MARQUETTE INTERCHANGE WEST LEG TEMPORARY BRIDGES

Steven J Miller, PE, Collins Engineers, Inc., Milwaukee, WI

ABSTRACT

This paper will discuss the use of prestressed concrete girders and prestressed concrete deck panels for 5 temporary bridges used to carry cross over traffic for an FHWA MEGA Project known as the Marquette Interchange Reconstruction.

In all, the project utilized five temporary bridges as a means to maintain traffic. During the design phase of the project, three of the five bridges were designed to utilize rolled steel girders. These three bridges were redesigned after construction award as a means to reduce project costs. The contractor proposed to use prestressed concrete in lieu of the original steel design. The remaining two bridges were not detailed in the contract documents, and the choice of design was left up to the contractor. The contractor also chose to utilize prestressed concrete for the design of these two bridges.

The span and girder configurations for the temporary bridges varied from typical straight girder layouts with simple geometry to highly skewed girder layouts with complex geometry. Precast prestressed concrete deck panels were utilized to speed construction and eliminate costly formwork removal.

The contractor's cost reduction proposal was accepted by the bridge owner in lieu of using the originally designed steel girder superstructures, and this acceptance resulted in overall cost savings of approximately $600,000 which were shared equally between the contractor and the owner. The bridges were critical path items to the overall project schedule, and their on-time construction was an extremely important factor in the overall success of this highly visible and critical project.

INTRODUCTION

The Marquette Interchange located in Milwaukee, Wisconsin is a gateway to Wisconsin and a vital connector that links almost one-third of the state's freeway traffic to the rest of the country. The original interchange, completed in 1968 paid back untold dividends as a transportation workhorse and as an engine for economic development statewide.

By the early 2000's the Marquette Interchange carried 300,000 vehicles per day, which was more than double the number for which it was designed. Additionally, significant growth in demand was expected to continue. The new Marquette Interchange, shown in Photo 1, will be completed in 2008 at a cost of $810 million dollars.

Photo 1-Scale Model of the proposed Interchange

To meet the needs of the community, the project required a careful balance of keeping freeway lanes and ramps open while limiting the total time that the downtown interchange would be under construction.

As shown in Figure 1 on the next page, the project was broken into 5 separate contracts. To facilitate construction, the east-west and north-south sections of the project were built in halves. To accommodate both directions of traffic on one side of the freeway, the existing six lane section was reduced to a four lane section, and temporary bridges and roadways were constructed to ensure that two lanes of traffic were open to through traffic during the life of the project.

In all, the project utilized five temporary bridges as a means to maintain traffic. During the design phase of the project, three of the five bridges (T1, T2 & T5) were designed to utilize rolled steel girders. These three bridges were redesigned after construction award as a means to reduce project costs. The contractor proposed to use prestressed concrete in lieu of the original steel design. The remaining two bridges (T6 & T8), were not detailed in the contract documents, and the choice of design was left up to the contractor. The contractor also chose to utilize prestressed concrete for the design of these two bridges.

The temporary bridges described here were built as part of the West Leg Contract which began in Early 2005 and was completed in 2006. The winning bid for the West Leg Project was $30.5 Million dollars.

