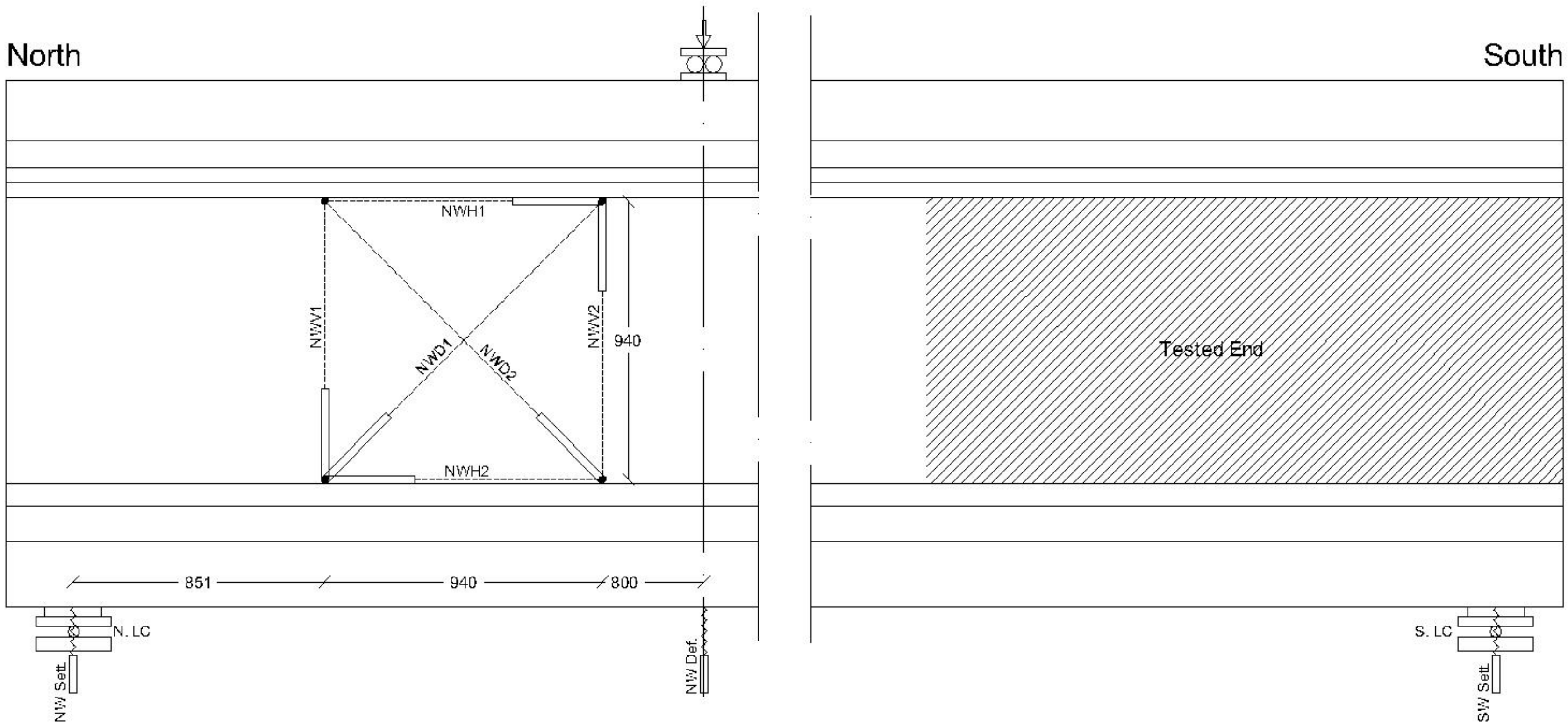
N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
-0.06	-0.27	0.000000	0.000001	0.000000	-0.000001	0.000000	-0.000001
6.96	30.96	-0.000001	0.000003	0.000001	0.000015	0.000009	0.000012
19.14	85.14	0.000001	-0.000001	0.000000	0.000014	0.000009	0.000011
34.20	152.14	0.000002	0.000002	0.000002	0.000014	0.000008	0.000011
54.90	244.22	0.000003	0.000000	0.000001	0.000015	0.000009	0.000012
78.54	349.38	0.000005	-0.000015	-0.000005	0.000012	0.000004	0.000008
99.48	442.53	0.000003	-0.000014	-0.000005	0.000010	0.000005	0.000008
120.13	534.35	0.000005	-0.000022	-0.000008	0.000010	0.000005	0.000007
142.39	633.37	0.000005	-0.000020	-0.000008	0.000009	0.000005	0.000007
165.19	734.79	0.000005	-0.000019	-0.000007	0.000012	0.000005	0.000009
188.17	837.02	0.000005	-0.000026	-0.000010	0.000009	0.000005	0.000007
211.39	940.31	0.000006	-0.000030	-0.000012	0.000010	0.000005	0.000007
236.05	1050.01	0.000006	-0.000038	-0.000016	0.000012	0.000005	0.000009
259.63	1154.91	-0.000028	-0.000064	-0.000046	0.000010	0.000046	0.000028
283.15	1259.53	-0.000049	-0.000081	-0.000065	0.000010	0.000046	0.000028
307.76	1368.96	-0.000048	-0.000088	-0.000068	0.000021	0.000046	0.000033
308.30	1371.37	-0.000058	-0.000125	-0.000092	0.000031	0.000057	0.000044
322.76	1435.69	-0.000058	-0.000125	-0.000092	0.000032	0.000058	0.000045
338.12	1504.02	-0.000057	-0.000127	-0.000092	0.000031	0.000058	0.000045
350.48	1559.00	-0.000079	-0.000108	-0.000094	0.000043	0.000089	0.000066
364.10	1619.59	-0.000074	-0.000103	-0.000089	0.000040	0.000088	0.000064
385.28	1713.81	-0.000074	-0.000110	-0.000092	0.000033	0.000088	0.000061
393.56	1750.64	-0.000073	-0.000108	-0.000090	0.000032	0.000088	0.000060

Table A.5.5 Measurements of South Strain Gauges on Transverse Steel Bars of Girder E1 – South End Testing (Labib 2012)

S. LC		S1	S2	S3	S4	S5	S6	S7	S8	S9
kips	KN									
-0.06	-0.27	0.000002	0.000002	0.000002	0.000003	0.000002	0.000002	0.000000	0.000003	0.000002
22.56	100.35	0.000008	0.000000	0.000000	0.000004	0.000037	0.000035	0.000007	0.000006	0.000006
48.48	215.65	0.000007	0.000001	0.000000	0.000007	0.000038	0.000040	0.000012	0.000014	0.000015
80.28	357.10	0.000001	-0.000003	-0.000004	0.000004	0.000032	0.000038	0.000005	0.000015	0.000016
124.68	554.60	-0.000007	0.000004	-0.000013	0.000004	0.000067	0.000035	0.000009	0.000023	0.000039
175.92	782.53	-0.000014	0.000001	-0.000017	0.000005	0.000066	0.000039	0.000010	0.000029	0.000053
221.40	984.84	-0.000025	-0.000003	-0.000024	0.000004	0.000057	0.000040	0.000005	0.000035	0.000055
266.10	1183.67	-0.000030	0.000000	-0.000017	0.000023	0.000079	0.000101	0.000198	0.000431	0.000368
314.64	1399.59	-0.000028	0.000009	0.000010	0.000074	0.000136	0.000326	0.000464	0.000687	0.000575
364.62	1621.91	-0.000025	0.000001	0.000011	0.000164	0.000250	0.000527	0.000723	0.000965	0.000821
414.84	1845.30	-0.000040	0.000008	0.000031	0.000238	0.000374	0.000683	0.000924	0.001173	A.G.
464.88	2067.89	-0.000045	0.000025	0.000105	0.000361	0.000512	0.000832	0.001123	0.001377	A.G.
518.52	2306.49	0.000023	0.000126	0.000275	0.000508	0.000701	0.001023	0.001353	0.001610	A.G.
569.82	2534.69	0.000159	0.000326	0.000500	0.000610	0.000834	0.001083	0.001488	A.G.	A.G.
620.40	2759.68	0.000221	0.000438	0.000589	0.000697	0.000917	0.001192	0.001549	A.G.	A.G.
673.68	2996.68	0.000227	0.000482	0.000612	0.000712	0.000968	0.001279	0.001761	A.G.	A.G.
674.70	3001.22	0.000247	0.000535	0.000650	0.000744	0.001007	0.001335	0.001888	A.G.	A.G.
711.24	3163.75	0.000254	0.000554	0.000673	0.000768	0.001029	0.001364	0.001928	A.G.	A.G.
738.18	3283.59	0.000274	0.000605	0.000710	0.000811	0.001072	0.001424	0.002036	A.G.	A.G.
769.26	3421.84	0.000321	0.000689	0.000772	0.000879	0.001130	0.001458	A.G.	A.G.	A.G.
802.20	3568.36	0.000346	0.000723	0.000816	A.G.	0.001185	0.001512	A.G.	A.G.	A.G.
839.16	3732.77	0.000424	0.000816	0.000890	A.G.	0.001273	0.001547	A.G.	A.G.	A.G.
853.74	3797.63	0.000434	0.000831	0.000906	A.G.	0.001296	0.001564	A.G.	A.G.	A.G.

