DESIGN AIDS OF NEBRASKA(NU) PRECAST/PRESTRESSED I-GIRDER BRIDGES

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ABSTRACT:

This paper presents the preliminary design charts for precast prestressed concrete NU-I girder bridges. Two sets of charts were developed to cover simple span bridges and two-span continuous bridges. The design aids were developed in accordance with the 2007 AASHTO LRFD Specifications for superstructure design and 2008 Nebraska Department of Roads(NDOR) Bridge Operations, Polices, and Procedures (BOPP manual).

This paper also presents the various factors involved in preliminary superstructure bridge design and their effect on the maximum bridge girder span. These factors include: girder section (from NU 900 to NU 2000), girder spacing (from 6-12 ft.), prestressing strands (up to 60), prestressing strand diameter (from 0.6 to 0.7 inch), and compressive strength of concrete (from 8 ksi to 15 ksi). The design of the girder strength at release was performed in accordance with the strength design method and the working stress method. A comparison of these results will be included. For multi-span bridges, threaded rod (TR) continuity system was used. This system allows the girders to be continuous for deck weight as well as live load. All of these design factors will be compared and analyzed to allow for an efficient preliminary bridge design.

Keywords: Design charts, NU-I girders, threaded rod continuity, strength design method, 0.7 inch strands, high strength concrete.

INTRODUCTION:

Precast prestressed concrete girder bridges have become the most dominate bridge system in the United States. In the early design stages, preliminary design becomes a vital first step in designing an economical bridge. Within the state of Nebraska, the two standard precast prestressed products used are Inverted Tee (IT) girders and University of Nebraska (NU) I girders. In the early 1990s, Nebraska Department of Roads (NDOR) developed design charts for NU-I girders in order to assist in member selection and preliminary design. In 2004, design charts were developed for IT girders. However, the NU-I girder charts have since become obsolete because they were developed for low strength concrete (6 ksi) and 0.5 inch prestressing strands. In addition, the charts were based off of AASHTO Standard Specifications. Since then, NDOR has adopted AASHTO LRFD Specifications for superstructure design and the Threaded Rod (TR) continuity systems in their standard practice. Therefore, the new design charts are based on the latest AASHTO LRFD Specifications for superstructure design and NDOR Bridge Operations, Policies, and Procedures (BOPP manual).

With the increasing use of 0.6 and 0.7 inch diameter strands as well as increasing concrete strengths, there is a need for new preliminary design charts for NU-I girders. The new design aids provide bridge designers with different alternatives of girder section size (from NU900 to NU2000), girder spacing (from 6-12ft), prestressing strands (up to 60), prestressing strand diameter (from 0.6 to 0.7 inch), and compressive strength of concrete (from 8ksi to 15ksi). Two sets of design charts are developed to cover simple span and two-span continuous bridges. Each set contains two different type of charts: summary charts and detailed charts. Summary charts give designers the largest possible span length allowed given girder spacing, concrete strength, and NU-I girder sections. Detailed charts give designers the minimum number of prestressing strands required given girder spacing, span length, and concrete strength. Both sets of charts provide designers with the limit state that controls the design. If needed, this allows the design to be optimized in an efficient manner.

All design charts were developed using two different design methods for concrete strength at release: Strength Design Method and Working Stress Method. In the state of Nebraska, the designer is permitted to use the strength design method and/or the working stress method. This allowed for the comparison of the two methods as well as give designers an option on which method to use based off of company policies. For two span continuous girder bridges, the TR continuity system was used. This system allows the deck weight to act continuously throughout the bridge system where as the conventional continuity system is continuous for live load only[1]. A comparison of TR continuity and the conventional bridge continuity system is shown later in this paper.

The new design aids provide bridge designers with an efficient and reliable tool to optimize the selection and preliminary design of NU-I girders. This will eliminate the tedious and time-consuming process of evaluating several alternatives to achieve a feasible and economical design. It is expected that the new design aids will save time, money, and effort spent in performing unnecessary design iterations. The developed design aids will satisfy both current and future needs of bridge designers.

OBJECTIVE:

The overall goal of this paper is to present preliminary design charts for precast prestressed concrete NU-I girder bridges for simple span and continuous span bridge systems. This goal is divided into four different subgroups:

- To present design charts for simple and two span continuous bridge girder systems.
- Investigate the effect of various factors, and their effect on the maximum span length. (i.e. prestressing strands and high strength concrete)
- Compare the differences of Strength Design Method vs. Working Stress Method for girder strength at prestress transfer.
- Investigate the advantages of using threaded rod continuity for multi-span continuous bridge girders vs. the conventional continuity method.

DESIGN PARAMETERS:

The design parameters used in the development of the design charts are shown in Table 1 below. All parameters were selected to satisfy the current and future needs of NDOR. For comparison purposes, it was important to establish a consistent set of design parameters to evaluate the effect of each individual design parameter.

Parameter	Values
Design Code	AASHTO LRFD and NDOR BOPP Manual
Design Criteria	Service III, Strength I Composite, Release Stresses, Shear Limit, Strength I Precast, Negative Moment Fatigue, Crack Control
Strand Type	Grade 270 low-relaxation, Yield Strength=243ksi, Jacking stress=0.75*f_{pu}, E_s = 28500 ksi
Strand Arrangement	7 rows (18,18,12,6,2,2,2) = 60 strands
Strand Spacing (in.)	2 Vertical x 2 Horizontal
Girder Size	NU 900, 1100, 1350, 1600, 1800, 2000
Minimum Assumed Span (ft.)	60
Spacing (ft.)	6, 8, 10, 12
Structural System	Simple Span, Two-Span Continuous (Equal spans)
Girder Compressive Strength at Final (ksi)	8, 10, 12, 15 ksi
Girder Compressive Strength at Release (ksi)	6, 7.5, 9, 11.25 ksi
Deck Compressive Strength (ksi)	4 ksi for girder f'c=8 ksi and 10 ksi, 5 ksi for higher girder strengths
Strand Diameter (in.)	0.6 (for 8, 10, and 12 ksi), 0.7 (for 12 and 15 ksi)
Strand Profile	Straight, Two point draped at 0.4L
Strand Debonding	Maximum of 50% of any row and 25% of total

Table 1: Design Parameters used in Development of Preliminary Design Charts.

GIRDER SECTION (NU 900 to NU 2000):

In the state of Nebraska, one of the most commonly used precast prestressed products is the University of Nebraska (NU) I girders. Six NU-I girders were used in the development of the design charts: NU 900, NU 1100, NU 1350, NU 1600, NU 1800, and NU 2000. All NU-I girders have the same top and bottom flange dimensions. The difference lies in the height of the web. Because the NU-I girders have a constant bottom flange width of 38.4 in., the maximum number of prestressing strands contained in one row within the bottom flange is 18 strands with 2 inch spacing[2]. Table 2 below gives the section properties for the six NU-I girders used in the development of the design charts. Figure 1 shows the typical dimensions and prestressing strand arrangement for NU-I girders.

	A (in^2)	y_t (in.)	w (k/ft)	I (in^4)	h (in.)	y_b (in.)
NU 900	648.1	19.3	0.680	110,262	35.4	16.1
NU 1100	694.6	23.7	0.724	182,279	43.3	19.6
NU 1350	752.7	29.1	0.785	302,334	53.1	24.0
NU 1600	810.8	34.6	0.840	458,482	63.0	28.4
NU 1800	857.3	38.9	0.894	611,328	70.9	32.0
NU 2000	903.8	43.0	0.942	790,592	78.7	35.7

Table 2: Section Properties for NU-I precast girders.

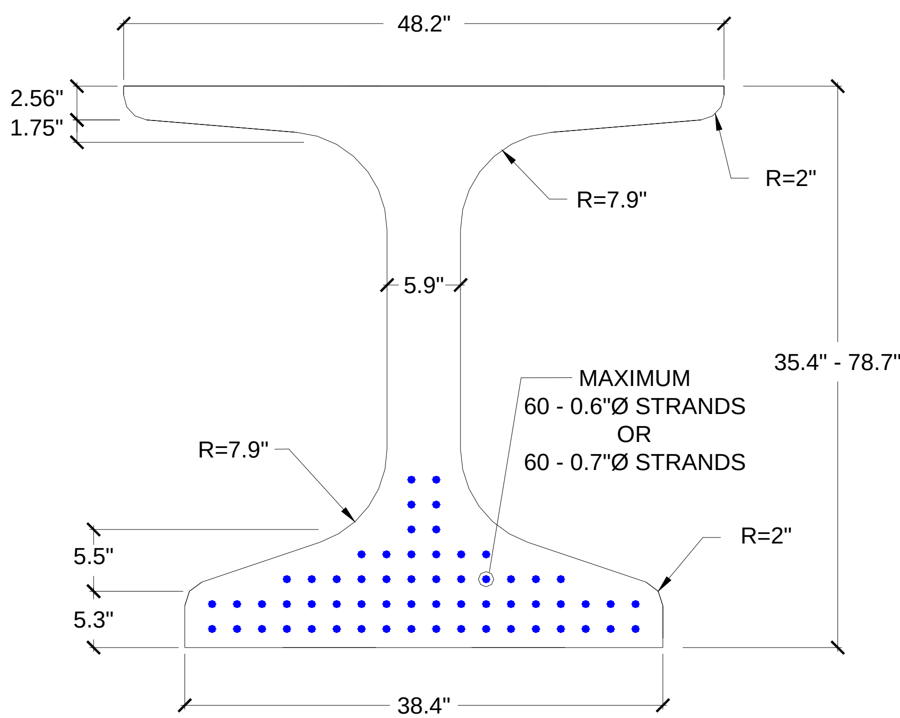

Figure 1: Typical NU-I girder @ midspan.

