ACCELERATED CONSTRUCTION OF URBAN INTERSECTIONS WITH PORTLAND CEMENT CONCRETE PAVEMENT (PCCP)

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AC	Asphalt Concrete
ACP	Asphalt Concrete Pavement
ACPA	American Concrete Pavement Association
ADT	Average Daily Traffic
C.O.	Change Order
CPM	Critical Path Method
FHWA	Federal Highway Administration
IPRF	Innovative Pavement Research Foundation
PCCP	Portland Cement Concrete Pavement
SR	State Route
VMS	Variable Message Sign
W/C	Water to cement ratio
WSP	Washington State Patrol
WSDOT	Washington State Department of Transportation

ACCELERATED CONSTRUCTION OF URBAN INTERSECTIONS WITH PORTLAND CEMENT CONCRETE PAVEMENT (PCCP)

Executive Summary

The frequent maintenance required on some asphalt concrete (AC) pavement sections has made reconstruction with Portland Cement Concrete Pavement (PCCP) a feasible alternative. However, many constructability issues need to be addressed in order to realize the full potential of this alternative. Accelerated paving encompasses three classes of activities: methods to accelerate the rate of strength gain, methods to minimize the construction time, and traffic control strategies to minimize user delay. In Eastern Washington, three major AC intersections with severe rutting problems were reconstructed with PCCP in autumn 2000. The entire reconstruction of each intersection, including demolition of the AC pavement and its replacement with PCCP, took place over a period of three days – starting on Thursday evening and opening the intersection to the traffic on Sunday afternoon. This report documents this effort in order to provide practitioners additional options for rapid reconstruction of urban intersections and includes documentation of the construction process, traffic management strategies, and an analysis of the costs. Additionally, video documentation has been produced for use in technology transfer. The results of this investigation can be used to educate pavement construction professionals and the academic community on the use of PCCP for accelerated reconstruction of major urban intersections with minimal user and traffic disruption, using innovative construction techniques and traffic management optimization principles. This investigation produced valuable information to demonstrate that concrete pavements can be constructed efficiently and quickly.

1.0 Introduction

Traditional pavement construction, repair, or replacement practices in urban areas are no longer acceptable due to increasing public impatience with traffic interruption. However, Public works agencies must continue to repair or replace deteriorated pavements while maintaining traffic on these roadways. Construction of these roadways is especially difficult in urban areas where traffic congestion is significant.

Intersections pose major construction staging and traffic interruption challenges because they affect two or more streets. Where it is feasible to close the entire intersection for a short time, a contractor can use accelerated paving techniques to complete reconstruction over a weekend. Accelerated techniques for concrete paving allow transportation officials to consider concrete for projects that might not otherwise be feasible due to misperception about concrete curing requirements. Specifications often require lengthy cure periods for conventional concrete mixtures. The result is that Portland cement concrete pavement (PCCP) reconstruction for urban intersections is frequently not considered due to perceived constructability problems, especially at locations with high traffic flow. With accelerated paving construction techniques, concrete can meet opening strengths in less than 12 hours, providing quick public access to a high-quality, long-lasting pavement. Accelerated construction techniques are suitable for new construction, reconstruction, or resurfacing projects.

The most efficient method of construction is to completely close the roadway. Complete closures allow the contractor to remove and replace the roadway in a continuous and safe operation. Interaction with traffic is avoided, as complicated work zone lane configurations are eliminated. However, with a major urban arterial this is often not an option, particularly when detours are not available. Another concern is that complete closures restrict access to businesses that are adjacent to the intersection.

Three urban intersections constructed with asphalt concrete (AC) in Eastern Washington were replaced with PCCP. Traffic volume passing through these intersections are as high as 30,000 Average Daily Traffic (ADT), with twenty percent heavy trucks. The three intersections were located along SR 395 at Yelm Street, Clearwater Avenue, and Kennewick Avenue. Figure 1 shows the general vicinity map of these intersections. This report will concentrate on the third intersection at Kennewick Avenue.