Table A.5.6 Measurements of North Strain Gauges on Transverse Steel Bars of Girder E1 – South End Testing (Labib 2012)

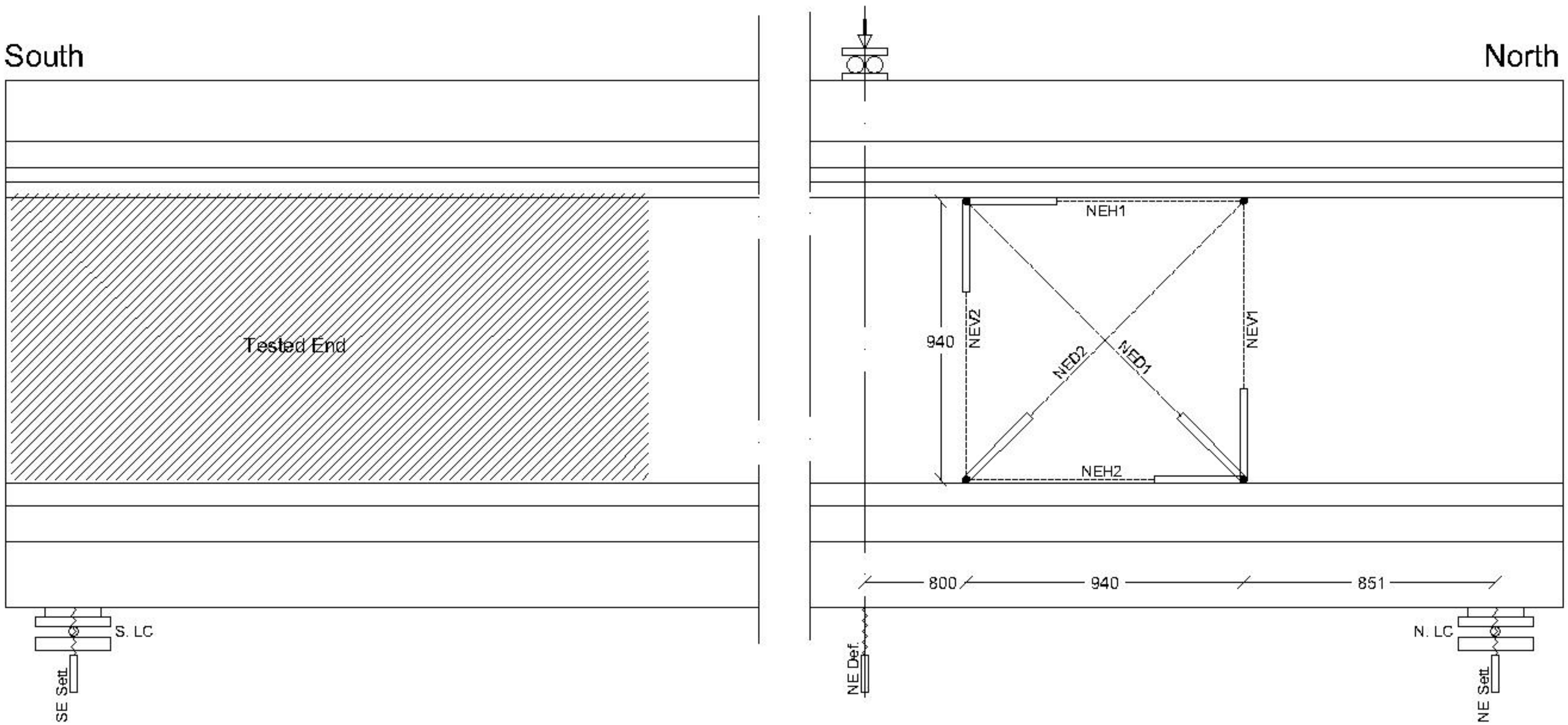
N. LC		N2	N4	N5	N6	N7	N8	N10
kips	KN							
-0.06	-0.27	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000001
6.96	30.96	0.000002	0.000009	0.000005	0.000009	0.000007	0.000011	0.000005
19.14	85.14	0.000005	-0.000002	0.000007	0.000002	0.000023	-0.000011	0.000239
34.20	152.14	0.000006	0.000000	0.000009	0.000004	0.000025	-0.000008	0.000156
54.90	244.22	0.000005	0.000001	0.000010	0.000005	0.000025	-0.000008	0.000169
78.54	349.38	0.000004	0.000003	0.000012	0.000006	0.000027	-0.000006	0.000201
99.48	442.53	0.000003	0.000003	0.000013	0.000006	0.000027	-0.000006	0.000212
120.13	534.35	0.000002	0.000003	0.000015	0.000007	0.000028	-0.000006	0.000208
142.39	633.37	-0.000005	-0.000002	0.000016	0.000000	-0.000001	0.000000	0.000221
165.19	734.79	-0.000006	-0.000002	0.000017	0.000000	0.000004	-0.000001	0.000233
188.17	837.02	-0.000007	-0.000001	0.000018	-0.000001	0.000007	0.000000	0.000251
211.39	940.31	-0.000008	0.000000	0.000020	0.000002	0.000006	0.000002	0.000267
236.05	1050.01	-0.000008	0.000002	0.000021	0.000003	0.000008	0.000003	0.000281
259.63	1154.91	0.000042	0.000238	0.000487	0.000233	0.000261	0.000200	0.000863
283.15	1259.53	0.000109	0.000361	0.000648	0.000325	0.000334	0.000278	0.000957
307.76	1368.96	0.000177	0.000480	0.000822	0.000379	0.000357	0.000323	0.000995
308.30	1371.37	0.000248	0.000550	0.000854	0.000387	0.000356	0.000333	0.001247
322.76	1435.69	0.000253	0.000561	0.000868	0.000392	0.000360	0.000337	0.001270
338.12	1504.02	0.000289	0.000620	0.000949	0.000430	0.000390	0.000374	0.001191
350.48	1559.00	0.000326	0.000683	0.001026	0.000482	0.000428	0.000429	0.001256
364.10	1619.59	0.000312	0.000723	0.001105	0.000516	0.000456	0.000462	0.001276
385.28	1713.81	0.000345	0.000783	0.001201	0.000578	0.000496	0.000522	0.001269
393.56	1750.64	0.000365	0.000809	0.001241	0.000602	0.000506	0.000544	0.001299



West View

(All Dimensions are in mm)

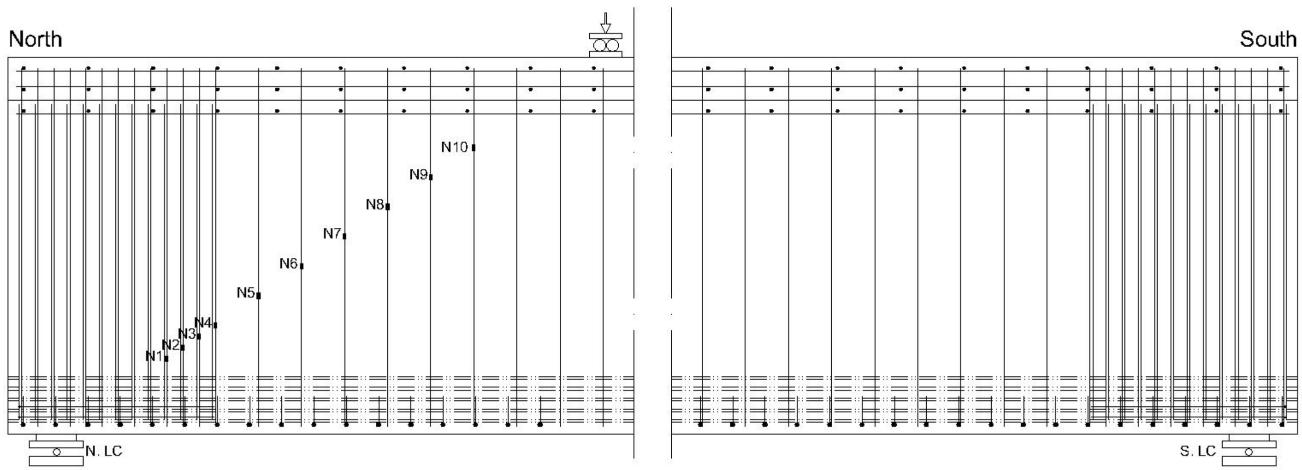
Fig. A.5.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder E1-North End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.5.4 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder E1-North End Testing (Labib 2012) (Cont'd)



West View Fig. A.5.5 Layout of Strain Gauges on Transverse Reinforcement for Girder E1-North End Testing (Labib 2012)

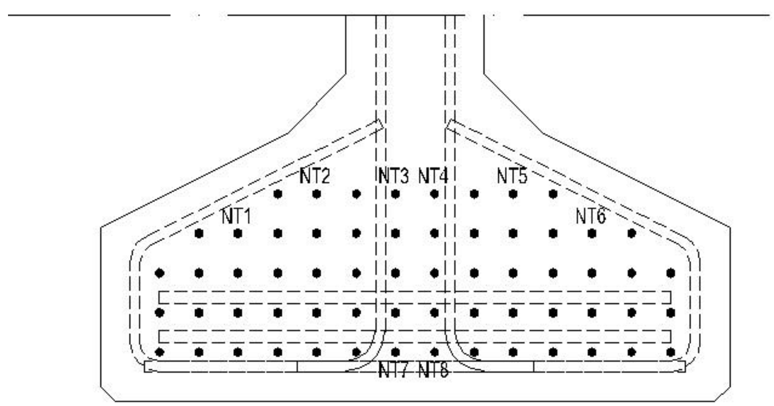


Fig. A.5.6 LVDTs Names on Selected Tendons of Girder E1-North End Testing (Labib 2012)

Table A.5.7 Measurements of Load and Deflection Relationships of Girder E1 – North End Testing (Labib 2012)