SIMPLE SPAN:

After establishing all design parameters, the design charts were first developed for simple span bridge girders. Two types of charts were developed: summary charts and detailed charts. The charts will provide the designer with an excellent starting point for preliminary design. Note that the charts also provide the governing limit state controlling the design. This will allow bridge designers to adjust various design parameters if needed to fit their specific design.

SUMMARY CHARTS:

Summary charts display the maximum attainable span versus girder spacing(6, 8, 10, and 12 ft.) for different girder sizes (NU 900, 1100, 1350, 1600, 1800, and 2000). This type of chart is convenient to use in the early stages of design to identify the spacing and approximate girder size to use for a given span length. Figure 2 shows an example of a summary chart. A total of 5 summary charts were developed to represent different combinations of concrete strength: 8, 10, 12 (0.6" and 0.7" strands), and 15 ksi.

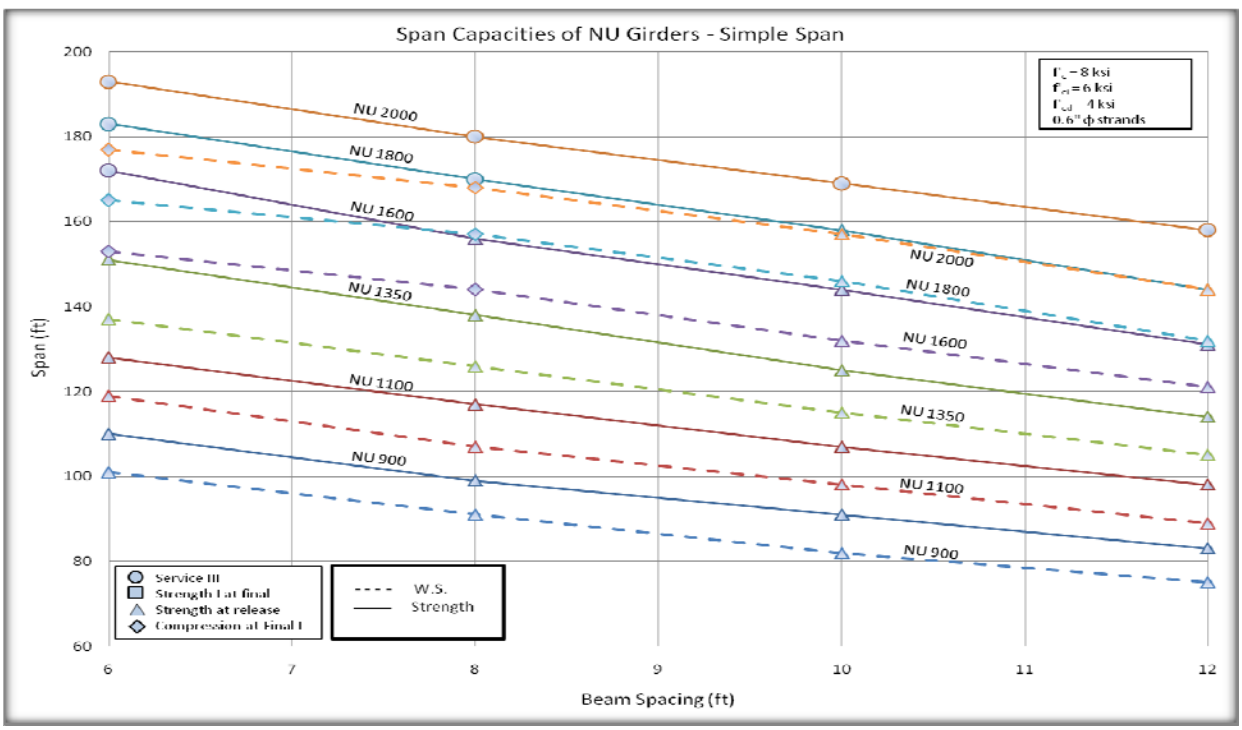

Figure 2: Example of a Summary Chart.

DETAILED CHARTS:

Detailed charts display the required number of strands and concrete strength for a specific girder given the span length and the girder spacing. Figure 3 shows an example of a detailed chart. A total of 30 detailed charts were developed in order to represent different combinations of girder size (NU 900 – NU 2000) and concrete strengths (8, 10, 12, and 15 ksi).

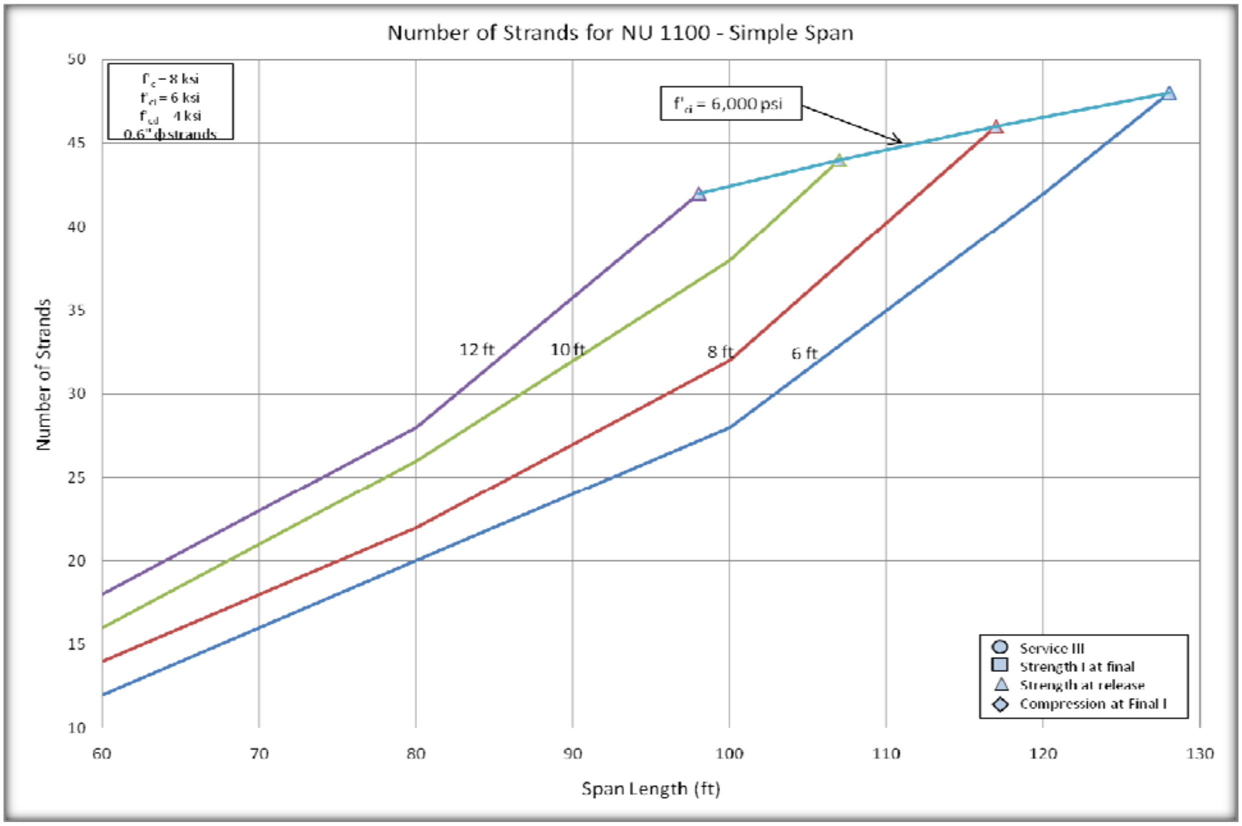

Figure 3: Example of detailed chart using Strength Design Method.

The design charts present the preliminary design information for bridge engineers in a prompt and convenient manner. An example of how to use the design charts is shown in Appendix A.