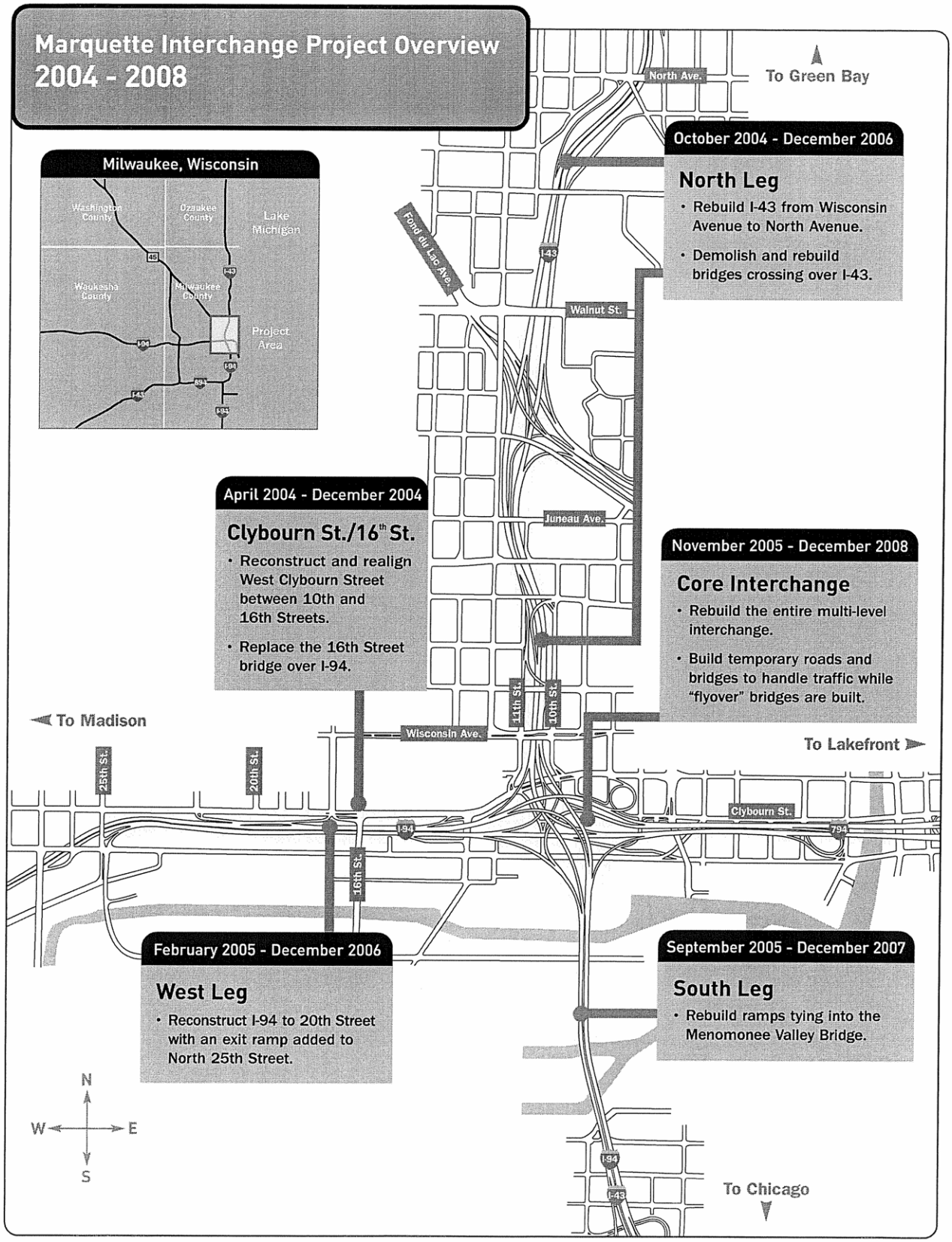


Figure 1- Overview of the Marquette Interchange Project

CONTRACTOR VALUE ENGINEERING

The contractor utilized the Wisconsin DOT's (WisDOT's) Cost Reduction Incentive (CRI) process as part of their strategy to win the West Leg Contract. The CRI process encourages contractors to propose innovative, groundbreaking ideas involving improved work methods, new products, and improved equipment. The original designer of three of the temporary bridges (T1, T2, & T5) designed all of the bridges using rolled steel girders. As the basis of their CRI proposal, the contractor proposed using prestressed concrete superstructures in lieu of the originally designed steel girder superstructures.

The benefits of using precast and prestressed concrete in bridges are well known in the industry. The use of precast concrete offers several structural and engineering advantages. These advantages include: high span depth ratios; reduced thermal movements due to a lower coefficient of expansion; minimal problems with fatigue; and excellent freeze-thaw and chemical resistance. Additionally, because of their mass and stiffness, the natural frequency of vibration of a prestressed girders rarely coincides with vehicle frequencies. This often results in reduced vibrations when compared with other bridge types.

Cost and schedule are also major benefit, and were the primary factors in the contractor's decision to use prestressed concrete instead of steel. The lower life cycle cost (initial cost + recurring maintenance) of prestressed concrete bridges is often one of the major factors in choosing prestressed concrete over other materials. Precast prestressed concrete bridges are usually lower in first cost than all other types of bridges.

Lower initial costs coupled with savings in maintenance, often provide maximum economy and make prestressed concrete the girder of choice. Painting of concrete structures is not normally required, and the costs to re-paint bridges can be up to 20% of a structure's initial cost. Painting of bridges can also be environmentally unfriendly. It is noted however, that because of the short term life of the bridges on this project, the benefit of decreased maintenance was not a deciding factor in the choice of materials.

The West Leg Project was let for construction in 2004, at a time, when steel prices were soaring due to skyrocketing demand. This likely magnified the difference in initial costs between steel and prestressed concrete. The spot price of almost every type of steel, including reinforcement steel doubled or worse in 2004, and sporadic shortages sometimes interrupted construction schedules.

The West Leg Contract, as well as the project as a whole, had interim milestones and final completion dates mandated by the owner. The contractor was not allowed time extensions for weather, material or labor issues. Liquidated damages were set at $5000 to $30,000 per day, per milestone. The demand for steel not only resulted in increased prices but also caused lead times for steel delivery to grow longer. The contractor also chose prestressed concrete as a lower risk means to meet the project schedule, since the availability of prestressed concrete girders was more certain than structural steel.

Precast prestressed bridge components are easy to erect, and also offer speed of construction as a major benefit. Precast concrete deck panels were used as a stay-in-place formwork for the construction of the deck for bridge T5. Construction of the T5 bridge was on the schedules critical path for the project, and the contractor chose to take advantage of the availability of an instant working surface, the labor savings from not having to remove the deck forms, and the speed of construction which the deck panels provided.

The CRI proved to be critical since it was a major factor in the contactor being awarded the contract. The estimated combined savings for the department and the contractor was approximately $600,000 for the three bridges. The choice of precast prestressed concrete was also a major factor in avoiding project delays.

TEMPORARY BRIDGE GIRDERS

All of the bridges utilized prestressed concrete I girders supported on various substructure elements. The bridges were designed for HS20 live loading and were designed to have a minimum service life of two years. The bridges were designed with standard AASHTO prestressed sections for 36", 45", and 54" I shapes. Table 1 below, provides general span and girder information for each of the temporary bridges.

Bridge Number.	Total Length	No. of Spans	Span Lengths	Prestressed I Girder	Prestressed Concrete F'c
T1	396'-9"	5	63'-5" to 110'-0"	AASHTO 45" & 54"	8000 psi
T2	169'-6 ½"	2	81'-4' to 84'-2"	AASHTO 45"	8000 psi
T5	469'-4"	7	44'-10" to 113'-0"	AASHTO 45" & 54"	8000 psi
T6	133'-0"	1	133'-0"	AASHTO 54"	9100 psi (1)
T8	148'-0"	2	78'-0"	AASHTO 36"	8000 psi