N. LC		S. LC		NW Def.		NE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm
0.12	0.53	0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
4.44	19.75	3.36	14.95	0.009	0.24	0.003	0.08	0.010	0.25	0.003	0.08	0.006	0.14	-0.002	-0.05
22.74	101.16	16.92	75.26	0.032	0.82	0.022	0.56	0.033	0.84	0.021	0.53	0.016	0.41	0.004	0.09
35.52	158.01	25.68	114.23	0.044	1.13	0.033	0.85	0.045	1.13	0.031	0.79	0.022	0.55	0.008	0.21
49.98	222.33	35.40	157.47	0.053	1.35	0.042	1.07	0.050	1.28	0.036	0.91	0.026	0.66	0.012	0.30
106.51	473.76	73.08	325.08	0.084	2.12	0.071	1.80	0.067	1.71	0.050	1.26	0.041	1.05	0.026	0.65
161.41	717.98	109.74	488.15	0.107	2.73	0.095	2.42	0.078	1.99	0.060	1.52	0.051	1.30	0.035	0.90
214.03	952.06	144.48	642.68	0.129	3.28	0.117	2.98	0.087	2.21	0.068	1.73	0.059	1.50	0.044	1.11
277.81	1235.78	186.30	828.70	0.155	3.94	0.143	3.63	0.097	2.46	0.076	1.92	0.066	1.68	0.051	1.29
337.10	1499.48	224.94	1000.58	0.180	4.58	0.168	4.27	0.105	2.67	0.083	2.10	0.071	1.81	0.056	1.43
399.98	1779.20	265.68	1181.80	0.207	5.26	0.195	4.96	0.113	2.88	0.089	2.27	0.076	1.93	0.062	1.57
470.84	2094.42	311.76	1386.78	0.240	6.10	0.228	5.80	0.124	3.15	0.098	2.49	0.081	2.07	0.067	1.69
520.59	2315.68	344.22	1531.17	0.269	6.82	0.255	6.48	0.134	3.41	0.104	2.64	0.086	2.18	0.069	1.76
587.07	2611.41	389.58	1732.94	0.309	7.85	0.294	7.47	0.149	3.78	0.115	2.92	0.092	2.33	0.074	1.89
606.87	2699.49	403.08	1792.99	0.321	8.16	0.306	7.78	0.154	3.90	0.119	3.01	0.093	2.37	0.075	1.91
629.91	2801.99	420.84	1871.99	0.335	8.51	0.320	8.13	0.158	4.02	0.122	3.11	0.095	2.42	0.077	1.96
653.67	2907.68	440.10	1957.66	0.350	8.90	0.336	8.53	0.164	4.16	0.127	3.24	0.097	2.47	0.079	2.01
674.85	3001.90	457.32	2034.26	0.365	9.28	0.351	8.91	0.169	4.29	0.131	3.34	0.099	2.51	0.082	2.08
702.46	3124.68	472.86	2103.39	0.381	9.69	0.367	9.32	0.176	4.46	0.137	3.48	0.101	2.57	0.083	2.10
725.08	3225.30	491.28	2185.32	0.398	10.11	0.384	9.75	0.181	4.60	0.142	3.60	0.103	2.61	0.085	2.15
746.50	3320.59	508.56	2262.19	0.414	10.52	0.400	10.17	0.187	4.74	0.146	3.72	0.105	2.66	0.087	2.20
747.46	3324.86	509.10	2264.59	0.416	10.58	0.403	10.22	0.188	4.77	0.147	3.75	0.105	2.66	0.087	2.21
747.16	3323.52	508.92	2263.79	0.418	10.61	0.404	10.26	0.189	4.79	0.148	3.76	0.105	2.66	0.087	2.21

Table A.5.8 Measurements of Tendons' slip at North End of Girder E1 – North End Testing (Labib 2012)

N. LC		NT1		NT2		NT3		NT4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
-0.06	-0.27	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
7.38	32.83	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
25.92	115.30	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
34.92	155.34	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
65.22	290.13	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.01
122.89	546.62	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
180.13	801.25	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
237.85	1058.02	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
304.58	1354.82	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
362.12	1610.78	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	0.00
434.30	1931.87	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
508.53	2262.03	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
549.51	2444.33	0.000	0.00	0.000	0.00	0.000	0.01	0.002	0.04
530.37	2359.19	0.000	0.00	0.000	0.00	0.000	0.01	0.002	0.04
573.87	2552.70	0.000	0.01	0.000	0.00	0.000	0.01	0.002	0.05
602.19	2678.68	0.000	0.01	0.000	0.01	0.000	0.01	0.002	0.06
622.89	2770.76	0.000	0.01	0.000	0.00	0.000	0.01	0.002	0.06
647.55	2880.46	0.001	0.01	0.000	0.01	0.001	0.02	0.003	0.07
671.79	2988.29	0.001	0.02	0.002	0.04	0.001	0.02	0.003	0.08
698.37	3106.53	0.001	0.02	0.003	0.07	0.001	0.02	0.003	0.09
721.84	3210.89	0.001	0.02	0.004	0.09	0.001	0.02	0.004	0.09
744.64	3312.31	0.001	0.02	0.005	0.13	0.001	0.03	0.004	0.10
747.46	3324.86	0.001	0.02	0.005	0.14	0.001	0.03	0.004	0.10

Table A.5.8 Measurements of Tendons' slip at North End of Girder E1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NT5		NT6		NT7		NT8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
-0.06	-0.27	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
7.38	32.83	0.000	0.00	0.000	0.00	0.000	-0.01	0.000	-0.01
25.92	115.30	0.000	0.00	0.000	0.00	-0.001	-0.02	-0.001	-0.01
34.92	155.34	0.000	0.00	0.000	0.00	-0.001	-0.02	0.000	-0.01
65.22	290.13	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
122.89	546.62	0.000	0.00	0.000	0.00	-0.001	-0.01	-0.001	-0.01
180.13	801.25	0.000	0.00	0.000	0.00	-0.001	-0.02	0.000	-0.01
237.85	1058.02	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
304.58	1354.82	0.000	0.00	0.000	0.00	-0.001	-0.02	-0.001	-0.02
362.12	1610.78	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
434.30	1931.87	0.000	0.00	0.000	0.00	-0.001	-0.02	-0.001	-0.02
508.53	2262.03	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
549.51	2444.33	0.000	0.00	0.000	0.00	-0.001	-0.01	0.001	0.03
530.37	2359.19	0.000	0.00	0.000	0.00	0.000	0.00	0.002	0.05
573.87	2552.70	0.000	0.01	0.000	0.01	0.000	0.01	0.002	0.06
602.19	2678.68	0.000	0.01	0.000	0.01	0.000	0.01	0.003	0.07
622.89	2770.76	0.000	0.01	0.000	0.01	0.000	0.01	0.003	0.07
647.55	2880.46	0.000	0.01	0.000	0.01	0.000	0.01	0.003	0.08
671.79	2988.29	0.001	0.01	0.000	0.01	0.001	0.01	0.003	0.09
698.37	3106.53	0.001	0.02	0.001	0.02	0.001	0.02	0.004	0.10
721.84	3210.89	0.004	0.09	0.001	0.02	0.001	0.03	0.004	0.11
744.64	3312.31	0.005	0.12	0.001	0.02	0.001	0.03	0.005	0.12
747.46	3324.86	0.005	0.12	0.001	0.02	0.001	0.03	0.005	0.12

Table A.5.9 Measurements of LVDTs for North Rosette Strains of Girder E1 – North End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
-0.06	-0.27	0.000002	-0.000002	0.000000	0.000000	0.000000	0.000000
7.38	32.83	-0.000008	-0.000012	-0.000010	-0.000002	-0.000004	-0.000003
25.92	115.30	-0.000020	-0.000024	-0.000022	-0.000002	-0.000002	-0.000002
34.92	155.34	-0.000024	-0.000026	-0.000025	0.000008	-0.000002	0.000003
65.22	290.13	-0.000020	-0.000034	-0.000027	0.000020	0.000002	0.000011
122.89	546.62	-0.000048	-0.000072	-0.000060	0.000060	0.000004	0.000032
180.13	801.25	-0.000084	-0.000120	-0.000102	0.000120	0.000004	0.000062
237.85	1058.02	-0.000130	-0.000180	-0.000155	0.000192	0.000050	0.000121
304.58	1354.82	-0.000200	-0.000244	-0.000222	0.000280	0.000142	0.000211
362.12	1610.78	-0.000258	-0.000284	-0.000271	0.000364	0.000240	0.000302
434.30	1931.87	-0.000330	-0.000352	-0.000341	0.000486	0.000376	0.000431
508.53	2262.03	-0.000426	-0.000424	-0.000425	0.000668	0.000570	0.000619
549.51	2444.33	-0.000534	-0.000478	-0.000506	0.000916	0.000832	0.000874
530.37	2359.19	-0.000540	-0.000460	-0.000500	0.000922	0.000834	0.000878
573.87	2552.70	-0.000600	-0.000534	-0.000567	0.000934	0.000864	0.000899
602.19	2678.68	-0.000694	-0.000568	-0.000631	0.001004	0.000958	0.000981
622.89	2770.76	-0.000742	-0.000598	-0.000670	0.001064	0.001014	0.001039
647.55	2880.46	-0.000794	-0.000636	-0.000715	0.001150	0.001110	0.001130
671.79	2988.29	-0.000850	-0.000680	-0.000765	0.001242	0.001210	0.001226
698.37	3106.53	-0.000912	-0.000738	-0.000825	0.001342	0.001320	0.001331
721.84	3210.89	-0.000978	-0.000800	-0.000889	0.001460	0.001432	0.001446
744.64	3312.31	-0.001042	-0.000862	-0.000952	0.001574	0.001554	0.001564
747.46	3324.86	-0.001046	-0.000872	-0.000959	0.001598	0.001572	0.001585