EFFECT OF DESIGN PARAMETERS:

While preparing the design charts, it was important to compare results obtained from the design and evaluate the effects that variation in design parameters had on the final results. The most important design aspects that affected the design includes: girder type, prestressing strand diameter, concrete strength at release, concrete strength at final, and continuity for multi-span bridges.

GIRDER TYPE (NU-I GIRDER COMPARED WITH AASHTO):

NU-I prestressed precast girders have been adopted by NDOR and are used extensively within the state of Nebraska. The NU-I girders have even been used in other states such Missouri and Texas, as well as in the country of Canada. Figure 4 below shows a comparions of the the maximum span lengths obtained using NU-I and AASHTO prestressed precast girders using constant design parameters. The girders were compared and matched using the height of the girders. For example, NU 1100 was compared with AASHTO Type III girder. It is evident from Figure 4 that the NU-I girders provide a maximum span length of up to 10% longer over using a comparable AASHTO girder.

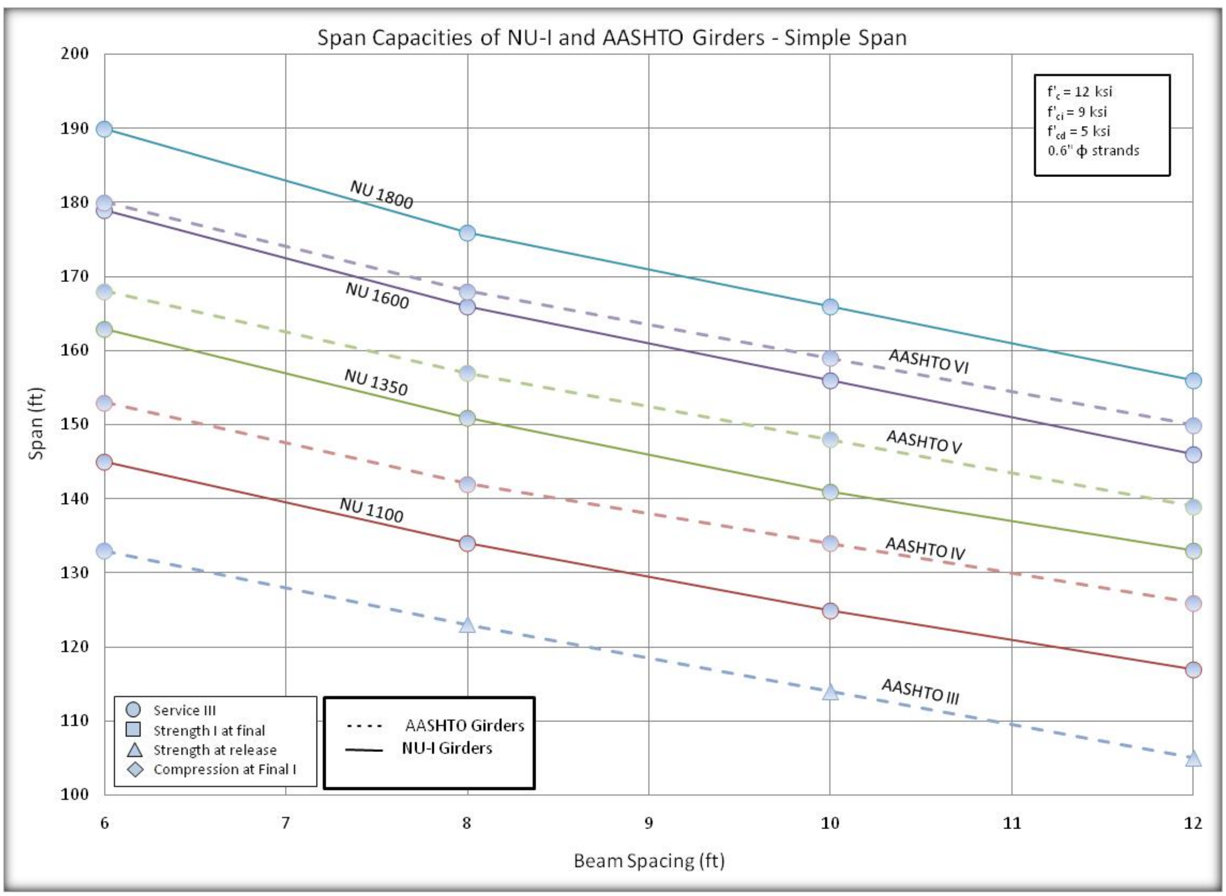

Figure 4: Example of summary chart comparing NU-I and AASHTO girders.

PRESTRESSING STRAND DIAMETER (0.6 inch to 0.7 inch):

Presently, 0.7 inch strands are not commonly used in the industry. However, due to recent successful research, the future of prestressed precast concrete will embrace the use of 0.7inch prestressing strands.

The use of 0.7 inch strands is in direct correlation with high strength concrete (HSC). There is a significant increase in the moment capacity when 0.6 and 0.7 inch strands are used in comparison with 0.5 inch strands. This increase occurs because the tensile force in the strands must reach equilibrium with the compressive forces occurring in the deck and girder. If the depth of the compression block in the top flange exceeds the deck thickness and reaches the top flange of the girder, the high concrete strength of the girder becomes an important factor in determining the moment capacity of the composite section.

The increase in strand diameter from 0.6 to 0.7 inch creates approximately 35% more prestressing area, which correlates to 35% more prestressing force. From 0.5 to 0.7 inch, there is a 92% increase in prestressing force. The use of larger prestressing strands allow for shallower section depths and longer span lengths. This would also result in significant savings in material and labor costs due to the decrease in the amount of prestressing strands. The use of fewer prestressing strands results in fewer number of chucks used in the pretensioning process, also resulting in a decrease in labor costs.

Figure 5 and Figure 6 below show the comparison of 0.6 and 0.7 inch prestressing strands using 12 ksi concrete. The summary chart in Figure 5 shows the maximum attainable span length vs. girder spacing. The detailed chart in Figure 6 shows the minimum number of prestressing strands needed vs. span length for an NU 900 girder.

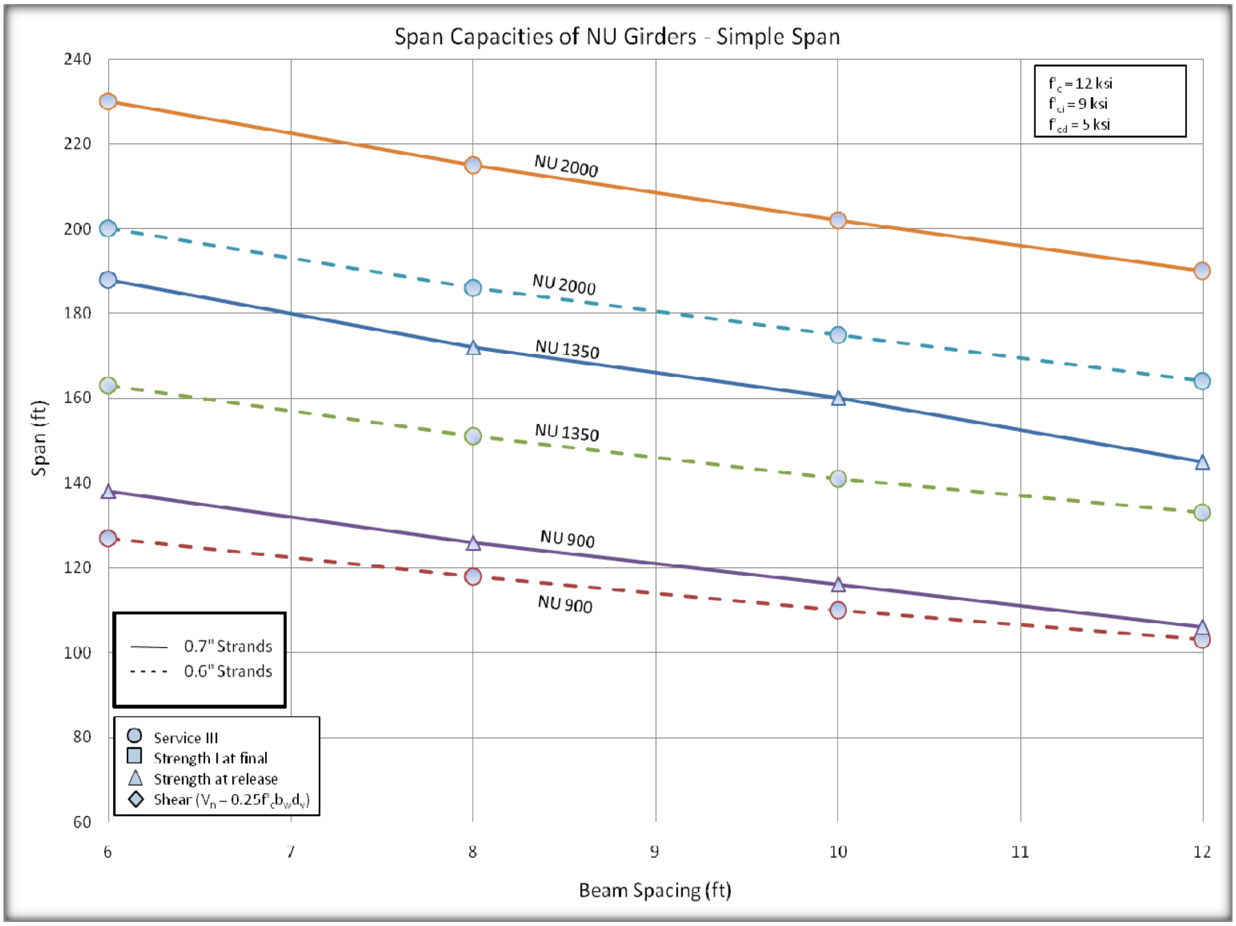

Figure 5: Summary chart comparison between 0.6 and 0.7 inch strands.