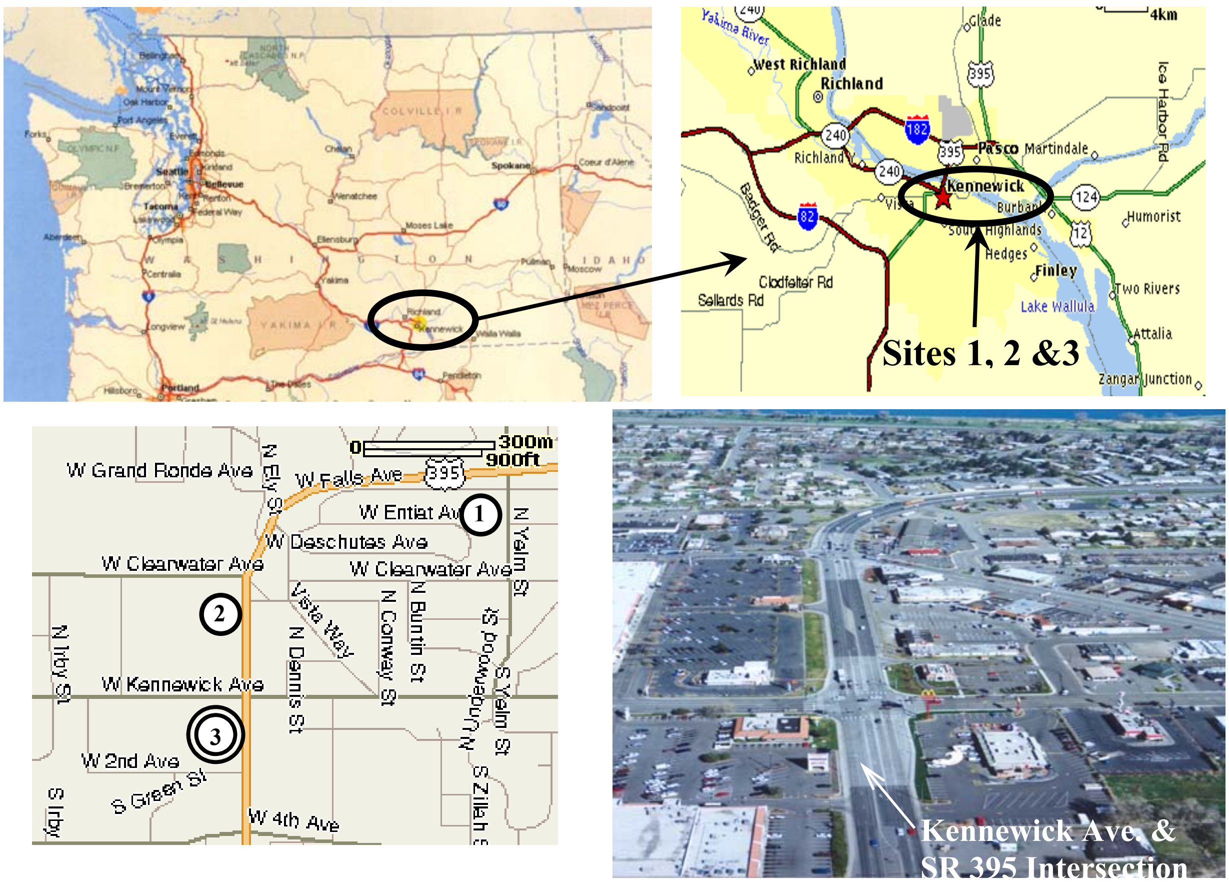


***Figure 1** – Map of the project area*

1.1 Project Background

Asphalt pavement has long been a popular road construction material. In areas where traffic becomes concentrated, such as urban intersections, flexible pavement may be prone to rutting over time. In areas with seasonal temperature extremes, such as found in the Tri Cities, Washington (Pasco, Richland and Kennewick), the ruts can quickly become severe. Several of the flexible pavement intersections in eastern Washington had been suffering from severe rutting caused by slow moving heavy vehicles, exasperated by high temperatures during the summer months.

The three intersections located along SR 395 at Yelm Street, Clearwater Avenue, and Kennewick Avenue had severe ruts, as much as 2 to 4 inches or more. Despite routine maintenance, minor ruts reappeared after a few months with severe ruts within a year after rehabilitation. Figure 2 depicts the level of severity of pavement rutting at the intersection of W. Kennewick Avenue and SR 395.

Figure 2 *– Severity of pavement rutting at the intersection of W. Kennewick Avenue and SR 395*

The Washington State Department of Transportation (WSDOT) has been using PCCP as a long term pavement solution at urban intersections since 1994. The purpose of this reconstruction is to provide a quality long-life pavement with minimal user disruption which will result in safety improvements and a significant reduction in user costs.