Table A.5.9 Measurements of LVDTs for North Rosette Strains of Girder E1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
-0.06	-0.27	-0.000004	-0.000003	-0.000004	-0.000002	-0.000002	-0.000002
7.38	32.83	-0.000012	-0.000012	-0.000012	-0.000004	0.000001	-0.000002
25.92	115.30	-0.000019	-0.000014	-0.000017	-0.000006	-0.000007	-0.000007
34.92	155.34	-0.000019	-0.000009	-0.000014	0.000002	-0.000019	-0.000009
65.22	290.13	-0.000005	-0.000003	-0.000004	0.000006	-0.000008	-0.000001
122.89	546.62	0.000015	0.000005	0.000010	0.000007	-0.000017	-0.000005
180.13	801.25	0.000044	0.000017	0.000031	0.000007	-0.000016	-0.000005
237.85	1058.02	0.000078	0.000059	0.000069	0.000007	-0.000028	-0.000011
304.58	1354.82	0.000121	0.000122	0.000122	0.000019	-0.000004	0.000008
362.12	1610.78	0.000157	0.000191	0.000174	0.000059	0.000059	0.000059
434.30	1931.87	0.000211	0.000280	0.000246	0.000118	0.000143	0.000131
508.53	2262.03	0.000316	0.000426	0.000371	0.000197	0.000242	0.000220
549.51	2444.33	0.000515	0.000693	0.000604	0.000338	0.000372	0.000355
530.37	2359.19	0.000512	0.000690	0.000601	0.000338	0.000389	0.000364
573.87	2552.70	0.000512	0.000713	0.000613	0.000331	0.000387	0.000359
602.19	2678.68	0.000537	0.000862	0.000700	0.000347	0.000453	0.000400
622.89	2770.76	0.000562	0.000945	0.000754	0.000378	0.000491	0.000435
647.55	2880.46	0.000593	0.001059	0.000826	0.000433	0.000558	0.000496
671.79	2988.29	0.000625	0.001158	0.000892	0.000493	0.000628	0.000561
698.37	3106.53	0.000666	0.001244	0.000955	0.000551	0.000687	0.000619
721.84	3210.89	0.000717	0.001321	0.001019	0.000628	0.000762	0.000695
744.64	3312.31	0.000759	0.001385	0.001072	0.000713	0.000857	0.000785
747.46	3324.86	0.000765	0.001397	0.001081	0.000729	0.000872	0.000801

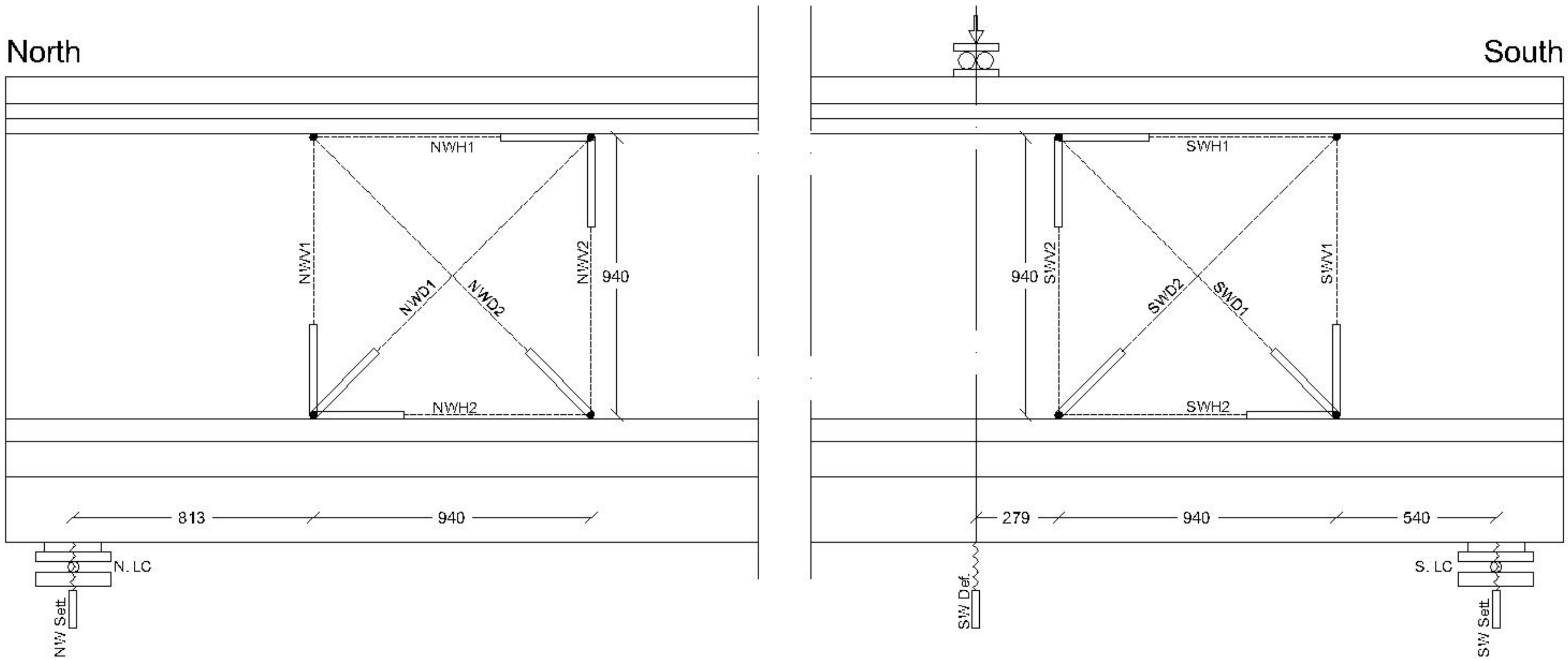
Table A.5.9 Measurements of LVDTs for North Rosette Strains of Girder E1 – North End Testing (Labib 2012) (Cont'd)

N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
-0.06	-0.27	0.000001	-0.000001	0.000000	0.000004	-0.000003	0.000001
7.38	32.83	0.000004	-0.000001	0.000002	0.000000	-0.000008	-0.000004
25.92	115.30	0.000005	-0.000005	0.000000	-0.000002	-0.000013	-0.000008
34.92	155.34	-0.000008	-0.000005	-0.000007	-0.000007	-0.000012	-0.000010
65.22	290.13	-0.000009	-0.000005	-0.000007	-0.000006	-0.000011	-0.000009
122.89	546.62	-0.000009	-0.000028	-0.000019	-0.000004	-0.000011	-0.000008
180.13	801.25	-0.000007	-0.000061	-0.000034	-0.000003	-0.000019	-0.000011
237.85	1058.02	-0.000007	-0.000085	-0.000046	-0.000002	-0.000028	-0.000015
304.58	1354.82	-0.000034	-0.000100	-0.000067	-0.000001	-0.000028	-0.000015
362.12	1610.78	-0.000051	-0.000114	-0.000083	0.000000	-0.000028	-0.000014
434.30	1931.87	-0.000064	-0.000132	-0.000098	0.000000	-0.000028	-0.000014
508.53	2262.03	-0.000078	-0.000134	-0.000106	0.000001	-0.000023	-0.000011
549.51	2444.33	-0.000115	-0.000136	-0.000126	-0.000032	-0.000003	-0.000018
530.37	2359.19	-0.000111	-0.000140	-0.000126	-0.000032	-0.000003	-0.000018
573.87	2552.70	-0.000113	-0.000170	-0.000142	-0.000080	-0.000029	-0.000055
602.19	2678.68	-0.000127	-0.000185	-0.000156	-0.000145	-0.000082	-0.000114
622.89	2770.76	-0.000133	-0.000202	-0.000168	-0.000177	-0.000114	-0.000146
647.55	2880.46	-0.000144	-0.000210	-0.000177	-0.000197	-0.000147	-0.000172
671.79	2988.29	-0.000149	-0.000221	-0.000185	-0.000201	-0.000184	-0.000193
698.37	3106.53	-0.000159	-0.000231	-0.000195	-0.000204	-0.000215	-0.000210
721.84	3210.89	-0.000166	-0.000242	-0.000204	-0.000211	-0.000244	-0.000228
744.64	3312.31	-0.000176	-0.000251	-0.000214	-0.000217	-0.000254	-0.000236
747.46	3324.86	-0.000179	-0.000252	-0.000216	-0.000215	-0.000259	-0.000237

Table A.5.10 Measurements of North Strain Gauges on Transverse Steel Bars of Girder E1 – North End Testing (Labib 2012)