Table 1- Span and Girder Information for Temporary Bridges

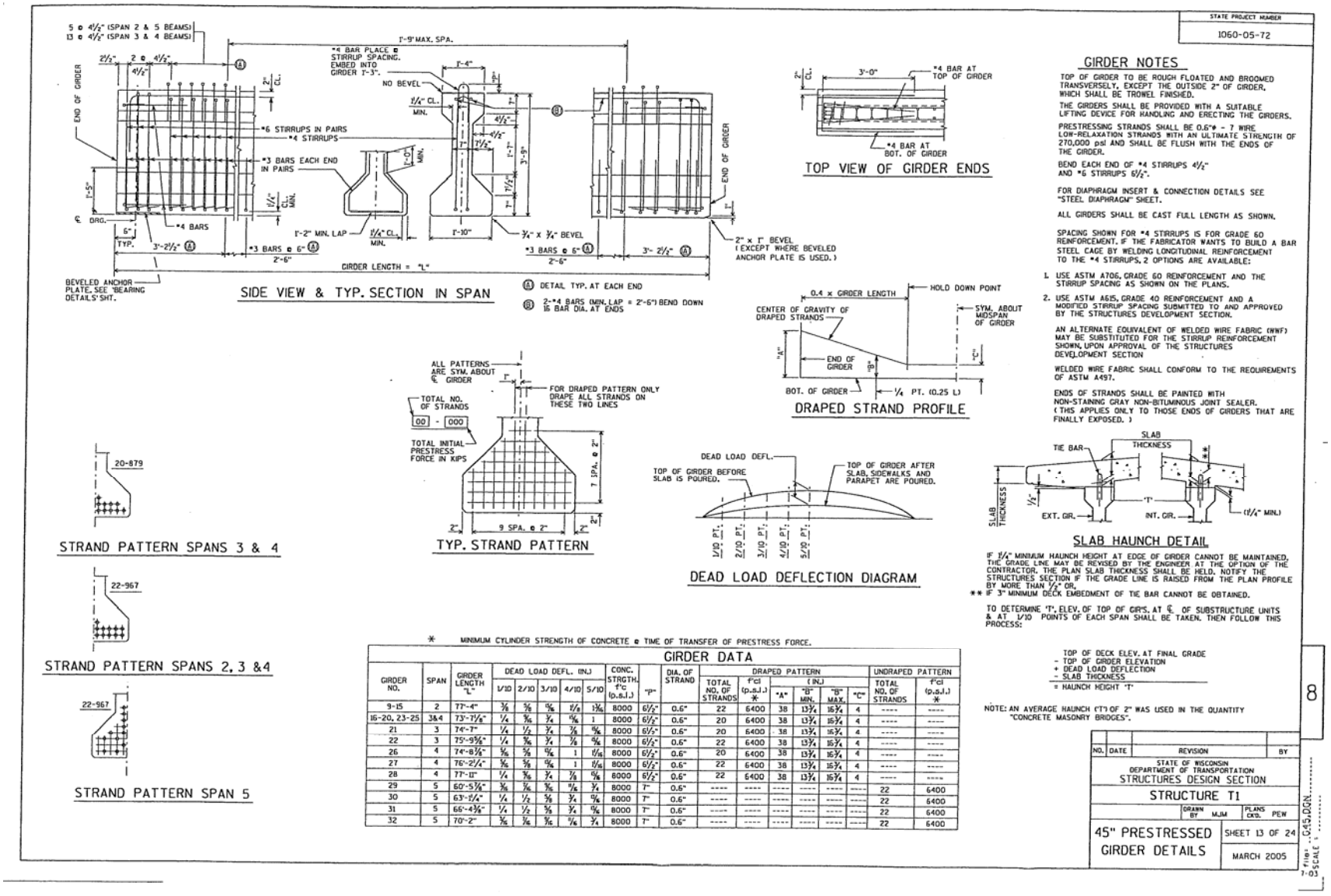
The following basic ultimate stresses for the superstructure designs are recommended in the WisDOT Bridge Manual and were used for the design for the temporary bridges.

- Prestressed "I" Girder Concrete 6000 psi to 8000 psi (1)
- Deck Concrete 4000 psi
- Prestressed Reinforcement Strand (2) 270 ksi
- Grade 60 Reinforcement 60 ksi

Details of the 45" deep girders used on Bridge T1 are shown in Figure 2. Girder details for the other sizes and on the other bridges are similar.

Footnotes
(1) A higher strength concrete was used for bridge T6 to eliminate a line of girders.

(2) WisDOT uses 0.5" or 0.6" diameter low relaxation strands in prestressed concrete "I" girder designs. Draped strand patterns are used as necessary to reduce stresses at the ends of the girders.



GIRDER NO.	SPAN	GIRDER LENGTH "L"	DEAD LOAD DEFL. (IN.) 1/10	2/10	3/10	4/10	5/10	CONC. STRGTH. f'c (p.s.i.)	"P"	DIA. OF STRAND	DRAPED PATTERN TOTAL NO. OF STRANDS	f'ci (p.s.i.) *	"A"	"B" MIN.	"B" MAX.	"C"	UNDRAPED PATTERN TOTAL NO. OF STRANDS	f'ci (p.s.i.) *
9-15	2	77'-4"	3/16	5/16	11/16	11/8	1 3/16	8000	6½"	0.6"	22	6400	38	13 3/4	16 3/4	4	----	----
16-20, 23-25	3&4	73'-7 1/8"	1/4	3/16	3/4	15/16	1	8000	6½"	0.6"	20	6400	38	13 3/4	16 3/4	4	----	----
21	3	74'-7"	1/4	1/2	3/4	7/8	15/16	8000	6½"	0.6"	20	6400	38	13 3/4	16 3/4	4	----	----
22	3	75'-9 5/16"	1/4	5/16	3/4	7/8	15/16	8000	6½"	0.6"	22	6400	38	13 3/4	16 3/4	4	----	----
26	4	74'-8 1/16"	5/16	5/8	11/16	1	1 1/16	8000	6½"	0.6"	20	6400	38	13 3/4	16 3/4	4	----	----
27	4	76'-2 1/4"	5/16	5/8	11/16	1	1 1/16	8000	6½"	0.6"	22	6400	38	13 3/4	16 3/4	4	----	----
28	4	77'-11"	1/4	3/16	3/4	7/8	15/16	8000	6½"	0.6"	22	6400	38	13 3/4	16 3/4	4	----	----
29	5	60'-5 3/16"	3/16	1/16	3/16	1/16	3/4	8000	7"	0.6"	----	----	----	----	----	----	22	6400
30	5	63'-11/4"	1/4	1/2	5/8	3/4	15/16	8000	7"	0.6"	----	----	----	----	----	----	22	6400
31	5	66'-4 3/16"	1/4	1/2	5/8	3/4	15/16	8000	7"	0.6"	----	----	----	----	----	----	22	6400
32	5	70'-2"	3/16	1/16	3/16	1/16	3/4	8000	7"	0.6"	----	----	----	----	----	----	22	6400