1.2 Research Objectives

Traditionally, reconstruction of intersections with PCCP requires several weeks and complex traffic management plans, which can cause significant user delays. However, the use of PCCP can result in lower long-term maintenance and user costs due to the reduction in overlay frequency. The major disadvantage to the use of PCCP for intersection reconstruction is that initial construction costs are typically higher. Despite the lower initial cost of AC pavements, life cycle cost analysis indicates that PCCP may be more cost effective under certain circumstances (Reference 1). The use of techniques to reduce construction time and user impacts can make the use of PCCP even more cost effective and provide a viable alternative to AC rehabilitation. To date, WSDOT has reconstructed 15 intersections with PCCP.

The objective of this research project is to document the rapid reconstruction of an intersection in Eastern Washington–at SR 395 and West Kennewick Avenue–where an AC intersection was reconstructed with PCCP over the weekend in a 70-hour period. The goal of this research project is to develop a body of knowledge and tools for reconstruction of intersections using PCCP.

2.0 Planning Process

The three-day complete intersection closure idea, from Thursday evening at 6:00 PM to Monday morning at 6:00 AM, evolved between the City of Kennewick and WSDOT because of the past problems on a previous PCCP intersection project. The goal was to reduce the construction period and minimize traffic disruption. Both the City of Kennewick and WSDOT benefited because meeting this goal reduced public complaints, business impacts, user-delay costs, and traffic control costs. Both WSDOT and the contractor benefited by increasing employee and public safety and reducing the time resources committed to the project. The contractor also benefited by increasing productivity.

2.1 Background

During 1998, four intersections on SR 395 were constructed using full depth, Portland cement concrete. Complaints from the public were numerous. Staging requirements did not allow construction on consecutive intersections. Traffic was “snaked” through the 2-mile work area causing confusion. This construction resulted in small, discontinuous work zones, reducing the contractor's efficiency. As a result, it took several months to complete the four intersections. The resulting traffic congestion and its effect on area businesses and residents was unacceptable. It became apparent that for future PCCP intersection reconstruction, the issue of lengthy traffic disruptions needed to be addressed and the construction process had to be drastically shortened.

This became the subject of much study and discussion for the engineers at WSDOT. They invited advice from the American Concrete Paving Association (ACPA) and contractors. WSDOT approached the City of Kennewick to discuss the issues relating to shortening the construction process. The City was willing to allow a 2-day weekend closure. However, a three-day closure was desired by the contractors to deal with the unknowns, such as utilities, subgrade, and lack of previous experience. Eventually, WSDOT and the City of Kennewick agreed on a three-day weekend closure for intersection reconstruction.

Late in the summer of 2000, three more intersections, where SR 395 passes through the City of Kennewick, were selected as the first test of the new construction strategy. It was agreed that each intersection would be closed to all traffic for a maximum of 84 hours, beginning on Thursday evening. During that time the existing asphalt pavement would be completely removed and replaced with PCCP. Traffic issues, such as detours, delay time, local and business access were also discussed and worked out between the City of Kennewick and WSDOT.

The three intersections to be reconstruction were:

- Yelm Street – September 14 to 17, 2000
- Clearwater Avenue – September 28 to October 1, 2000
- Kennewick Avenue – October 5 to 8, 2000

2.2 Public Relations

The WSDOT project office provided an effective public relations campaign prior to the 3-day closures. Numerous public meetings were held during the design phase for public input. WSDOT representatives contacted businesses a week and then just days prior to the start of construction. Flyers were handed out explaining the process and reminding the businesses that there would be detour routes (see Appendix A). Weekly meetings were held by the project engineer to update the local media. The project office maintained an open door policy. These activities were aimed at making the closures as organized and painless as possible for the public.

Media coverage was essential to the success of this project. During the first closure, Yelm Street intersection, television media coverage was constant. The closure was the top story on the morning and evening news. Newspapers provided coverage as well (Appendix G). Coverage started a week ahead of the actual construction. This ensured that the public was well informed of the closures.

Informed local drivers avoided the area entirely, reducing traffic delays. As a result, complaints from the public were reduced by over 70% compared to the project constructed two years before.