N. LC		N1	N2	N3	N4	N5	N6	N7	N8	N9	N10
Kips	KN										
-0.06	-0.27	0.000000	0.000000	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	A.G.	A.G.
7.38	32.83	-0.000002	-0.000002	0.000000	0.000001	0.000000	0.000000	0.000000	0.000000	A.G.	A.G.
25.92	115.30	-0.000003	-0.000003	0.000001	0.000003	0.000003	0.000001	0.000000	0.000002	A.G.	A.G.
34.92	155.34	-0.000012	-0.000011	-0.000007	0.000005	-0.000005	0.000012	-0.000008	-0.000002	A.G.	A.G.
65.22	290.13	-0.000012	-0.000012	-0.000007	0.000008	-0.000003	0.000013	-0.000009	-0.000002	A.G.	A.G.
122.89	546.62	-0.000010	-0.000010	-0.000002	0.000015	0.000003	0.000011	-0.000013	-0.000005	A.G.	A.G.
180.13	801.25	-0.000004	-0.000004	0.000012	0.000027	0.000025	0.000011	-0.000017	-0.000007	A.G.	A.G.
237.85	1058.02	0.000024	0.000024	0.000064	0.000067	0.000122	0.000028	-0.000009	-0.000004	A.G.	A.G.
304.58	1354.82	0.000074	0.000073	0.000148	0.000143	0.000261	0.000076	0.000016	0.000008	A.G.	A.G.
362.12	1610.78	0.000120	0.000120	0.000226	0.000212	0.000379	0.000122	0.000043	0.000020	A.G.	A.G.
434.30	1931.87	0.000183	0.000184	0.000329	0.000301	0.000529	0.000180	0.000076	0.000036	A.G.	A.G.
508.53	2262.03	0.000267	0.000266	0.000425	0.000384	0.000690	0.000235	0.000108	0.000055	A.G.	A.G.
549.51	2444.33	0.000437	0.000437	0.000559	0.000481	0.000652	0.000319	0.000220	0.000173	A.G.	A.G.
530.37	2359.19	0.000438	0.000437	0.000555	0.000483	0.000650	0.000329	0.000235	0.000194	A.G.	A.G.
573.87	2552.70	0.000493	0.000493	0.000606	0.000528	0.000695	0.000361	0.000265	0.000227	A.G.	A.G.
602.19	2678.68	0.000577	0.000577	0.000670	0.000566	0.000725	0.000405	0.000318	0.000294	A.G.	A.G.
622.89	2770.76	0.000620	0.000620	0.000706	0.000599	0.000736	0.000435	0.000351	0.000333	A.G.	A.G.
647.55	2880.46	0.000688	0.000688	0.000769	0.000657	0.000773	0.000487	0.000401	0.000396	A.G.	A.G.
671.79	2988.29	0.000758	0.000759	0.000836	0.000723	0.000822	0.000546	0.000470	0.000452	A.G.	A.G.
698.37	3106.53	0.000833	0.000834	0.000909	0.000796	0.000868	0.000602	0.000534	0.000507	A.G.	A.G.
721.84	3210.89	0.000912	0.000913	0.000985	0.000883	0.000931	0.000659	0.000589	0.000561	A.G.	A.G.
744.64	3312.31	0.000984	0.000985	0.001062	0.001047	0.000994	0.000682	0.000570	0.000597	A.G.	A.G.
747.46	3324.86	0.000996	0.000998	0.001076	0.001060	0.001004	0.000690	0.000576	0.000609	A.G.	A.G.

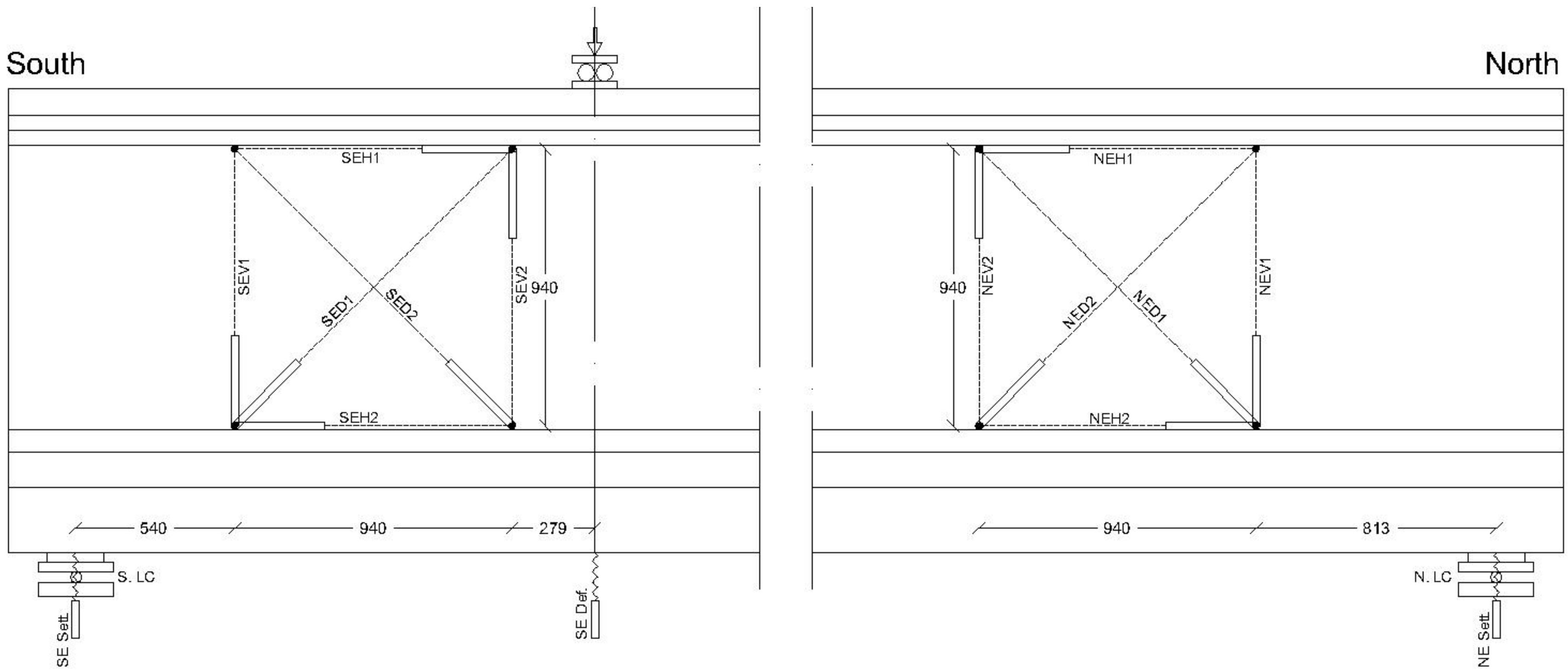
Experimental Data of Girder E2



West View

(All Dimensions are in mm)

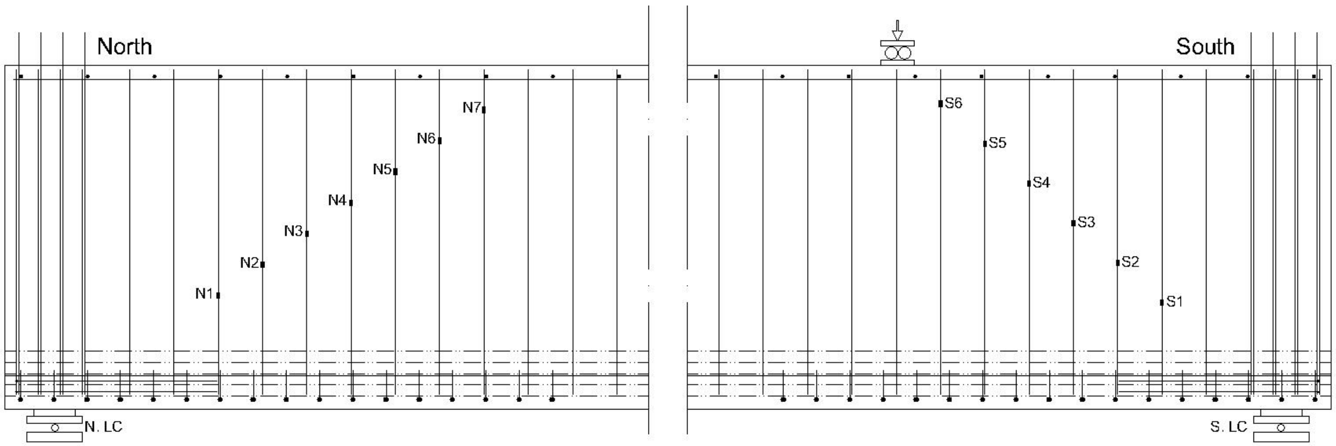
Fig. A.6.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder E2-South End Testing (Labib 2012)



East View

(All Dimensions are in mm)

Fig. A.6.1 Layout of LVDTs underneath the Girder and in Rosette Strains for Girder E2-South End Testing (Labib 2012) (Cont'd)



West View

Fig. A.6.2 Layout of Strain Gauges on Transverse Reinforcement for Girder E2-South End Testing (Labib 2012)

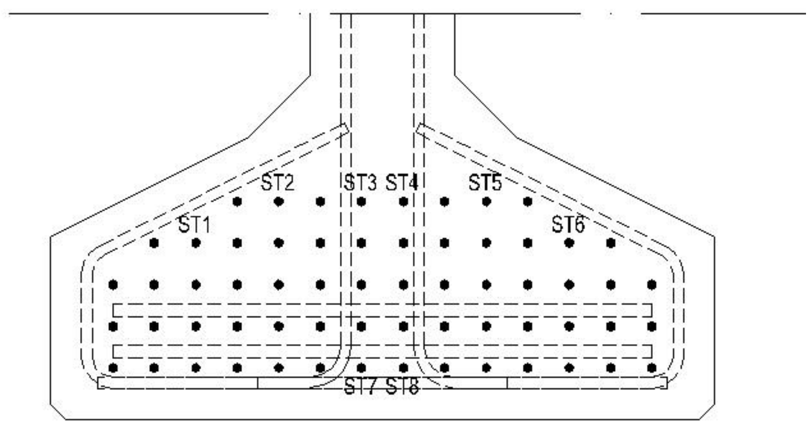


Fig. A.6.3 LVDTs Names on Selected Tendons of Girder E2-South End Testing (Labib 2012)

Table A.6.1 Measurements of Load and Deflection Relationships of Girder E2 – South End Testing (Labib 2012)