For clarity purposes, only NU 900, 1350, and 2000 are graphed. However, it is still quite clear that the use of 0.7 inch strands over 0.6 inch strands allows for a significant increase in span capacity. The largest variation in span length occurs with NU 2000 at 6ft girder spacing with a 15% increase in maximum span length. It is important to note that for smaller sections such as NU 900, there is an increase of 9% in maximum span length. This distinction occurs due to the strength at release limit state controlling the design. However, there is still a significant increase in span length when comparing 0.6 to 0.7 inch strands.

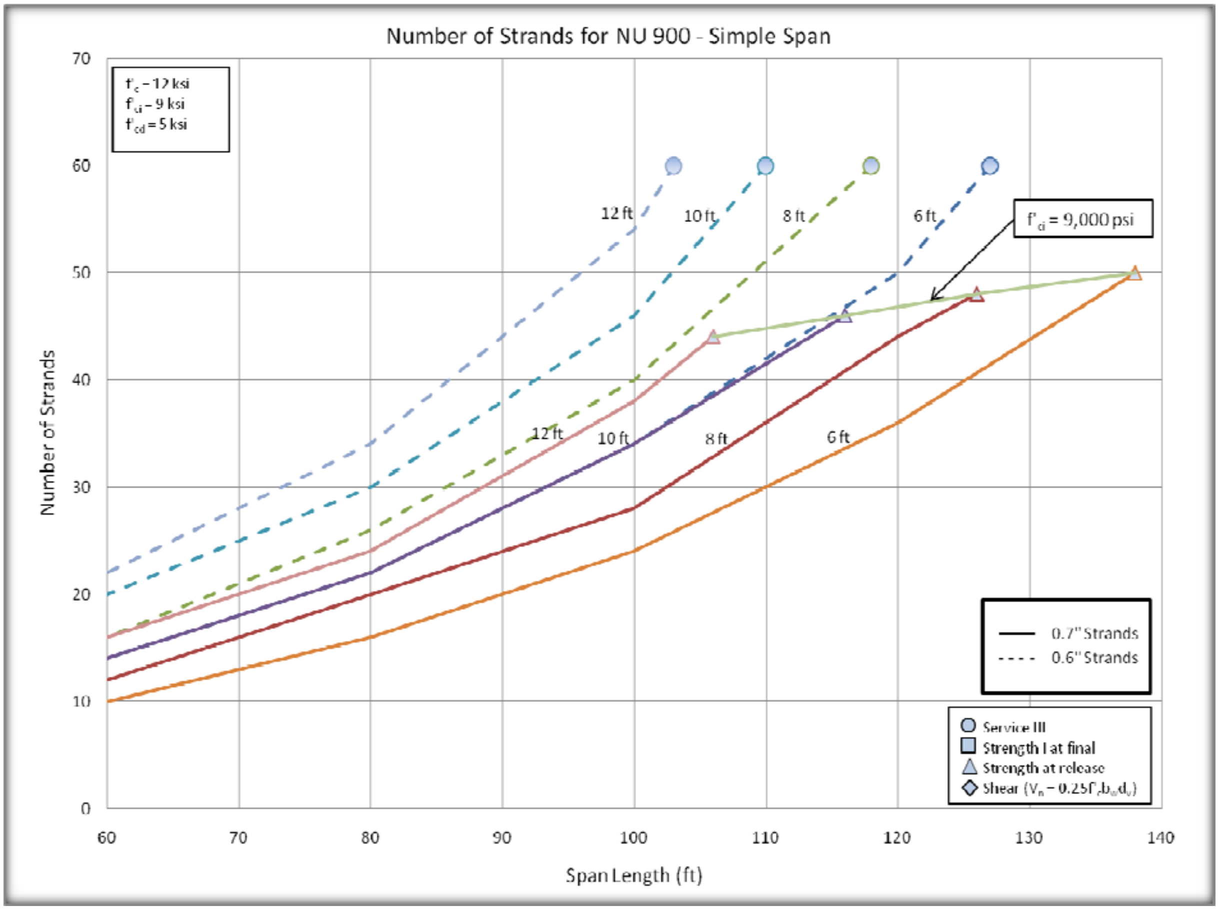

Figure 6: Detailed chart comparison between 0.6 and 0.7 inch strands.

The detailed chart in Figure 6 shows similarities to the summary chart in Figure 5. The girders using 0.6 inch strands are all controlled due to Service III limit state and can utilize the maximum 60 prestressing strands. For 0.7 inch strands, Strength at Release limit state governs the design. However, longer span lengths are attainable with fewer prestressing strands, which results in a significant decrease in material and labor costs.

COMPRESSIVE STRENGTH OF CONCRETE (8 ksi to 15 ksi):

The use of high strength concrete(HSC) is another significant aspect of precast/prestressed concrete design. Generally, standard concrete strength used in the state of Nebraska has been 8 ksi. HSC allows for higher compressive strength with very little increase in cost compared to 6 ksi. As stated before, HSC is especially important when used in correlation with 0.7 inch prestressing strands. The design charts created include concrete compressive strengths of 8, 10, 12, and 15 ksi. Compressive strengths of 8, 10, and 12 ksi include the use of 0.6 inch prestressing strands. Compressive strength of 12 and 15 ksi include the use of 0.7 inch prestressing strands. The compressive concrete strength at release is equivalent to $0.75*f'_c$.

The summary chart in Figure 7 and detailed chart in Figure 8 show the relationship between different compressive concrete strengths of 8, 10, and 12 ksi using 0.6 inch prestressing strands. As seen in the chart, NU 2000 has approximately a 4% increase in span length between 8 and 12 ksi. However, NU 900 has a 24% increase in span length, mostly due to the Strength at Release limit state.