Following the closures, WSDOT received very favorable comments from both businesses and residents. The contractor attributed the success of the Kennewick area intersection reconstruction to the following:

- WSDOT held preliminary meetings with the City of Kennewick to discuss construction impact and City concerns
- Businesses were invited to pre-construction meetings
- WSDOT met with contractors to discuss construction feasibility
- The public was kept informed via newspapers, radio, and television news broadcasts
- WSDOT's web page was updated with information
- WSDOT provided flyers to businesses each week
- WSDOT and the contractor partnered with the modifications to the traffic control plan allowing continuous work operations with increased safety for employees
- Clearwater Avenue and West Kennewick Avenue were constructed concurrently, maximizing crew efficiency
- The contractor provided a detailed schedule with known milestones
- The contractor's aggressive construction schedule was either met or exceeded
- Work operations were continuous, some element of construction was always happening
- WSDOT and contractor decision makers were available to resolve issues.

During construction and shortly after the construction was completed, a survey among the adjacent businesses was conducted regarding the weekend closure. The results of this survey are presented in Appendix I.

3.0 Traffic Management

Traffic management and construction staging is typically the primary issue associated with the construction of PCCP intersections. An important consideration during design is to obtain input from any party that will be affected by the intersection reconstruction. These parties include, but are not limited to, local governments, emergency services, business owners, and private citizens. An important element to contract administration has been the wide publicity by WSDOT Public Information to local governments, businesses, and to the media, including newspapers and radio.

The importance of communication cannot be overstated. The project engineer invited any party affected by or interested in the construction to attend weekly meetings. At these meetings, concerns were voiced regarding the contractor's proposed work for that week. In most cases the contractor was able to accommodate concerns, whether that meant accommodating staging for access to businesses or addressing safety issues.

The selected prime contractor was provided with the project traffic control plan, designed by WSDOT, and was encouraged to suggest any modifications that would improve the construction efficiency. The modifications made included: use of portable signals, reduce construction stages from 5 to 3, improved worker safety, and improved construction access and efficiency. The most significant modification was the reduction in construction stage from 5 to 3. This was accomplished by staging traffic in either the north or southbound lanes. Traffic in this configuration allowed larger work areas and distances from motorists therefore, increasing productivity and safety. It provided the highway user a traffic plan that was consistent and did not change on a daily basis. This allows commuters to become familiar with the work zone.

The revision of the traffic plan required the removal of some median curb, modification to the temporary striping plan, a temporary signal to assure signal visibility for left turns. WSDOT and the contractor shared the costs of these modifications to the traffic plan.

3.1 Detour Plan

Local traffic was detoured to adjacent streets, while state highway traffic was detoured over nearby interstate highway. Figure 3 shows the schematic detour plan for Kennewick Avenue intersection.