Figure 2- Bridge T1, Prestressed Girder Details

T1 & T2 Bridges

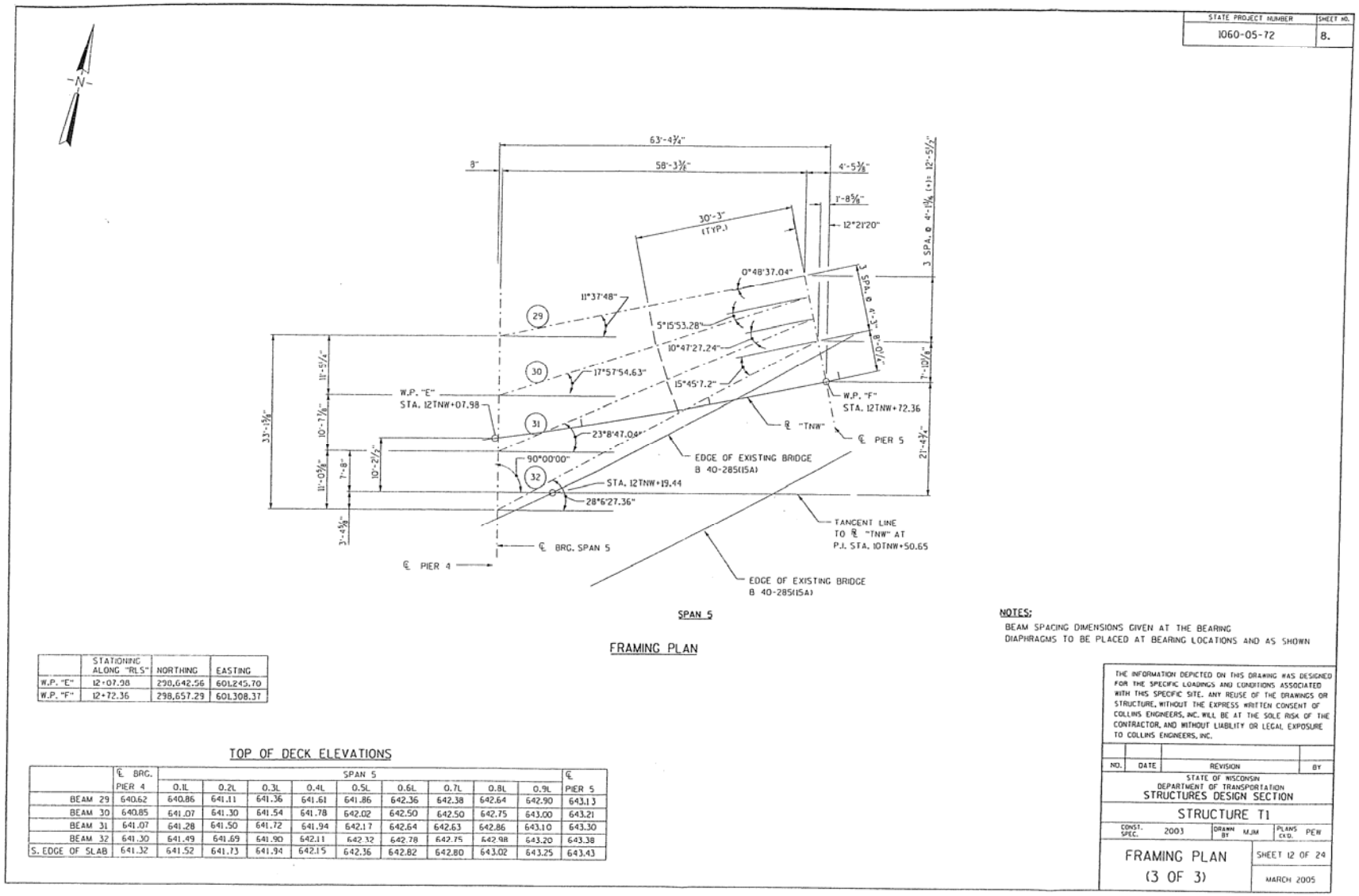
T1 & T2 bridges combined to carry I-43 southbound to I-94 westbound traffic over 13th street. The bridges were constructed in early 2005, prior to the demolition of the existing southbound to westbound structure removals. The milestone completion dates for bridges T1 & T2 were July 19th 2005 and June 8th 2005 respectively. The bridges were open and carrying traffic before their milestone completion dates.

Both bridges had complex geometric arrangements which resulted in varying skew and girder spacing within each span, and from one span to another. As an example, the girders in Span 5 of the T1 bridge (Photo 2), ranged in skew from 11°-37'-48" at the north edge of the bridge deck to 28°-6'-27" at the south edge of the bridge deck. Likewise, the girder spacing at Pier 4 was approximately 11'-0" and narrowed to 4'-3" at Pier 5. The variations in girder skews and spacing required simple spans to be used, since continuous span arrangements were not a viable option. The complex geometry also required that extra attention be paid during detailing of the girder layouts to avoid conflicts. Figures 3 and 4 show typical span framing layouts for bridges T1 & T2 respectively.

Photo 2-Span 5 of Bridge T1, note girder skews & connection of decks.

Another unique design aspect was the attachment of the temporary bridges to the bridge decks of adjacent existing bridges that remained in service. The edges of the bridge decks were connected with dowels spaced at 4'-0" on center (see Figure 5).

Normal practice would be to design each of the structures to act independently, due to differences in thermal expansion/contraction characteristics and other movements. The bridge owner however, preferred that the temporary bridges move with the existing bridges. The bearings and the piers of the temporary bridges were designed to move and deflect with the existing bridges. The bearings were designed to transmit the vertical loads of the temporary bridges to their respective substructures, however, the girders were free to translate over the bearings both transversely and longitudinally.



SPAN 5

FRAMING PLAN

NOTES:
BEAM SPACING DIMENSIONS GIVEN AT THE BEARING
DIAPHRAGMS TO BE PLACED AT BEARING LOCATIONS AND AS SHOWN

	STATIONING ALONG "RLS"	NORTHING	EASTING
W.P. "E"	12+07.98	298,642.56	601,245.70
W.P. "F"	12+72.36	298,657.29	601,308.37

TOP OF DECK ELEVATIONS

	℄ BRG.	SPAN 5									℄
	PIER 4	0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L	PIER 5
BEAM 29	640.62	640.86	641.11	641.36	641.61	641.86	642.36	642.38	642.64	642.90	643.13
BEAM 30	640.85	641.07	641.30	641.54	641.78	642.02	642.50	642.50	642.75	643.00	643.21
BEAM 31	641.07	641.28	641.50	641.72	641.94	642.17	642.64	642.63	642.86	643.10	643.30
BEAM 32	641.30	641.49	641.69	641.90	642.11	642.32	642.78	642.75	642.98	643.20	643.38
S. EDGE OF SLAB	641.32	641.52	641.73	641.94	642.15	642.36	642.82	642.80	643.02	643.25	643.43