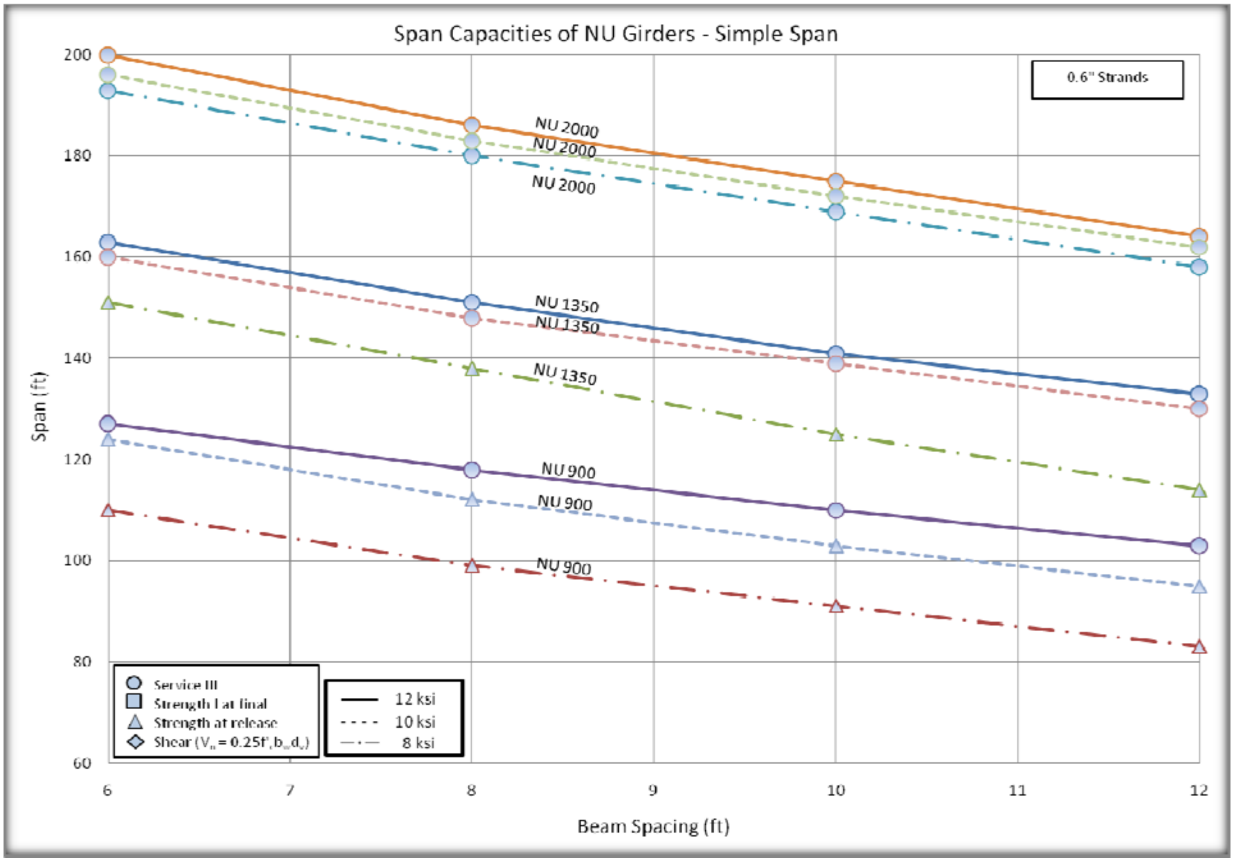

Figure 7: Summary chart for 8, 10, and 12 ksi concrete strengths.

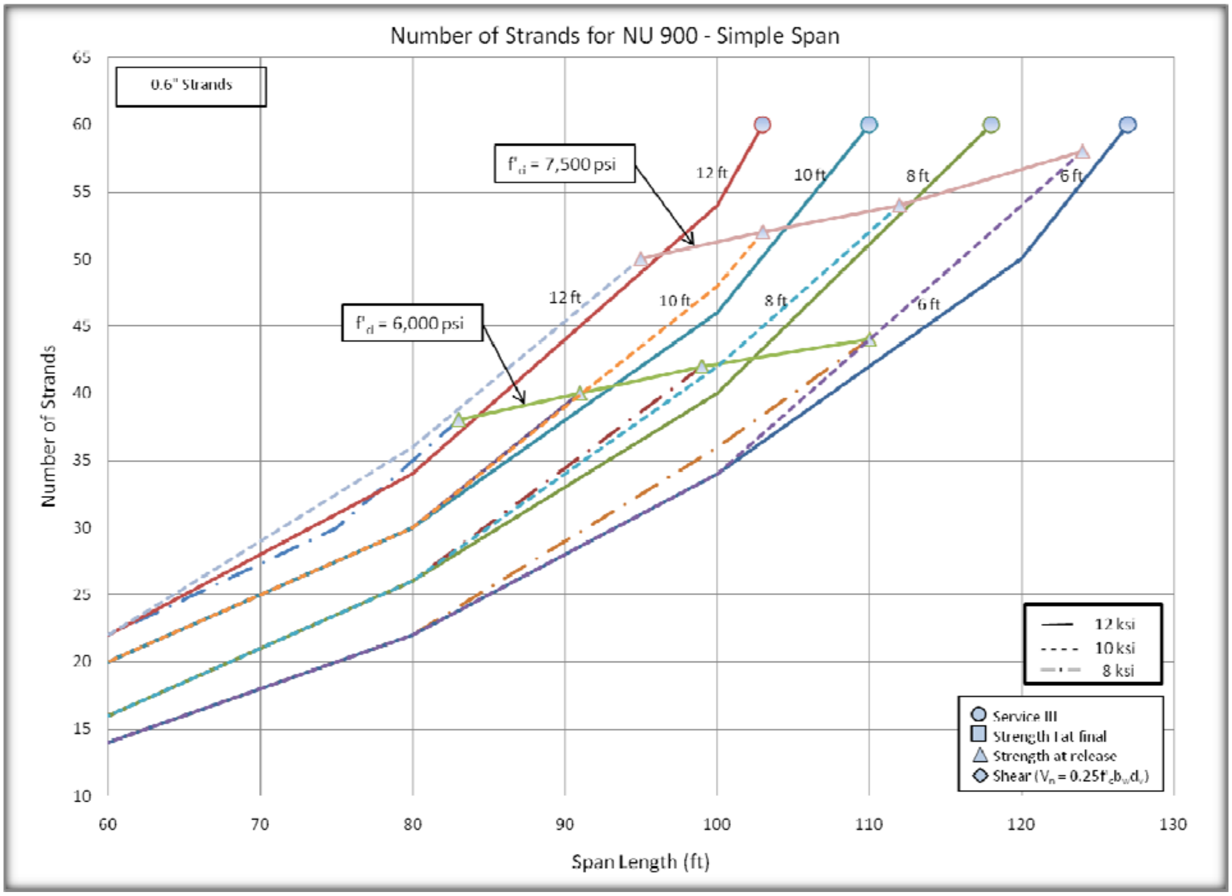

Figure 8: Detailed chart comparison between 8, 10 and 12 ksi concrete strengths.

It can be concluded that the compressive strength at release and the depth of the girder controls the effect of high strength concrete. For shallower sections, the higher strength concrete of 12 ksi has a higher strength at prestress transfer. Therefore, it was not controlled by strength at release limit state and can obtain much higher maximum span lengths.

STRENGTH DESIGN METHOD VS. WORKING STRESS METHOD FOR CONCRETE STRENGTH AT RELEASE:

The compressive strength at prestress transfer plays a vital role in the design of prestressed precast concrete bridge girders. Often times, the concrete strength at release can govern a design, thus preventing a more efficient design. This paper compares the results obtained from Strength at Release Method vs. Workings Stress Method based off of the simple span design charts. The strength design at release method allows for longer spans because of the elimination of unnecessary limits imposed by the working stress method on the concrete at release. This allows the design to be controlled by Service III rather than service at release. This approach permits the prestressing strands to be released at a lower concrete strength than the working stress method. Currently, the Nebraska Department of Roads (NDOR) leaves the decision of whether to use strength design or working stress design up to the bridge designer's digression.

Using the strength design method, the precast members can be treated as a reinforced concrete column subjected to an axial compressive force and the moment that coincides[3]. The method will solve for f'_{ci} and the centroid axis by solving the force and moment equilibrium equations. Another advantage of the strength design method approach allows for the calculation of any top bonded reinforcement required to maintain strength at transfer with controlled tension cracking without using the uncracked section analysis of an already cracked section[4].

As stated earlier, the strength design method allows the prestressing strands to be released at a lower concrete strength than the working stress method. This would allow for a more rapid production cycle. It would lower the cost for curing and demand for debonding and/or draping of strands. Overall, there would be a significant increase in efficiency for the precast/prestressing industry.

With a decrease in the required concrete strength at release, there is an allowance for higher span lengths, lower costs for accelerated curing, and lower demand for debonding and draping of strands at the ends of the girders[4]. The strength design method allows designers to eliminate the limit of $0.196*\sqrt{f'_{ci}}$ as stated in the AASHTO LRFD 2007 code[5]. See Figure 9 for a summary chart and Figure 10 for a detailed chart comparison of strength design vs. working stress design methods for concrete strength at prestress transfer.

The summary chart in Figure 9 shows a large difference in the maximum attainable span length between the strength design method and the working stress method. There is approximately 10% greater span lengths when using the strength design method. For the working stress method, the main governing limit is $0.6*f'_{ci}$, compression in the bottom fibers at prestress transfer[4]. This limit accounts for the decrease in maximum span length calculated, related to the strength design method. The detailed chart in Figure 10 reiterates the same concepts, the strength design method allows for significantly larger maximum span lengths.