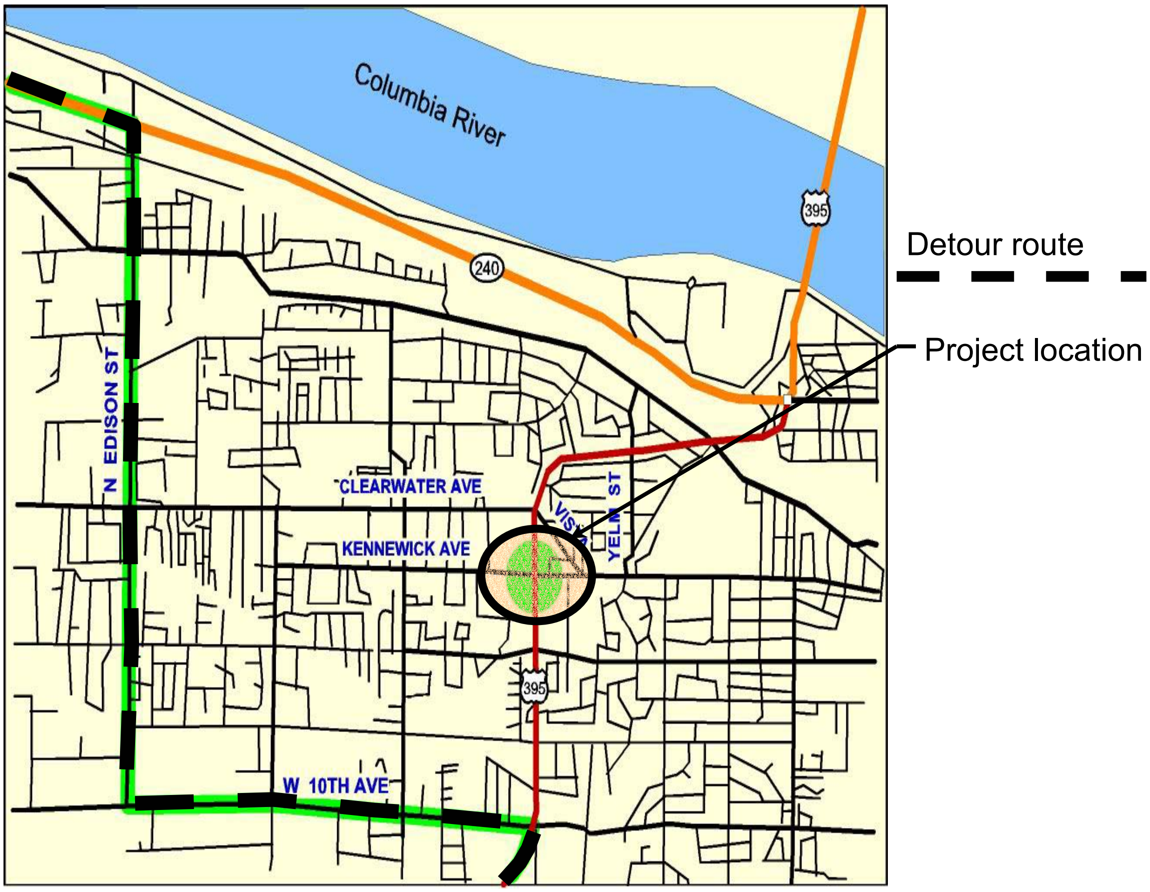


Figure 3 *– Schematic detour plan for the intersection at SR 395 and Kennewick Avenue*

A multi-staged, detour plan was implemented that provided local access, access to commercial sites, and special routes for heavy trucks passing through the area. It was this plan that made it possible for the contractor to modify the reconstruction of the intersection approaches and complete this work in the week prior to the intersection closure. Nearly three weeks in construction time were saved on the overall (three intersections) project due to the revision of the traffic control plan that allowed construction on both Clearwater and Kennewick Avenue concurrently. The contractor did not modify the detour plan, only the traffic plan prior to closure of the intersection.

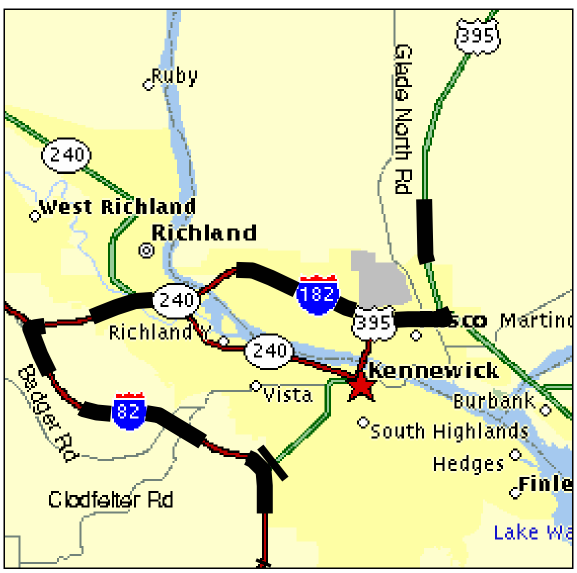
3.2 Detour Routes

Car traffic was detoured as follows (Figure 3):

- Northbound – SR 395 to West 10th Avenue to North Edison Street to SR 240 to SR 395
- Southbound – SR 395 to SR 240 to North Edison Street to West 10th Avenue to SR 395

Truck Traffic was detoured as follows:

- From SR 395 (Figure 4)
  - Northbound – SR 395 to Interstate 82 to Interstate 182 to SR 395 (about 13 miles)
  - Southbound – SR 395 to Interstate 182 to Interstate 82 to SR 395 (about 13 miles)
- From SR 240 (Figure 5)
  - SR 240 to Interstate 182 to Interstate 82 to SR 395



Detour route

***Figure 4** – Detour route for truck traffic from SR 395*

***Figure 5** – Detour route for truck traffic from SR 240*

Flaggers were placed at all key locations to keep the car traffic flowing. Truck traffic utilized signing placed on the state highways. WSP was instrumental in enforcing traffic and detour restrictions during the weekend closure.