NO.	DATE	REVISION	BY

STATE OF WISCONSIN
DEPARTMENT OF TRANSPORTATION
STRUCTURES DESIGN SECTION

STRUCTURE T1

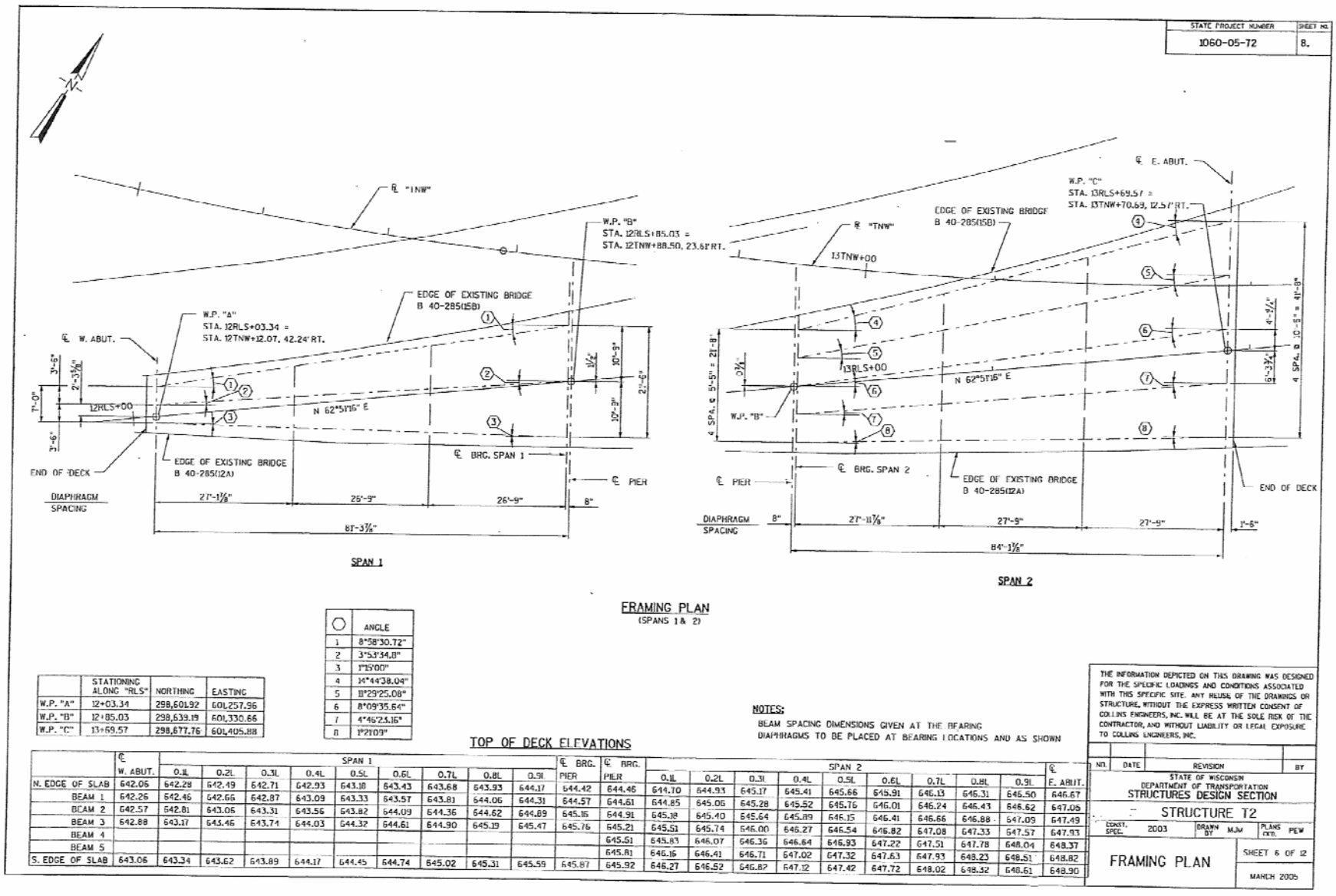
CONST. SPEC. 2003 | DRAWN BY M.JM | PLANS CK'D. PEW

FRAMING PLAN
(3 OF 3)

SHEET 12 OF 24

MARCH 2005

Figure 3- Bridge T1, Typical Framing Plan, Span 5



	STATIONING ALONG "RLS"	NORTHING	EASTING
W.P. "A"	12+03.34	298,601.92	601,257.96
W.P. "B"	12+85.03	298,639.19	601,330.66
W.P. "C"	13+69.57	298,677.76	601,405.88

⬡	ANGLE
1	8°58'30.72"
2	3°53'34.8"
3	1°15'00"
4	14°44'38.04"
5	11°29'25.08"
6	8°09'35.64"
7	4°46'23.16"
8	1°27.09"

TOP OF DECK ELEVATIONS

	℄ W. ABUT.	SPAN 1 0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L	℄ BRG. PIER	℄ BRG. PIER	SPAN 2 0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L	℄ E. ABUT.
N. EDGE OF SLAB	642.06	642.28	642.49	642.71	642.93	643.18	643.43	643.68	643.93	644.17	644.42	644.46	644.70	644.93	645.17	645.41	645.66	645.91	646.13	646.31	646.50	646.67
BEAM 1	642.26	642.46	642.66	642.87	643.09	643.33	643.57	643.81	644.06	644.31	644.57	644.61	644.85	645.06	645.28	645.52	645.76	646.01	646.24	646.43	646.62	647.06
BEAM 2	642.57	642.81	643.06	643.31	643.56	643.82	644.09	644.36	644.62	644.89	645.16	644.91	645.18	645.40	645.64	645.89	646.15	646.41	646.66	646.88	647.09	647.49
BEAM 3	642.88	643.17	643.46	643.74	644.03	644.32	644.61	644.90	645.19	645.47	645.76	645.21	645.51	645.74	646.00	646.27	646.54	646.82	647.08	647.33	647.57	647.93
BEAM 4												645.51	645.83	646.07	646.36	646.64	646.93	647.22	647.51	647.78	648.04	648.37
BEAM 5												645.81	646.16	646.41	646.71	647.02	647.32	647.63	647.93	648.23	648.51	648.82
S. EDGE OF SLAB	643.06	643.34	643.62	643.89	644.17	644.45	644.74	645.02	645.31	645.59	645.87	645.92	646.27	646.52	646.82	647.12	647.42	647.72	648.02	648.32	648.61	648.90