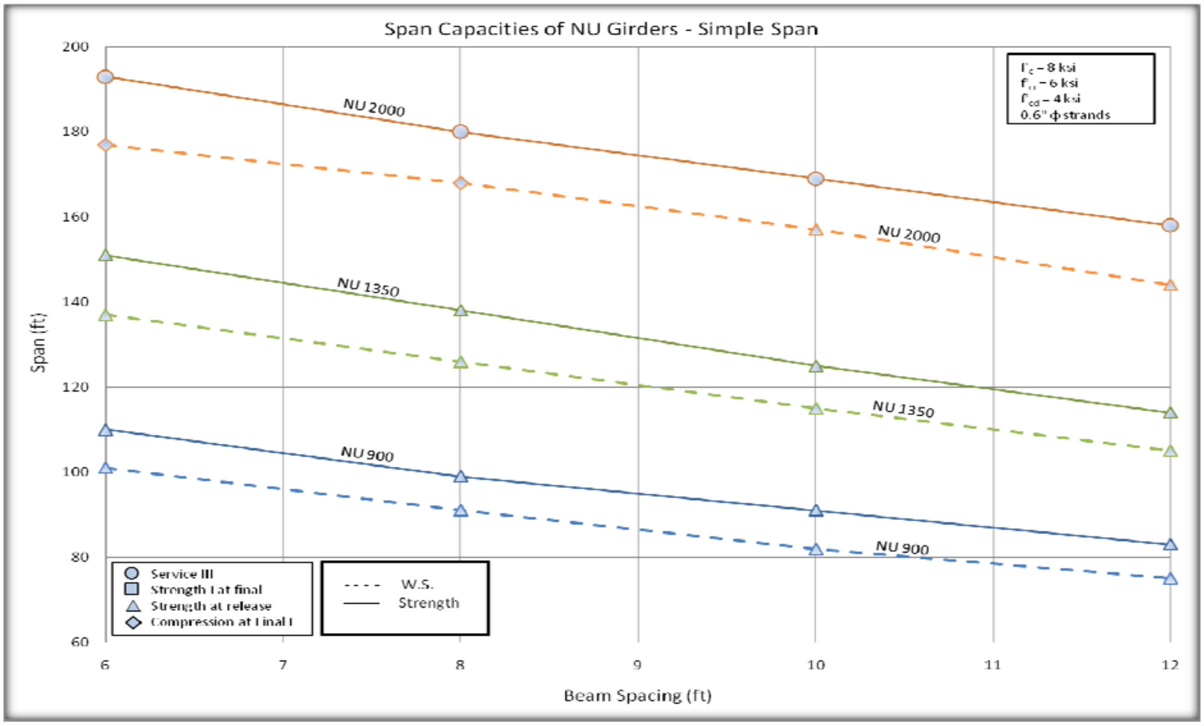

Figure 9: Summary chart comparing Strength Design Method and Working Stress Method.

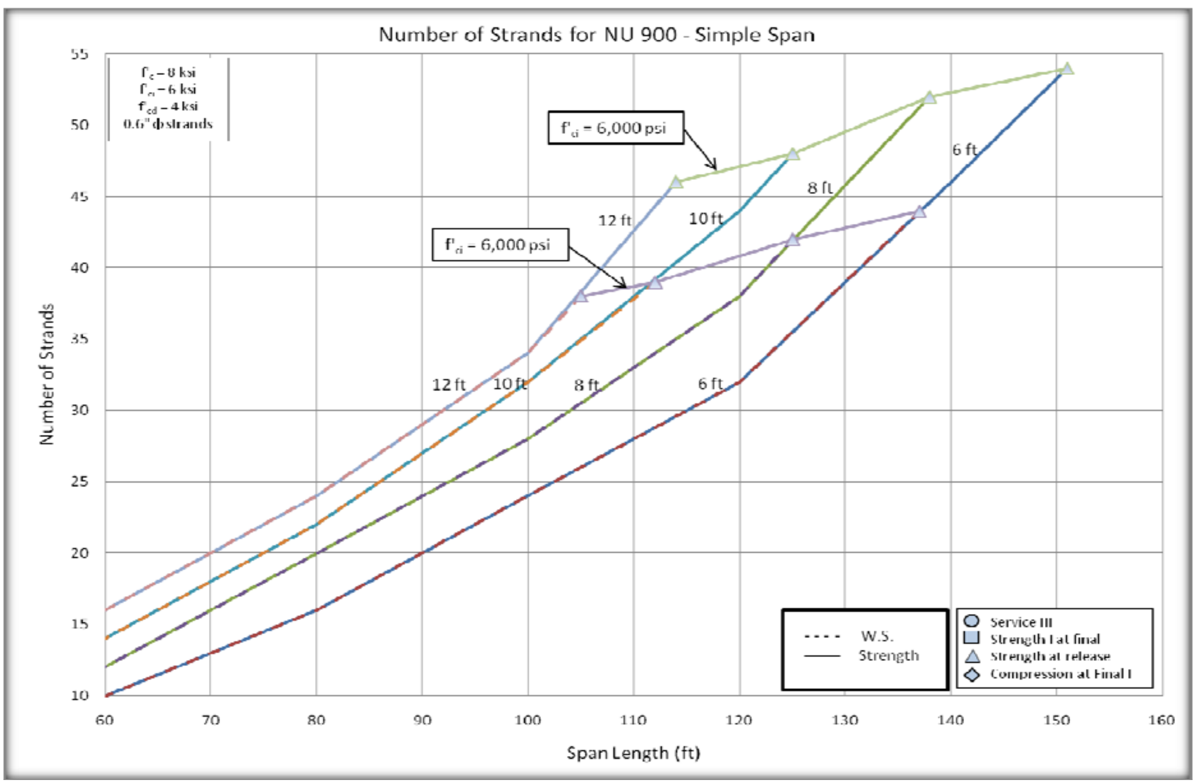

Figure 10: Detailed chart comparing Strength Design Method and Working Stress Method.

TWO-SPAN CONTINUOUS:

The second set of design charts created were two-span (equal span) continuous bridge girders. NDOR standard TR continuity system was used to achieve continuity for both deck weight and live load. Similar to the simple span design aides, two types of charts were developed: summary charts and detailed charts.

This system allows the girders to be continuous for deck weight, in addition to the live load. This means girder weight works as a simply supported span. Deck weight, diaphragm, haunch, wearing surface, barrier weight, and live load will all act continuously throughout the bridge girder. The system is considered to be conventionally reinforced in the negative moment zone. Therefore, strength, steel fatigue, and concrete fatigue of the top surface of the deck must be satisfied.

All criteria was designed in accordance with the 2007 AASHTO LRFD Specifications for superstructure design and 2008 Nebraska Department of Roads(NDOR) Bridge Operations, Polices, and Procedures (BOPP manual).

In the positive moment region, the analysis occurred at 0.4L from the abutment. This is the section with the greatest positive moment acting on the bridge girder. For strength I design, a load multiplier of 2.0 was used for the ultimate moment M_{LL+IM} and ultimate shear V_{LL+IM}[2], a typical NDOR policy. Service live loads were obtained from a precast/prestressed structural analysis program Conspan. The total number of strands were calculated by checking the Service III and Strength I requirements at the critical section of 0.4L for the positive moment area.

In the negative moment region, the critical section for negative moment was located at the face of the diaphragm. A total constant of 10 – 1 3/8" Grade 150 (A_s = 15.8 in^2) threaded rods were used in the pier area for the bridge system. Minimum deck reinforcement of #4 @ 12" in the top layer and #5 @ 12" placed in the bottom layer were used. One or two #5, #6, #7 or #8 bars may be placed in-between each bar, whichever creates the largest moment capacity in the composite section analysis. Checking the negative moment allows for the calculation of maximum span length. TR continuity is discussed in more detail further in the paper.

Service design criteria requires the following fatigue limits for steel and concrete to be met:

- Fatigue check for concrete is equal to $0.5*(f_{DL} + f_{eff\ prestress}) + f_{fatigue\ LL} \leq 0.4f'_c$ (ksi)[1].
- Fatigue bar stress is equal to $f_r \leq 24 - 33*f_{min}$ (ksi)[1]

Fatigue truck loading was used to calculate the threaded rod and deck bar stresses, as well as the concrete stresses in the bottom fibers of the bridge girder. In fatigue load calculations, only one design truck was applied with a constant spacing of 30ft between the 32.0 kip axles. A dynamic load factor of 1.15 was used as well as a live load effect factor of

1.5. For Grade 150 steel stress, a maximum stress due to dead loads of f_{min} = 54 ksi and maximum stress range due to live load $f_r = 36 - f_{min} / 3$ was used.

THREADED ROD CONTINUITY SYSTEM:

In 1998, the University of Nebraska (UNL) with the aid of the Nebraska Department of Roads (NDOR) developed a non-post tensioning TR continuity system called the 1st generation TR continuity system. In this system, the girders were designed as simple span and the rest of the system is designed continuously for deck weight, super-imposed dead load (SIDL), and live load (LL). The 1st generation continuity system has evolved over the years into the 2nd generation continuity system, and now is designed by placing TR above the top flanges of the girder. This system is vastly effective and allows for larger span lengths as well as larger girder spacing.

Continuity causes strong tensile forces at the top fibers of the girder and strong compressive forces at the bottom fibers. The current threaded rod continuity design consists of placing threaded rods 0.75 inches above the top flange of the girders to resist the tensile forces in the negative moment region. A steel shoe plate will be placed on the bottom of the girder in order to help resist the high compressive forces[6]. Figure 11 below shows a typical cross section for a NU-I girder being designed with TR continuity system.