Traffic flowed well through the weekend. Isolated backups and detour problems were resolved as soon as possible. In some instances, where truckers violated the detour and traffic restrictions, they were pulled over and cited by WSP. The use of flaggers and active presence of WSP helped keep the car and truck traffic restriction violations to a minimum during the closure period. Figures 6 through 11 show the detour and closure operations.

Figure 6 *– Traffic backup from the south during construction of approach legs*

Figure 7 *– Traffic flow pushed to the west during construction of approach legs*

Figure 8 *– WSP closing the road*

Figure 9 *– Road closure*

Figure 10 *– Typical detour sign*

Figure 11 *– Road closure notice using Variable Message Sign (VMS)*

4.0 Concrete Materials

The primary concern with accelerated pavement construction is determining when traffic can begin to use the new pavement. The basis for this decision should be made on the concrete strength and not arbitrarily on the time from placement. Strength directly relates to load-carrying capacity and provides certainty that the pavement is ready to accept loads by construction or public traffic.

For concrete pavement applications, flexural strength is the most direct indicator of load capacity. Flexural strength values indicate the tensile strength at the bottom of the slab where wheel loads induce tensile stresses.

For the intersection to be opened to traffic, the PCCP compressive strength of 2,500 psi must be achieved, which was determined from the maturity meters.

WSDOT requirements call for a design flexural strength of 650 psi at 14 days and 2500 psi compressive strength for opening to traffic. Typically this is obtained in 3 to 7 days. For this project, the concrete mix design was critical in maintaining the accelerated schedule. The contractor's schedule required a mix which would allow for opening to traffic within 24 hours. In order to determine the strength of concrete, maturity meters were utilized (see Section 5.5).

Air-entraining admixtures meeting ASTM C 260 requirements are used to entrain microscopic air bubbles in concrete. Entrained air improves concrete durability by reducing the adverse effects of freezing and thawing. Generally, accelerated-concrete pavement will provide good durability. Most accelerated paving mixtures have entrained air and a relatively low water content that improves strength and decreases chloride permeability. Freeze-thaw deterioration can occur if water freezes and expands within a concrete binder with a poor air-void distribution or if the concrete contains poor-quality aggregates. Properly cured concrete with an adequate air-void distribution resists water penetration and relieves pressures that develop in the cement paste. Air-entrained concrete pavement is resistant to freeze-thaw deterioration even in the presence of deicing chemicals. The concrete used for this project had 6.3% total air content.

Finely ground cement increases surface area and allows more cement contact with mixing water and, consequently, the cement hydrates faster. In this project ASTM C 150 Type III portland cement was used. Type III cement, which is much finer than other types of portland cement, usually develops strength quickly.

A low water-cementitious material ratio (w/c) contributes to low permeability and improved durability. A w/c ratio between 0.40 and 0.50 provides moderate chloride permeability for concrete made from conventional materials. A w/c ratio below 0.40 typically provides low chloride permeability. The concrete used in this project has a w/c ratio of 0.36.

Water-reducing admixtures reduce the quantity of water necessary in a concrete mixture or improve workability at a given water content. Water-reducing admixtures increase early strength in accelerated concrete paving mixtures by lowering the quantity of water required for appropriate concrete placement and finishing techniques. Water reducers disperse the cement, reducing the number of cement agglomerations. More efficient and effective cement hydration occurs, thus increasing strength at all ages.

In order to prevent premature set of concrete during transportation from the mix plant to the job site or while the truck is being queued before delivery, set-retarding admixture (Delvo) was used in this project.

4.1 Concrete Mix Proportioning Considerations

Rapid strength gain is one of the requirements for reducing facility closure time. While many methods exist to do this, the contractor was determined to keep the mix as simple as possible and limit the number of variables to a minimum. The batch plant was located 20 to 25 minutes away from the job site and the construction crew needed 45 minutes to 1 hour to place the concrete without rapid setting.