N. LC		S. LC		SW Def.		SE Def.		NW Sett.		NE Sett.		SW Sett.		SE Sett.	
kips	KN	kips	KN	in.	mm	in.	mm	in.	mm	in.	mm	in.	mm	in.	Mm
-0.06	-0.27	0.00	0.00	0.001	0.01	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
128.05	569.58	300.24	1335.53	0.204	5.17	0.160	4.07	0.075	1.90	0.081	2.06	0.000	-0.01	0.019	0.48
150.61	669.94	353.46	1572.27	0.222	5.63	0.180	4.56	0.082	2.08	0.086	2.18	-0.001	-0.02	0.031	0.80
163.39	726.79	383.76	1707.05	0.233	5.91	0.190	4.83	0.085	2.16	0.088	2.25	-0.001	-0.02	0.031	0.79
176.65	785.77	416.46	1852.51	0.256	6.50	0.218	5.55	0.091	2.32	0.091	2.31	-0.001	-0.02	0.039	0.99
182.59	812.20	437.40	1945.65	0.265	6.73	0.227	5.76	0.094	2.38	0.091	2.31	-0.001	-0.02	0.039	0.99
190.87	849.03	457.92	2036.93	0.277	7.04	0.241	6.11	0.097	2.46	0.091	2.31	-0.001	-0.02	0.039	0.99
202.15	899.21	483.30	2149.83	0.288	7.31	0.253	6.42	0.100	2.55	0.092	2.33	-0.001	-0.03	0.039	0.99
213.25	948.59	511.44	2275.00	0.300	7.62	0.267	6.79	0.105	2.66	0.094	2.38	-0.001	-0.03	0.048	1.22
224.53	998.76	538.80	2396.70	0.313	7.94	0.282	7.16	0.109	2.77	0.095	2.40	-0.001	-0.03	0.048	1.22
235.75	1048.68	565.32	2514.67	0.325	8.24	0.297	7.54	0.113	2.87	0.095	2.41	-0.001	-0.03	0.056	1.43
243.55	1083.37	585.96	2606.48	0.335	8.52	0.310	7.86	0.117	2.97	0.095	2.41	-0.002	-0.04	0.056	1.43
254.41	1131.68	611.28	2719.11	0.349	8.85	0.325	8.25	0.121	3.08	0.095	2.42	-0.002	-0.04	0.056	1.42
264.61	1177.06	636.48	2831.20	0.362	9.20	0.340	8.63	0.125	3.18	0.096	2.43	-0.002	-0.05	0.066	1.69
273.01	1214.43	657.66	2925.42	0.374	9.50	0.354	8.99	0.128	3.26	0.096	2.44	-0.002	-0.05	0.067	1.69
283.39	1260.60	681.54	3031.64	0.389	9.88	0.370	9.39	0.132	3.34	0.096	2.44	-0.002	-0.05	0.067	1.69
292.15	1299.57	703.38	3128.79	0.404	10.25	0.386	9.81	0.135	3.43	0.096	2.44	-0.002	-0.05	0.074	1.88
298.45	1327.59	716.70	3188.04	0.414	10.53	0.400	10.16	0.138	3.52	0.096	2.45	-0.002	-0.05	0.074	1.87
305.36	1358.29	728.82	3241.95	0.427	10.83	0.415	10.54	0.141	3.58	0.096	2.44	-0.002	-0.05	0.074	1.88
305.84	1360.42	737.10	3278.78	0.448	11.38	0.438	11.11	0.144	3.66	0.096	2.45	-0.002	-0.05	0.085	2.16
310.76	1382.31	749.28	3332.96	0.468	11.88	0.459	11.65	0.147	3.73	0.096	2.44	-0.002	-0.05	0.092	2.35
314.18	1397.52	756.42	3364.72	0.484	12.30	0.476	12.08	0.149	3.78	0.096	2.44	-0.002	-0.05	0.093	2.35
313.58	1394.85	754.80	3357.52	0.488	12.40	0.480	12.20	0.149	3.79	0.096	2.44	-0.002	-0.06	0.093	2.35

Table A.6.2 Measurements of Tendons' slip at South End of Girder E2 – South End Testing (Labib 2012)

S. LC		ST1		ST2		ST3		ST4	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.00	0.000	0.00	0.000	0.00
13.56	60.32	0.000	-0.01	-0.005	-0.14	0.000	0.00	0.000	0.00
37.08	164.94	0.000	0.00	-0.006	-0.14	0.000	0.00	0.000	0.00
87.06	387.26	0.000	0.00	-0.006	-0.14	0.000	0.00	0.000	0.00
138.06	614.12	0.000	0.00	-0.005	-0.14	0.000	0.00	0.000	0.00
190.26	846.32	0.000	0.00	-0.005	-0.14	0.000	0.00	0.000	0.00
243.84	1084.65	0.000	-0.01	-0.006	-0.14	0.000	0.00	0.000	0.00
299.64	1332.87	0.000	0.00	-0.006	-0.14	0.000	0.00	0.000	0.00
355.86	1582.94	0.000	0.00	-0.006	-0.14	0.000	0.00	0.000	0.00
416.28	1851.71	0.000	0.00	-0.006	-0.14	0.000	0.00	0.002	0.06
437.40	1945.65	0.000	0.00	-0.006	-0.15	0.000	0.00	0.006	0.14
467.88	2081.23	0.000	0.00	-0.004	-0.10	0.000	0.01	0.025	0.63
501.96	2232.83	0.001	0.02	-0.002	-0.05	0.004	0.09	0.032	0.81
534.84	2379.09	0.001	0.03	0.001	0.03	0.011	0.28	0.037	0.94
565.62	2516.00	0.002	0.06	0.005	0.12	0.015	0.39	0.040	1.02
598.32	2661.46	0.004	0.11	0.011	0.28	0.021	0.53	0.045	1.13
630.84	2806.12	0.007	0.19	0.018	0.46	0.027	0.69	0.050	1.28
661.20	2941.16	0.012	0.31	0.026	0.66	0.034	0.85	0.056	1.43
690.66	3072.21	0.018	0.47	0.034	0.85	0.041	1.04	0.063	1.60
718.50	3196.05	0.028	0.71	0.045	1.14	0.051	1.28	0.072	1.83
743.70	3308.14	0.054	1.38	0.076	1.93	0.079	2.02	0.096	2.44
756.42	3364.72	0.068	1.73	0.095	2.40	0.106	2.69	0.113	2.86
754.80	3357.52	0.071	1.80	0.098	2.49	0.111	2.81	0.116	2.95

Table A.6.2 Measurements of Tendons' slip at South End of Girder E2 – South End Testing (Labib 2012) (Cont'd)

S. LC		ST5		ST6		ST7		ST8	
kips	KN	in.	mm	in.	mm	in.	mm	in.	mm
0.00	0.00	0.000	0.00	0.000	0.01	0.000	0.00	0.000	0.00
13.56	60.32	-0.002	-0.05	0.000	0.00	0.000	0.00	0.000	0.00
37.08	164.94	-0.002	-0.05	0.000	0.00	0.000	0.00	0.000	0.00
87.06	387.26	-0.002	-0.05	0.000	0.00	-0.001	-0.03	0.000	0.00
138.06	614.12	-0.002	-0.05	0.000	-0.01	0.000	0.00	0.000	0.00
190.26	846.32	-0.002	-0.05	0.000	0.00	-0.001	-0.03	0.000	0.00
243.84	1084.65	-0.002	-0.05	0.000	0.00	-0.001	-0.03	0.000	0.00
299.64	1332.87	-0.002	-0.05	0.000	0.00	0.000	0.00	0.000	0.00
355.86	1582.94	-0.002	-0.05	-0.001	-0.01	-0.001	-0.02	0.000	0.00
416.28	1851.71	-0.002	-0.05	0.000	0.00	-0.001	-0.02	0.000	0.00
437.40	1945.65	-0.002	-0.05	0.000	-0.01	-0.001	-0.02	0.000	0.00
467.88	2081.23	0.000	0.00	0.000	0.00	-0.001	-0.02	0.000	0.00
501.96	2232.83	0.002	0.04	0.000	0.00	-0.001	-0.02	0.000	0.00
534.84	2379.09	0.003	0.09	0.001	0.03	-0.001	-0.02	0.000	0.00
565.62	2516.00	0.005	0.14	0.002	0.05	-0.001	-0.02	0.000	0.00
598.32	2661.46	0.009	0.22	0.004	0.10	0.000	0.01	0.000	0.00
630.84	2806.12	0.012	0.31	0.006	0.16	0.000	0.01	0.000	0.00
661.20	2941.16	0.017	0.43	0.010	0.25	0.002	0.06	0.000	0.00
690.66	3072.21	0.024	0.60	0.016	0.40	0.003	0.07	0.000	0.00
718.50	3196.05	0.033	0.84	0.026	0.67	0.004	0.11	0.000	0.00
743.70	3308.14	0.050	1.27	0.049	1.26	0.010	0.26	0.000	0.00
756.42	3364.72	0.060	1.52	0.060	1.54	0.015	0.37	0.000	0.00
754.80	3357.52	0.062	1.56	0.062	1.57	0.014	0.36	0.000	0.00

Table A.6.3 Measurements of LVDTs for South Rosette Strains of Girder E2 – South End Testing (Labib 2012)