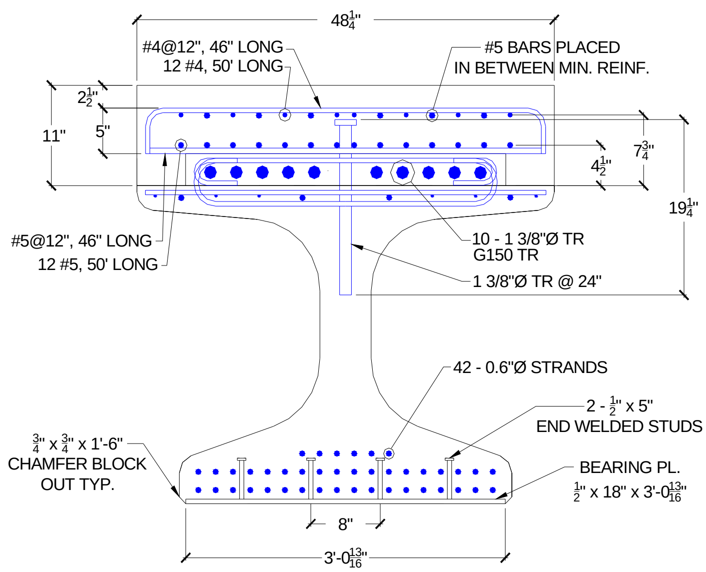

Figure 11: Standard TR Continuity Detail

There are many advantages of the TR continuity system vs. the conventional bridge continuity system. TR continuity allows for longer span lengths, shallower girder depths, and a reduction in girder lines. The major advantages of this system are that the precast concrete girders are made continuous for about two-thirds of the total load, while the threaded rod system establishes continuity over the piers and resists the negative moment due to deck slab weight[6]. The deflection and midspan bending moments are also greatly reduced, resulting in less prestressing and less camber. Lastly, this system allows designers to avoid post-tensioning[7]. All of these advantages make for a more efficient and cost effective design.

A summary chart is shown below in Figure 12 to compare the maximum span lengths obtained from TR continuity system and the conventional continuity system.

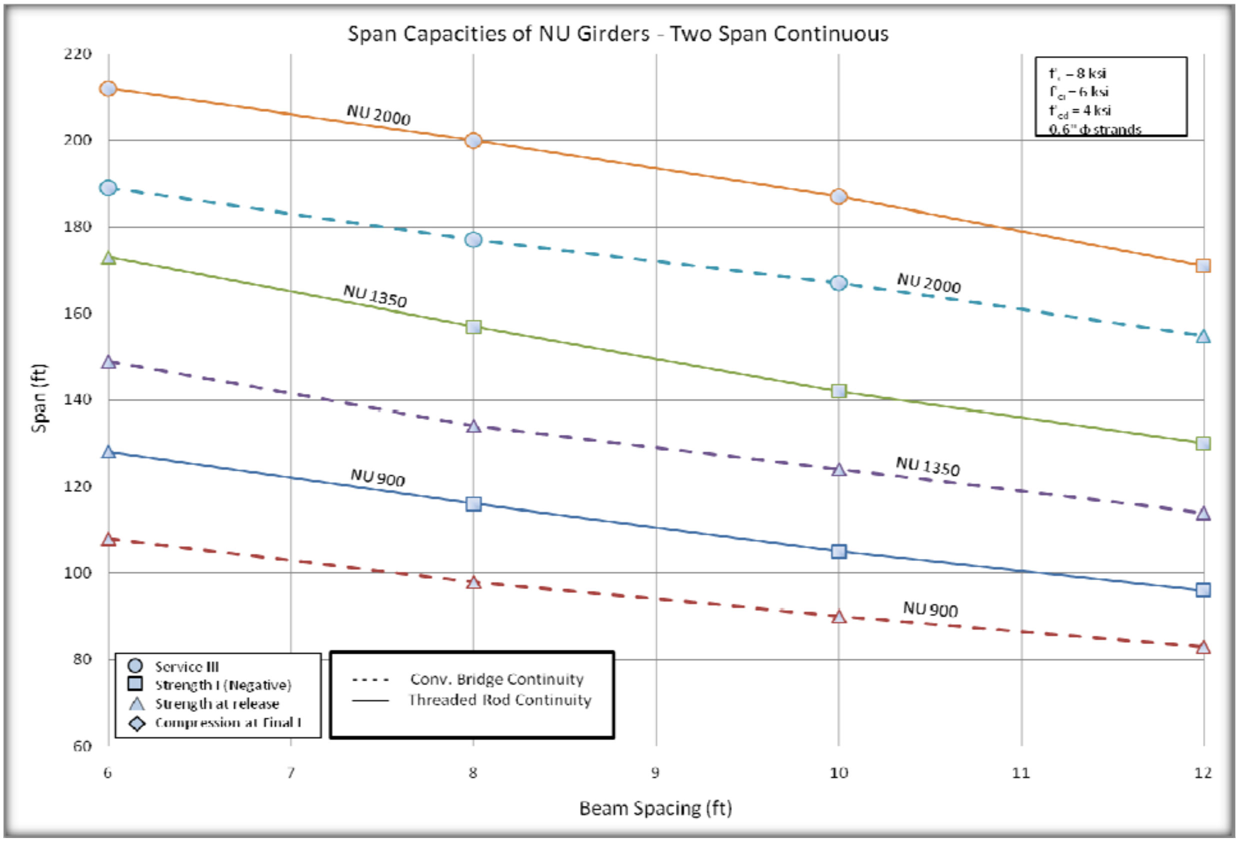

Figure 12: Summary chart comparison between TR continuity and Conventional continuity.

The summary chart in Figure 12 shows the significant advantage in maximum attainable span length when using Threaded Rod(TR) continuity versus the conventional bridge continuity method. The difference in span length can reach as high as 10-18% for any NU-I girder precast section. For the conventional bridge continuity system, the designs were governed by the positive moment section, typically by strength at release.

For the TR continuity system, designs using 6ft girder spacing were typically governed by the positive moment strength at release limit state. However, the majority of the designs were governed by the negative moment section by the Strength I (composite) limit state. To increase the maximum attainable span length for the TR continuity system, one could do the following to increase the negative moment capacity: add a steel plate to the bottom of the girder, add more threaded rods, increase the haunch thickness, increase top flange thickness, or increase web thickness. These options would allow for even high span lengths than show in Figure 12.

CONCLUSION:

Due to the growing development of larger prestressing strands and high strength concrete, there is an increasing need for preliminary design charts to be created and utilized for design engineers. The design aids for NU-I girders provide bridge designers with an efficient and reliable tool to be used in optimizing their specific design.

It was important that constant design parameters were used in correlation with the Nebraska Department of Roads (NDOR) in order to assemble the most practical design charts for bridge designers. This paper also recommends using the following design criteria:

- Utilize the Strength Design Method for calculation of strength at prestress transfer.
- Use Threaded Rod (TR) continuity when designing a multi-span continuous bridge.
- Use of High Strength Concrete (HSC) and larger prestressing strands(0.6 and 0.7inch)

All recommendations given by this paper allow for the most reliable, efficient, and cost effective superstructure design for NU-I girders. The recommendations also allow for a higher span length, shallower depths, and fewer girder lines. The design aids satisfy the current and future needs for all superstructure NU-I bridge girder designs.

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REFERENCES:

1. Tadros, Maher K. "Design Aids for Threaded Rod Precast Prestressed Girder Continuity System." Nebraska Department of Roads. August 2007.
2. NDOR Bridge Operations, Policies &Procedures "BOPP 2009."
3. Noppakunwijai, P., Tadros M.K., Sun Chuanbing, "Application of the Strength Design Method for Flexural Members at Prestress Transfer", PCI JOURNAL, September-October 2003, pp. 2-14.

4. Noppakunwijai, P., Tadros M.K., Zhongguo, Ma, and Mast, Robert F. "Strength Design of Pretensioned Flexural Concrete Members at Prestress Transfer", PCI JOURNAL, V. 46, No. 1, January-February 2001, pp. 34-52.
5. American Association of State Highway and Transportation Officials (AASHTO) (2007) "AASHTO LRFD Bridge Design Specifications", 4th Edition, Washington, DC.
6. Wang, Ning. "Threaded Rod Continuity System For Precast Prestressed Girder Bridges." Disseration, University of Nebraska-Lincoln. November 2006.
7. Hennessey, Shane A., Butler, Ted, Lafferty, Mark D., and Sun, Chuanbing. "Value Engineering in Practice: A look at the Clarks Viaduct in Nebraska", PCI JOURNAL, , September-October 2005, pp. 40-49.
8. Precast/Prestressed Concrete Institute (PCI) (2003) "Precast Prestressed Concrete Bridge Design Manual", 2nd Edition, Chicago, IL.