Table 1 shows the concrete mix design used for the intersections in Kennewick:

Table 1 – Concrete Mix Design

Material	Type	Quantity
Cement (lbs/yd^3)	ASTM C 150 Type III	705
Aggregate (lbs/yd^3)	1 ½”	940
	¾”	799
	3/8” Pea Gravel	140
Sand (lbs/yd^3)	Coarse	590
	Fine	481
Water (lbs/yd^3)	-	254
Air-entraining admixture (oz/yd^3)	ASTM C 260	11
Water-reducing admixture (oz/yd^3)	ASTM C 494	30.3
Set-retarding admixture (oz/yd^3)	ASTM C 494 / Delvo	17.6

Table 2 shows the characteristics of the concrete delivered to the site:

Table 2 – Concrete characteristics

Characteristic	Quantity
Slump	3 ¼ in.
w/c ratio	0.36
Air Content	6.3%
Unit Weight	149.8 pcf
Concrete temperature	85°F
Air Temperature	82°F

4.2 Concrete Testing

Acceptance testing for the PCCP was done by statistical acceptance according to WSDOT Standard Specification 1-06.2(2)D. WSDOT's statistical acceptance accounts for the air content and the 28-day compressive strength. The lower quality limits for air content is 3.0 percent. The upper quality limit for air content is 7.0 percent. The lower quality limit for compressive strength is 1000 psi less than that established in the mix design as the arithmetic mean of the five sets of 28 day compressive strength cylinders or 3000 psi, whichever is greater. These compressive strength cylinders are cast at the same time as the flexural beams that were used to pre-qualify the mix design. There is no upper quality limit for compressive strength. The 2002 WSDOT Standard Specification for Acceptance of Portland Cement Concrete Pavement is shown in Appendix F.

WSDOT Standard Specifications allows for both statistical and non-statistical acceptance. Typically, statistical acceptance is not done on projects where the concrete quantities are small, such as intersections, as sublots between tests have 400 cubic yards (500 m^3). The total concrete on the Kennewick intersection was 715 cubic yards (547 m^3). However, the Kennewick Intersection project showed that statistical acceptance works well when enough samples are taken.

The frequency of testing provided, as required in the specifications, is one test per a maximum of 500 cubic yards (400 m^3) with a minimum of three tests. For smaller projects, WSDOT recommends increasing the testing frequency to increase the number of samples for the statistical analysis and reduce any potential penalty to the contractor should a particular sublot yield poor results.

In this project, the ready mix supplier provided quality control personnel for every concrete placement on the project. This was essential to avoid penalties. Quality assurance was provided by WSDOT.

Table 3 shows the results of the compressive strength testing conducted in developing the strength-maturity relationship for this mix.

Table 3 – Concrete compressive strength gain

Time at Test, Hrs	Compressive Strength, f'_c, psi
6	2050
12	3290
18	3770
24	4015
30	4200
36	4225
42	4140
48	4245
54	4245
60	4495
66	4685
72	4690

As can be seen from the table above, this mix is capable of reaching the opening strength requirements shortly after placing (≈8 hours). The strength gain data shown in Table 3 is plotted in Figure 12.