S. LC		SED1	SWD1	SD1 AVG	SED2	SWD2	SD2 AVG
kips	KN						
0.00	0.00	0.000002	0.000001	0.000002	0.000001	0.000002	0.000002
13.56	60.32	0.000005	0.000002	0.000004	0.000007	0.000011	0.000009
37.08	164.94	0.000005	-0.000010	-0.000003	0.000012	0.000012	0.000012
87.06	387.26	0.000007	-0.000036	-0.000015	0.000025	0.000011	0.000018
138.06	614.12	-0.000009	-0.000077	-0.000043	0.000033	0.000037	0.000035
190.26	846.32	-0.000048	-0.000120	-0.000084	0.000049	0.000049	0.000049
243.84	1084.65	-0.000090	-0.000162	-0.000126	0.000069	0.000066	0.000068
299.64	1332.87	-0.000125	-0.000206	-0.000166	0.000087	0.000086	0.000087
355.86	1582.94	-0.000166	-0.000255	-0.000211	0.000113	0.000108	0.000111
416.28	1851.71	-0.000278	-0.000339	-0.000309	0.000529	0.000562	0.000546
437.40	1945.65	-0.000279	-0.000369	-0.000324	0.000592	0.000603	0.000598
467.88	2081.23	-0.000376	-0.000414	-0.000395	0.000813	0.000830	0.000822
501.96	2232.83	-0.000438	-0.000466	-0.000452	0.000959	0.000977	0.000968
534.84	2379.09	-0.000518	-0.000526	-0.000522	0.001113	0.001124	0.001119
565.62	2516.00	-0.000623	-0.000585	-0.000604	0.001270	0.001287	0.001279
598.32	2661.46	-0.000743	-0.000652	-0.000698	0.001466	0.001488	0.001477
630.84	2806.12	-0.000825	-0.000727	-0.000776	0.001667	0.001682	0.001675
661.20	2941.16	-0.000916	-0.000809	-0.000863	0.001870	0.001885	0.001878
690.66	3072.21	-0.000994	-0.000894	-0.000944	0.002082	0.002096	0.002089
718.50	3196.05	-0.001087	-0.000999	-0.001043	0.002349	0.002352	0.002351
743.70	3308.14	-0.001274	-0.001220	-0.001247	0.002971	0.002968	0.002970
756.42	3364.72	-0.001441	-0.001389	-0.001415	0.003333	0.003314	0.003324
754.80	3357.52	-0.001490	-0.001406	-0.001448	0.003401	0.003381	0.003391

Table A.6.3 Measurements of LVDTs for South Rosette Strains of Girder E2 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEV1	SWV1	SV1 AVG	SEV2	SWV2	SV2 AVG
kips	KN						
0.00	0.00	0.000011	MF.	0.000011	0.000000	0.000001	0.000001
13.56	60.32	0.000023	MF.	0.000023	0.000004	0.000003	0.000004
37.08	164.94	0.000000	MF.	0.000000	-0.000019	0.000013	-0.000003
87.06	387.26	0.000000	MF.	0.000000	-0.000037	0.000025	-0.000006
138.06	614.12	0.000037	MF.	0.000037	-0.000066	0.000025	-0.000021
190.26	846.32	0.000039	MF.	0.000039	-0.000075	0.000027	-0.000024
243.84	1084.65	0.000031	MF.	0.000031	-0.000099	0.000026	-0.000037
299.64	1332.87	0.000021	MF.	0.000021	-0.000132	0.000026	-0.000053
355.86	1582.94	0.000005	MF.	0.000005	-0.000170	0.000024	-0.000073
416.28	1851.71	0.000083	MF.	0.000083	0.000329	0.000435	0.000382
437.40	1945.65	0.000137	MF.	0.000137	0.000369	0.000457	0.000413
467.88	2081.23	0.000350	MF.	0.000350	0.000589	0.000663	0.000626
501.96	2232.83	0.000486	MF.	0.000486	0.000710	0.000772	0.000741
534.84	2379.09	0.000628	MF.	0.000628	0.000794	0.000880	0.000837
565.62	2516.00	0.000776	MF.	0.000776	0.000855	0.001028	0.000942
598.32	2661.46	0.000947	MF.	0.000947	0.000958	0.001226	0.001092
630.84	2806.12	0.001116	MF.	0.001116	0.001030	0.001378	0.001204
661.20	2941.16	0.001288	MF.	0.001288	0.001110	0.001518	0.001314
690.66	3072.21	0.001471	MF.	0.001471	0.001185	0.001648	0.001417
718.50	3196.05	0.001718	MF.	0.001718	0.001228	0.001819	0.001524
743.70	3308.14	0.002317	MF.	0.002317	0.001849	0.002195	0.002022
756.42	3364.72	0.002653	MF.	0.002653	0.002144	0.002358	0.002251
754.80	3357.52	0.002720	MF.	0.002720	0.002196	0.002400	0.002298

Table A.6.3 Measurements of LVDTs for South Rosette Strains of Girder E2 – South End Testing (Labib 2012) (Cont'd)

S. LC		SEH1	SWH1	SH1 AVG	SEH2	SWH2	SH2 AVG
kips	KN						
0.00	0.00	0.000000	0.000002	0.000001	-0.000037	0.000000	-0.000019
13.56	60.32	0.000006	0.000008	0.000007	0.000000	0.000006	0.000003
37.08	164.94	-0.000016	-0.000002	-0.000009	-0.000026	0.000006	-0.000010
87.06	387.26	-0.000029	-0.000026	-0.000028	-0.000002	0.000006	0.000002
138.06	614.12	-0.000057	-0.000054	-0.000056	0.000001	-0.000012	-0.000006
190.26	846.32	-0.000072	-0.000082	-0.000077	0.000000	-0.000012	-0.000006
243.84	1084.65	-0.000087	-0.000111	-0.000099	-0.000008	-0.000012	-0.000010
299.64	1332.87	-0.000099	-0.000140	-0.000120	-0.000004	-0.000012	-0.000008
355.86	1582.94	-0.000111	-0.000164	-0.000138	-0.000012	-0.000012	-0.000012
416.28	1851.71	-0.000142	-0.000222	-0.000182	0.000015	-0.000109	-0.000047
437.40	1945.65	-0.000139	-0.000224	-0.000182	-0.000004	-0.000109	-0.000057
467.88	2081.23	-0.000147	-0.000248	-0.000198	-0.000035	-0.000147	-0.000091
501.96	2232.83	-0.000148	-0.000266	-0.000207	-0.000065	-0.000177	-0.000121
534.84	2379.09	-0.000150	-0.000279	-0.000215	-0.000108	-0.000210	-0.000159
565.62	2516.00	-0.000170	-0.000273	-0.000222	-0.000154	-0.000244	-0.000199
598.32	2661.46	-0.000198	-0.000262	-0.000230	-0.000213	-0.000286	-0.000250
630.84	2806.12	-0.000256	-0.000287	-0.000272	-0.000273	-0.000329	-0.000301
661.20	2941.16	-0.000312	-0.000324	-0.000318	-0.000341	-0.000376	-0.000359
690.66	3072.21	-0.000384	-0.000345	-0.000365	-0.000418	-0.000420	-0.000419
718.50	3196.05	-0.000496	-0.000387	-0.000442	-0.000526	-0.000482	-0.000504
743.70	3308.14	-0.000549	-0.000446	-0.000498	-0.000807	-0.000601	-0.000704
756.42	3364.72	-0.000590	-0.000462	-0.000526	-0.001005	-0.000660	-0.000833
754.80	3357.52	-0.000594	-0.000473	-0.000534	-0.001072	-0.000660	-0.000866

Table A.6.4 Measurements of LVDTs for North Rosette Strains of Girder E2 – South End Testing (Labib 2012)

N. LC		NWD1	NED1	ND1 AVG	NWD2	NED2	ND2 AVG
kips	KN						
-0.06	-0.27	0.000004	0.000000	0.000002	0.000005	0.000014	0.000010
6.00	26.69	0.000006	0.000002	0.000004	0.000000	0.000013	0.000007
16.02	71.26	-0.000001	0.000002	0.000001	0.000000	0.000008	0.000004
37.68	167.62	-0.000021	-0.000006	-0.000014	0.000005	0.000005	0.000005
59.70	265.57	-0.000044	-0.000029	-0.000037	0.000011	0.000022	0.000017
81.72	363.53	-0.000065	-0.000050	-0.000058	0.000018	-0.000010	0.000004
104.41	464.42	-0.000086	-0.000071	-0.000079	0.000024	0.000000	0.000012
127.93	569.05	-0.000108	-0.000096	-0.000102	0.000030	0.000003	0.000017
151.69	674.74	-0.000128	-0.000120	-0.000124	0.000040	0.000000	0.000020
176.53	785.24	-0.000154	-0.000165	-0.000160	0.000049	0.000000	0.000025
182.59	812.20	-0.000157	-0.000165	-0.000161	0.000048	-0.000010	0.000019
195.25	868.51	-0.000167	-0.000165	-0.000166	0.000049	0.000024	0.000037
209.11	930.17	-0.000177	-0.000173	-0.000175	0.000054	0.000021	0.000038
222.85	991.29	-0.000187	-0.000186	-0.000187	0.000057	0.000002	0.000030
236.05	1050.01	-0.000195	-0.000199	-0.000197	0.000064	0.000013	0.000039
248.95	1107.40	-0.000207	-0.000209	-0.000208	0.000070	-0.000002	0.000034
262.51	1167.72	-0.000217	-0.000219	-0.000218	0.000073	0.000026	0.000050
275.05	1223.50	-0.000226	-0.000228	-0.000227	0.000080	0.000000	0.000040
286.99	1276.61	-0.000234	-0.000238	-0.000236	0.000086	0.000024	0.000055
299.89	1334.00	-0.000245	-0.000248	-0.000247	0.000094	0.000022	0.000058
308.96	1374.30	-0.000250	-0.000261	-0.000256	0.000097	0.000014	0.000056
314.18	1397.52	-0.000256	-0.000264	-0.000260	0.000099	0.000011	0.000055
313.58	1394.85	-0.000256	-0.000266	-0.000261	0.000099	-0.000005	0.000047

Table A.6.4 Measurements of LVDTs for North Rosette Strains of Girder E2 – South End Testing (Labib 2012) (Cont'd)