Figure 4- Bridge T2, Typical Framing Plan, Spans 1 & 2

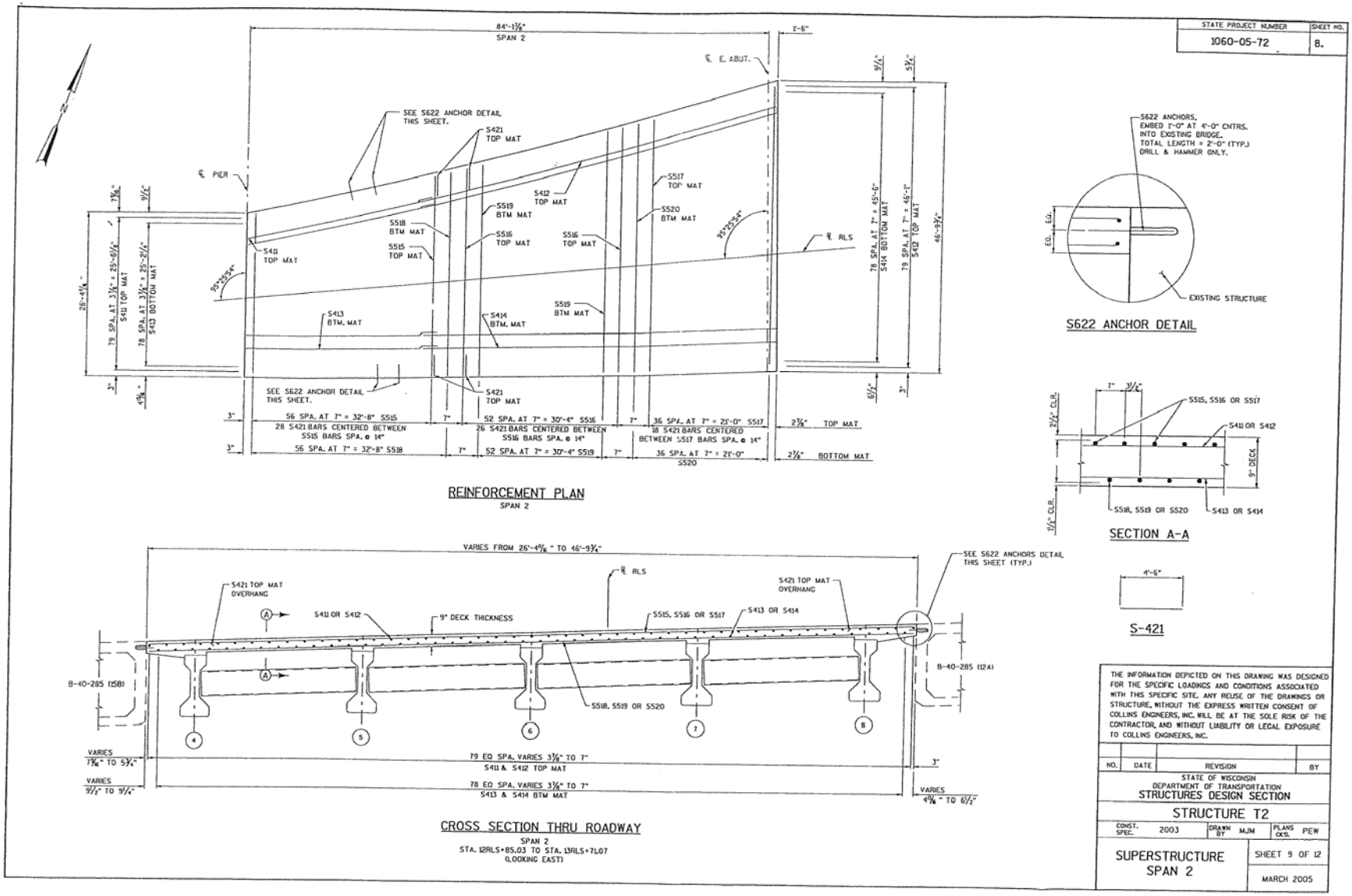


Figure 5-Typical Deck Connection

T5 Bridge

This structure was built in early 2005 to carry I-794 crossover traffic during various stages of construction. The temporary bridge is located between existing I-794 eastbound and I-794 west bound bridges as shown in Photo 3. The bridge is a 7 span, 469 foot long structure, with spans ranging from 45 feet to 113 feet long.

Photo 3-Looking west at bridge T5.

Construction of the T5 bridge was on the critical path schedule for the project. Precast concrete deck panels were chosen by the contractor to take advantage of the availability of an instant working surface, the labor savings from not having to remove the deck forms, and the speed of construction that the deck panels provided.

The maximum 3" thick panels were designed for HS20 live load moment, dead load of the panels, dead load of the cast-in-place concrete supported by the panels, and a construction load of 50 psf. Composite action of the panels with the cast-in-place slab is obtained by utilizing the lifting hooks to transfer horizontal shear forces. Typical details of WisDOT's standard precast deck panels are shown in Figures 6 and 7.

Similar to the T1 & T2 bridges the T5 bridge was constructed by attaching the new deck to the existing decks on either side of the bridge by use of dowels. All bearings on the T5 bridge were designed as expansion bearings to allow movement in concert with the adjacent existing bridges. The expansion bearings were designed as simple steel sliding plate bearings (see Figure 8). The dowels replaced the fixed bearings.