APPENDIX A - DESIGN EXAMPLE:

The following example demonstrates how to use the design aids in an efficient manner.

Design a simple span NU I-Girder bridge for HL93 loading with a 105 ft design span. The total width of the bridge is 46'-8". Use strength design method for concrete strength at release. Assume depth requirements only allow use of NU 900 girders. Using the preliminary design charts, the various design alternatives are shown in Table 3.

I-Girder	Girder Depth (in.)	Deck t (in.)	Total Depth (in.)	Spacing (ft)	No. Girder Lines	Concrete Strength	Strand Dia (in.)	Number of Strands
NU 900	35.4	7.5	43.9	6	8	8	0.6	40
NU 900	35.4	7.5	43.9	6	8	10	0.6	44
NU 900	35.4	7.5	43.9	8	6	10	0.6	50
NU 900	35.4	7.5	43.9	6	8	12	0.6	40
NU 900	35.4	7.5	43.9	8	6	12	0.6	48
NU 900	35.4	7.5	43.9	10	5	12	0.6	56
NU 900	35.4	7.5	43.9	6	8	12	0.7	28
NU 900	35.4	7.5	43.9	8	6	12	0.7	36
NU 900	35.4	7.5	43.9	10	5	12	0.7	40
NU 900	35.4	8.0	44.4	12	4	12	0.7	44
NU 900	35.4	7.5	43.9	6	8	15	0.7	28
NU 900	35.4	7.5	43.9	8	6	15	0.7	36
NU 900	35.4	7.5	43.9	10	5	15	0.7	42
NU 900	35.4	8.0	44.4	12	4	15	0.7	44

Table 3: Design Alternatives for Example No. 1.

For this example, only NU 900 girders were used. The alternative solutions were based on variations in girder spacing, concrete compressive strength, strand diameter, and number of strands. For the total depth, a haunch thickness of 1 inch was assumed. The number of girder lines is selected to prevent from exceeding the overhang length limits.

Recommendation:

For this situation, it would be suggested to use the case highlighted in red. All of the cases are viable options and fit within the governing limits. However, due to the 12 ft spacing, only 4 girder lines are required. This alone will save a significant amount of money for cost of materials and cost of labor. Figure 12 and Figure 13 show how the preliminary design charts are utilized in this design example.

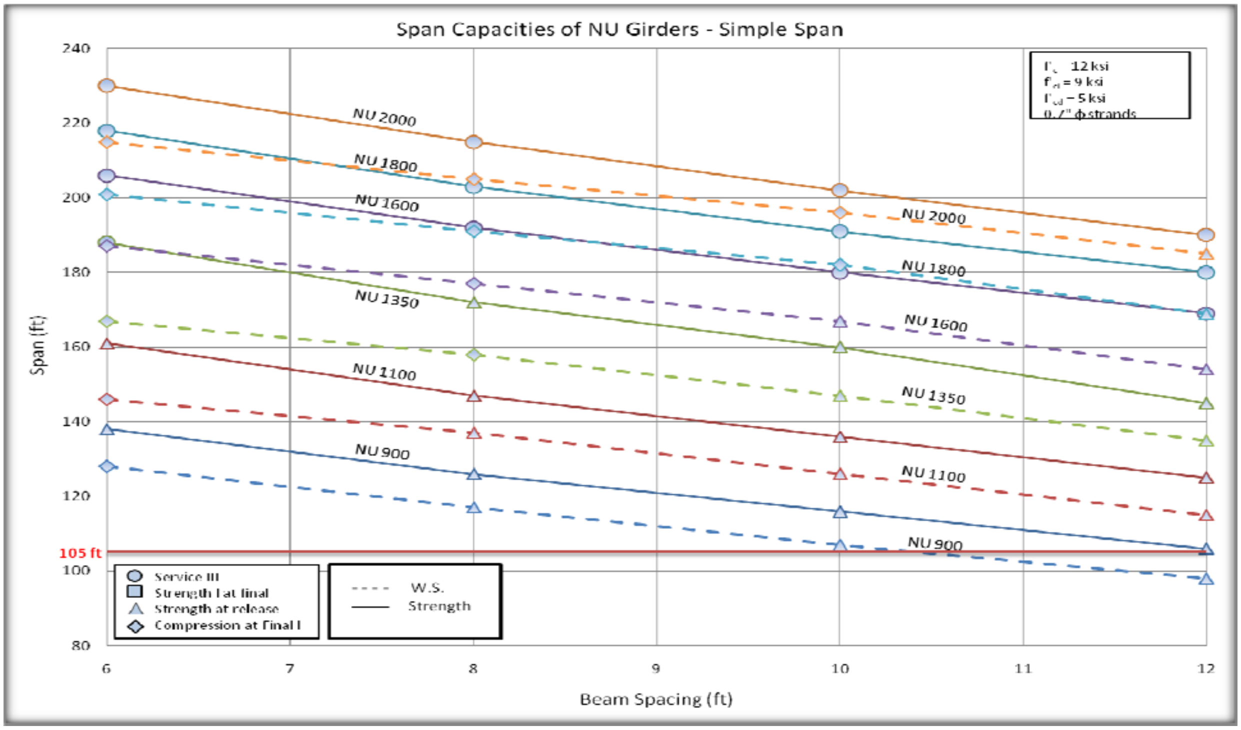

Figure 12: Summary chart used to solve Example 1.

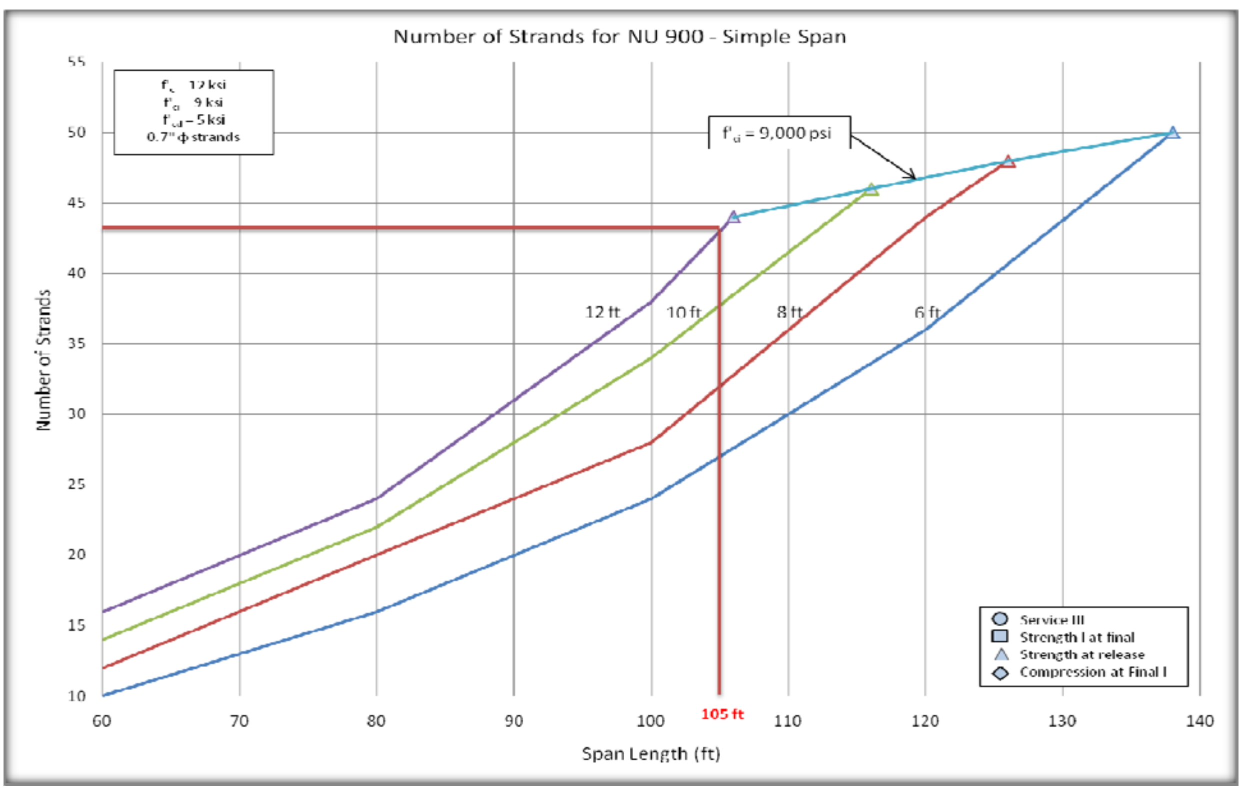

Figure 13: Detailed chart used to solve Example 1.