N. LC		NWV1	NEV1	NV1 AVG	NWV2	NEV2	NV2 AVG
kips	KN						
-0.06	-0.27	-0.000002	-0.000005	-0.000004	0.000007	0.000000	0.000004
6.00	26.69	-0.000004	0.000004	0.000000	0.000014	0.000001	0.000008
16.02	71.26	-0.000004	0.000001	-0.000002	0.000014	0.000001	0.000008
37.68	167.62	-0.000004	0.000005	0.000001	0.000014	-0.000001	0.000007
59.70	265.57	-0.000004	0.000009	0.000003	0.000014	0.000000	0.000007
81.72	363.53	0.000000	0.000002	0.000001	0.000014	0.000001	0.000008
104.41	464.42	-0.000002	0.000003	0.000001	0.000012	0.000002	0.000007
127.93	569.05	0.000002	0.000006	0.000004	0.000012	0.000002	0.000007
151.69	674.74	0.000000	0.000005	0.000003	0.000014	0.000001	0.000008
176.53	785.24	-0.000007	0.000005	-0.000001	0.000014	-0.000001	0.000007
182.59	812.20	-0.000009	0.000002	-0.000004	0.000014	-0.000002	0.000006
195.25	868.51	-0.000007	-0.000002	-0.000005	0.000016	0.000000	0.000008
209.11	930.17	-0.000009	0.000004	-0.000003	0.000012	-0.000001	0.000006
222.85	991.29	-0.000009	0.000007	-0.000001	0.000014	-0.000001	0.000007
236.05	1050.01	-0.000009	0.000003	-0.000003	0.000012	-0.000003	0.000005
248.95	1107.40	-0.000013	0.000004	-0.000005	0.000009	-0.000004	0.000003
262.51	1167.72	-0.000009	0.000001	-0.000004	0.000014	-0.000002	0.000006
275.05	1223.50	-0.000004	0.000004	0.000000	0.000016	-0.000001	0.000008
286.99	1276.61	-0.000009	-0.000003	-0.000006	0.000014	-0.000001	0.000007
299.89	1334.00	-0.000004	0.000007	0.000002	0.000012	-0.000001	0.000006
308.96	1374.30	-0.000007	0.000000	-0.000004	0.000012	-0.000001	0.000006
314.18	1397.52	-0.000004	-0.000001	-0.000003	0.000012	0.000000	0.000006
313.58	1394.85	-0.000004	0.000004	0.000000	0.000014	0.000000	0.000007

Table A.6.4 Measurements of LVDTs for North Rosette Strains of Girder E2 – South End Testing (Labib 2012) (Cont'd)

N. LC		NWH1	NEH1	NH1 AVG	NWH2	NEH2	NH2 AVG
kips	KN						
-0.06	-0.27	0.000001	0.000000	0.000001	0.000001	0.000001	0.000001
6.00	26.69	-0.000004	-0.000001	-0.000003	-0.000002	0.000002	0.000000
16.02	71.26	-0.000021	-0.000015	-0.000018	0.000000	-0.000006	-0.000003
37.68	167.62	-0.000055	-0.000031	-0.000043	-0.000001	-0.000006	-0.000004
59.70	265.57	-0.000090	-0.000065	-0.000078	-0.000001	0.000000	-0.000001
81.72	363.53	-0.000123	-0.000099	-0.000111	-0.000001	0.000001	0.000000
104.41	464.42	-0.000155	-0.000136	-0.000146	-0.000001	0.000000	-0.000001
127.93	569.05	-0.000186	-0.000167	-0.000177	-0.000001	0.000001	0.000000
151.69	674.74	-0.000215	-0.000197	-0.000206	-0.000001	0.000002	0.000001
176.53	785.24	-0.000241	-0.000256	-0.000249	-0.000007	0.000014	0.000004
182.59	812.20	-0.000247	-0.000258	-0.000253	-0.000008	0.000014	0.000003
195.25	868.51	-0.000263	-0.000258	-0.000261	-0.000007	0.000014	0.000004
209.11	930.17	-0.000275	-0.000262	-0.000269	-0.000007	0.000014	0.000004
222.85	991.29	-0.000289	-0.000276	-0.000283	-0.000008	0.000012	0.000002
236.05	1050.01	-0.000296	-0.000291	-0.000294	-0.000007	0.000014	0.000004
248.95	1107.40	-0.000307	-0.000308	-0.000308	-0.000007	0.000013	0.000003
262.51	1167.72	-0.000319	-0.000311	-0.000315	-0.000007	0.000013	0.000003
275.05	1223.50	-0.000326	-0.000317	-0.000322	-0.000007	0.000014	0.000004
286.99	1276.61	-0.000333	-0.000324	-0.000329	-0.000007	0.000015	0.000004
299.89	1334.00	-0.000343	-0.000334	-0.000339	-0.000007	0.000015	0.000004
308.96	1374.30	-0.000350	-0.000342	-0.000346	-0.000007	0.000015	0.000004
314.18	1397.52	-0.000357	-0.000347	-0.000352	-0.000010	0.000014	0.000002
313.58	1394.85	-0.000359	-0.000347	-0.000353	-0.000009	0.000015	0.000003

Table A.6.5 Measurements of South Strain Gauges on Transverse Steel Bars of Girder E2 – South End Testing (Labib 2012)

S. LC		S1	S2	S3	S4	S5	S6
Kips	KN						
0.00	0.00	0.000001	0.000002	0.000003	0.000001	0.000003	0.000002
13.56	60.32	0.000009	0.000003	0.000011	0.000002	0.000010	0.000001
37.08	164.94	0.000018	0.000008	0.000021	0.000005	0.000019	0.000004
87.06	387.26	0.000018	0.000010	0.000031	0.000004	0.000022	0.000002
138.06	614.12	0.000024	0.000015	0.000039	0.000009	0.000026	0.000007
190.26	846.32	0.000035	0.000023	0.000049	0.000015	0.000032	0.000042
243.84	1084.65	0.000030	0.000022	0.000052	0.000012	0.000028	0.000048
299.64	1332.87	0.000037	0.000025	0.000062	0.000016	0.000030	0.000041
355.86	1582.94	0.000053	0.000030	0.000078	0.000023	0.000030	0.000028
416.28	1851.71	0.002604	0.002030	0.001977	0.002184	0.001929	0.000641
437.40	1945.65	0.002604	0.002347	0.002330	0.002505	A.G.	0.000715
467.88	2081.23	0.001142	A.G.	A.G.	A.G.	A.G.	0.000929
501.96	2232.83	0.001120	A.G.	A.G.	A.G.	A.G.	0.001052
534.84	2379.09	0.001118	A.G.	A.G.	A.G.	A.G.	0.001167
565.62	2516.00	0.002604	A.G.	A.G.	A.G.	A.G.	0.001268
598.32	2661.46	0.001165	A.G.	A.G.	A.G.	A.G.	0.001356
630.84	2806.12	A.G.	A.G.	A.G.	A.G.	A.G.	0.001379
661.20	2941.16	A.G.	A.G.	A.G.	A.G.	A.G.	0.001441
690.66	3072.21	A.G.	A.G.	A.G.	A.G.	A.G.	0.001501
718.50	3196.05	A.G.	A.G.	A.G.	A.G.	A.G.	0.001607
743.70	3308.14	A.G.	A.G.	A.G.	A.G.	A.G.	0.001968
756.42	3364.72	A.G.	A.G.	A.G.	A.G.	A.G.	A.G.
754.80	3357.52	A.G.	A.G.	A.G.	A.G.	A.G.	A.G.

Table A.6.6 Measurements of North Strain Gauges on Transverse Steel Bars of Girder E2 – South End Testing (Labib 2012)

N. LC		N1	N2	N3	N4	N5	N6	N7
kips	KN							
-0.06	-0.27	0.000008	0.000008	0.000000	-0.000052	0.000000	0.000042	-0.000028
6.00	26.69	-0.000005	0.000042	0.000008	-0.000125	0.000003	0.000066	-0.000051
16.02	71.26	0.000049	0.000070	-0.000312	-0.000005	-0.000120	0.000250	0.000048
37.68	167.62	0.000050	0.000071	-0.000310	-0.000004	-0.000118	0.000250	0.000048
59.70	265.57	0.000051	0.000073	-0.000307	-0.000002	-0.000115	0.000252	0.000049
81.72	363.53	0.000053	0.000074	-0.000305	-0.000002	-0.000112	0.000252	0.000049
104.41	464.42	0.000053	0.000074	-0.000315	-0.000008	-0.000083	0.000247	0.000045
127.93	569.05	0.000053	0.000073	-0.000319	-0.000011	-0.000059	0.000243	0.000043
151.69	674.74	0.000000	0.000013	0.000001	-0.000125	0.000033	0.000144	-0.000040
176.53	785.24	0.000051	0.000076	-0.000034	-0.000182	0.000067	0.000082	-0.000034
182.59	812.20	0.000055	0.000079	0.000017	-0.000179	0.000017	0.000086	-0.000034
195.25	868.51	0.000111	0.000118	-0.000017	-0.000278	0.000059	-0.000013	0.000009
209.11	930.17	0.000185	0.000194	0.000022	-0.000351	0.000019	-0.000096	0.000007
222.85	991.29	0.000184	0.000193	0.000025	-0.000314	0.000021	-0.000039	-0.000088
236.05	1050.01	-0.000029	-0.000029	-0.000010	-0.000159	0.000058	0.000121	0.000005
248.95	1107.40	-0.000072	0.000425	0.000032	0.000150	0.000023	-0.000201	-0.000382
262.51	1167.72	-0.000074	0.000422	0.000030	0.000148	0.000022	-0.000503	-0.000085
275.05	1223.50	-0.000072	0.000423	0.000031	0.000150	0.000023	-0.000258	-0.000330
286.99	1276.61	-0.000071	0.000423	0.000031	0.000151	0.000024	-0.000259	-0.000329
299.89	1334.00	-0.000065	0.000422	0.000033	0.000153	0.000025	-0.000259	-0.000328
308.96	1374.30	-0.000061	0.000423	0.000035	0.000155	0.000027	-0.000257	-0.000324
314.18	1397.52	-0.000060	0.000423	0.000035	0.000157	0.000027	-0.000256	-0.000323
313.58	1394.85	0.001244	0.001142	0.000030	0.000144	0.000029	-0.000257	-0.000325