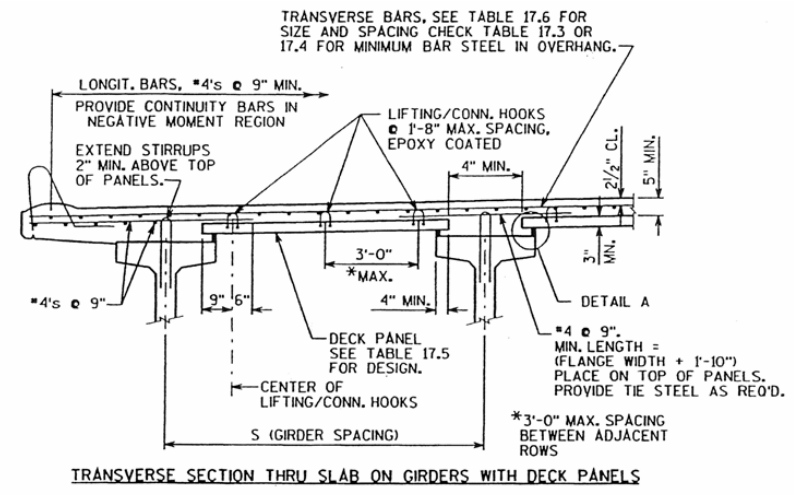
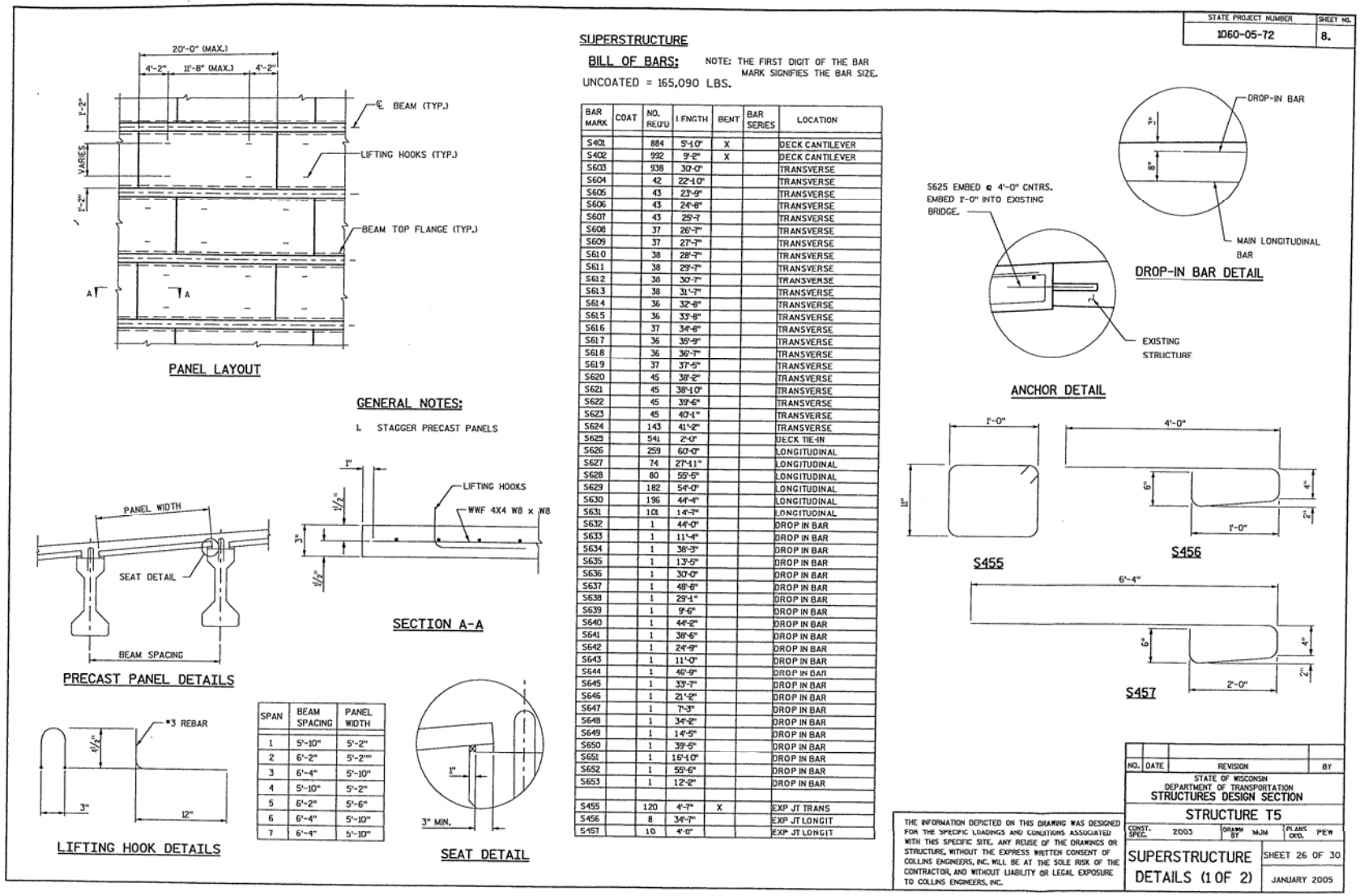


Figure 6- Typical Precast Panel Details used by WisDOT



BAR MARK	COAT	NO. REQ'D	LENGTH	BENT	BAR SERIES	LOCATION
S401		884	5'-10"	X		DECK CANTILEVER
S402		992	9'-2"	X		DECK CANTILEVER
S603		938	30'-0"			TRANSVERSE
S604		42	22'-10"			TRANSVERSE
S605		43	23'-9"			TRANSVERSE
S606		43	24'-8"			TRANSVERSE
S607		43	25'-7			TRANSVERSE
S608		37	26'-7"			TRANSVERSE
S609		37	27'-7"			TRANSVERSE
S610		38	28'-7"			TRANSVERSE
S611		38	29'-7"			TRANSVERSE
S612		38	30'-7"			TRANSVERSE
S613		38	31'-7"			TRANSVERSE
S614		36	32'-8"			TRANSVERSE
S615		36	33'-8"			TRANSVERSE
S616		37	34'-8"			TRANSVERSE
S617		36	35'-9"			TRANSVERSE
S618		36	36'-7"			TRANSVERSE
S619		37	37'-5"			TRANSVERSE
S620		45	38'-2"			TRANSVERSE
S621		45	38'-10"			TRANSVERSE
S622		45	39'-6"			TRANSVERSE
S623		45	40'-1"			TRANSVERSE
S624		143	41'-2"			TRANSVERSE
S625		541	2'-0"			DECK TIE-IN
S626		259	60'-0"			LONGITUDINAL
S627		74	271'-11"			LONGITUDINAL
S628		80	55'-5"			LONGITUDINAL
S629		182	54'-0"			LONGITUDINAL
S630		196	44'-4"			LONGITUDINAL
S631		101	14'-7"			LONGITUDINAL
S632		1	44'-0"			DROP IN BAR
S633		1	11'-4"			DROP IN BAR
S634		1	38'-3"			DROP IN BAR
S635		1	13'-5"			DROP IN BAR
S636		1	30'-0"			DROP IN BAR
S637		1	48'-8"			DROP IN BAR
S638		1	25'-1"			DROP IN BAR
S639		1	9'-6"			DROP IN BAR
S640		1	44'-2"			DROP IN BAR
S641		1	38'-6"			DROP IN BAR
S642		1	24'-9"			DROP IN BAR
S643		1	11'-0"			DROP IN BAR
S644		1	46'-9"			DROP IN BAR
S645		1	33'-7"			DROP IN BAR
S646		1	21'-2"			DROP IN BAR
S647		1	7'-3"			DROP IN BAR
S648		1	34'-2"			DROP IN BAR
S649		1	14'-5"			DROP IN BAR
S650		1	39'-6"			DROP IN BAR
S651		1	16'-10"			DROP IN BAR
S652		1	55'-6"			DROP IN BAR
S653		1	12'-2"			DROP IN BAR
S455		120	4'-7"	X		EXP JT TRANS
S456		8	34'-7"			EXP JT LONGIT
S457		10	4'-0"			EXP JT LONGIT

SPAN	BEAM SPACING	PANEL WIDTH
1	5'-10"	5'-2"
2	6'-2"	5'-2""
3	6'-4"	5'-10"
4	5'-10"	5'-2"
5	6'-2"	5'-6"
6	6'-4"	5'-10"
7	6'-4"	5'-10"

Figure 7-Typical Deck Connection

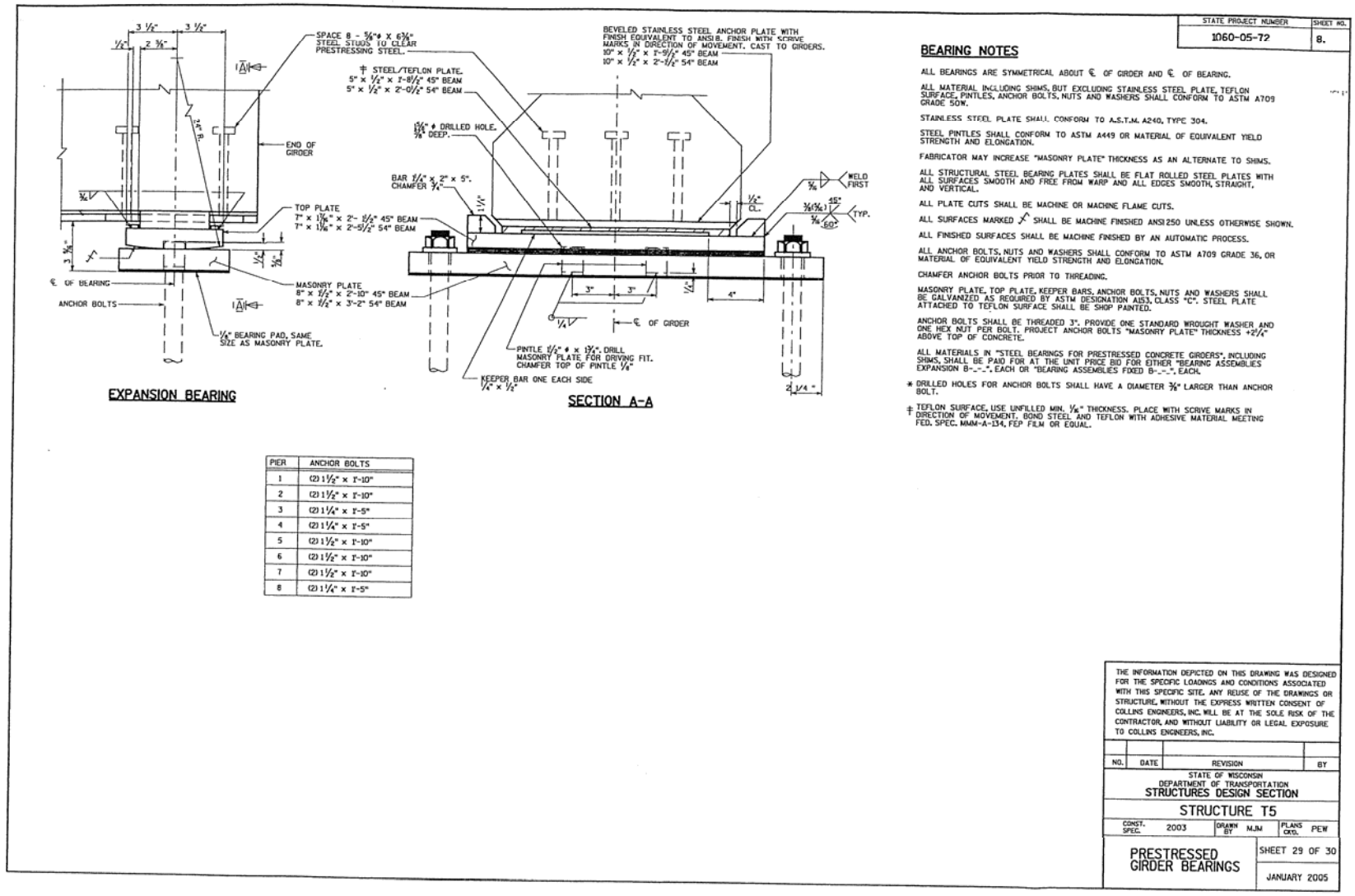


Figure 8-Typical Bearing Details, Bridge T5

T6 & T8 Bridges

The T6 bridge was a 113 foot long single span structure with 54W prestressed I girders. The bridge carried I-794 eastbound traffic over 13th Street.

The T8 bridge was a 148 foot long two span structure which carried I-43 northbound traffic over Clybourn Street. AASHTO 36" sections were used due to limited vertical clearance. The structure was designed as continuous for live load and superimposed dead loads. Continuity was obtained by casting monolithic diaphragms between the girder ends over the piers.

Unlike the other bridges, the T6 and T8 temporary bridges had simple straight geometric arrangements. The bridges were not a re-design, but the contractor chose to use prestressed concrete girders as the girder of choice. Again cost and availability of materials were the major factors in choosing prestressed concrete girders over their steel counter parts.

SUMMARY

Each of the temporary bridges played their own unique role in maintaining traffic and avoiding disruptions to the downtown business community during reconstruction of the interchange. Three of the five bridges had unusual geometry, including highly skewed arrangements, and varying girder spacing. The complex geometry required that close attention be paid during both design and construction to avoid conflicts in the various bridge elements, and potential errors during fabrication. Additional complexities during the design process included the connection of deck elements between existing and proposed structures. The proposed structures were designed to move in concert with the existing bridges.

The benefits of using precast and prestressed concrete in bridges are well known in the industry. Lower life cycle costs, speed of construction, and structural and engineering advantages are often deciding factors in choosing precast and prestresssed concrete bridges over other bridge types. The use of precast and prestressed concrete for the temporary bridges was an important element in the contractor's winning bid. In 2004, shortages in steel supplies, due to high demand caused steel prices to soar. Those same shortages caused lead times for steel delivery to grow longer. The contractor chose to use precast and prestressed concrete for both budget and schedule reasons.

The Marquette Interchange Project is the first FHWA MEGA project ever in the state of Wisconsin. The interchange is currently in its third year of construction, and the project remains on schedule.