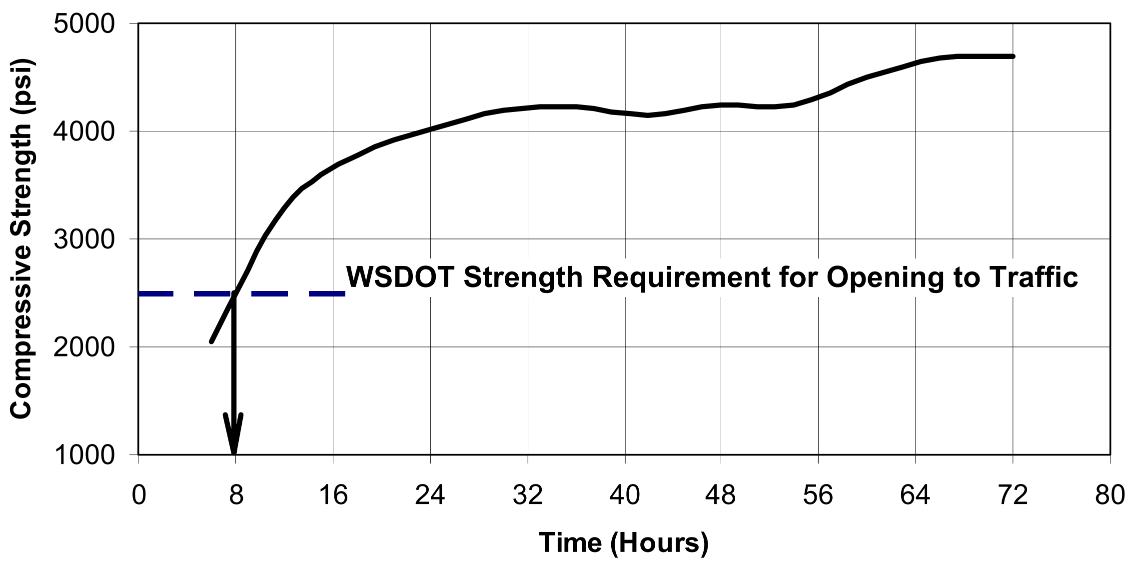


Figure 12 *– Compressive strength gain vs. time*

Figures 13 and 14 show concrete sampling from the concrete mix truck and air content measurement. Tests were conducted on each concrete truck delivery. These tests included unit weight measurement, slump test (to measure flowability and consistency), and air content measurements.

Figure 13 – *Concrete sampling from mixer truck*

Figure 14 – *Air content measurement*

The results of the Kennewick intersection testing are shown in Table 4.

Table 4 – The results of the Kennewick intersection testing

Cylinder No.	**Size (In.)**	**Date Made**	**Unit Weight** lbs/ft^3 (kg/m^3)	**W/C Ratio**	**% Air**	**Date Tested**	**Compressive Strength, f'_c** psi (Mpa)
25A	6×12	10/6/2000	148.6 (2380)	0.38	4.5	11/3/2000	4926 (33.96)
25B	6×12	10/6/2000	148.6 (2380)	0.38	4.5	11/3/2000	4978 (34.32)
26A	6×12	10/7/2000	151.1 (2420)	0.39	3.4	11/3/2000	5207 (35.90)
26B	6×12	10/7/2000	150.5 (2410)	0.39	3.4	11/3/2000	5407 (37.28)

The results of the Kennewick intersection core testing are shown in Table 5.

Table 5 – The results of the Kennewick intersection core testing

Core Location	**Date Cored**	**Date Tested**	**Core Density** lbs/ft^3 (kg/m^3)	**Core Depth** in (mm)	**Core Depth Specification** in (mm)
North Approach on SR 395	10/1/2000	10/3/2000	148.02 (2371)	12.28 (312)	11.81 (300)
South Approach on SR 395	10/1/2000	10/3/2000	150.08 (2404)	12.20 (310)	

Construction

Figure 15 shows the Intersection of SR 395 and Kennewick Avenue prior to reconstruction of that intersection (Stage 0).

Figure 15: *The Intersection of SR 395 and Kennewick Avenue prior to construction*

The 3-day closure rebuilt the intersection square (radius return to radius return). The approach legs were rebuilt in the days prior to the complete intersection closure. The reconstruction of the approach legs for Kennewick Avenue intersection were staged as follows and depicted in Figure 16:

- Stage 1: Construction of the left hand turn lane with traffic on both sides of the turn lane. Traffic reduced to one lane in each direction.
- Stage 2: Construction of the northern approaches with traffic (one lane in each direction) pushed to the south.
- Stage 3: Construction of the southern approaches with traffic (one lane in each direction) pushed to the north.

and finally, after the approach legs were completed,

- Stage 4: Construction of the intersection square (radius return to radius return).

Stage 1: *Construction of the left hand turn lane*

Stage 2: *Construction of the northern approach with traffic pushed to the south*

Stage 3: *Construction of the southern approach with traffic pushed to the north*

Stage 4: *Construction of the intersection square (radius return to radius return)*

Figure 16 – *Construction sequence of the approach legs in SR 395*

The contractor had to prepare and execute an hourly progress schedule during the intersection closure. This was critical to the contractor since the contractor set the liquidated damages at $2,400 per hour for each hour that public was denied the full use of the intersection after 6:00 AM on Monday. The intersections were shut down by 7:00 PM on Thursday evening and construction started by 8:00 PM. The contractor maintained a "milestone" schedule where by certain activities had to occur by a certain time.

The schedule used by the contractor was as follows:

- Thursday evening to Friday morning – Excavate the existing roadway and prepare the grade for concrete.
- Friday at 10:00 AM to early evening – Form and place concrete.
- Saturday at 8:00 AM to late evening – Form and place concrete.
- Sunday – Prepare roadway for opening to traffic

The intersections were opened on Sunday between 4:00 PM and 6:00 PM, well ahead of the 6:00 AM Monday morning opening.

Figure 17 shows the contractor's CPM schedule.

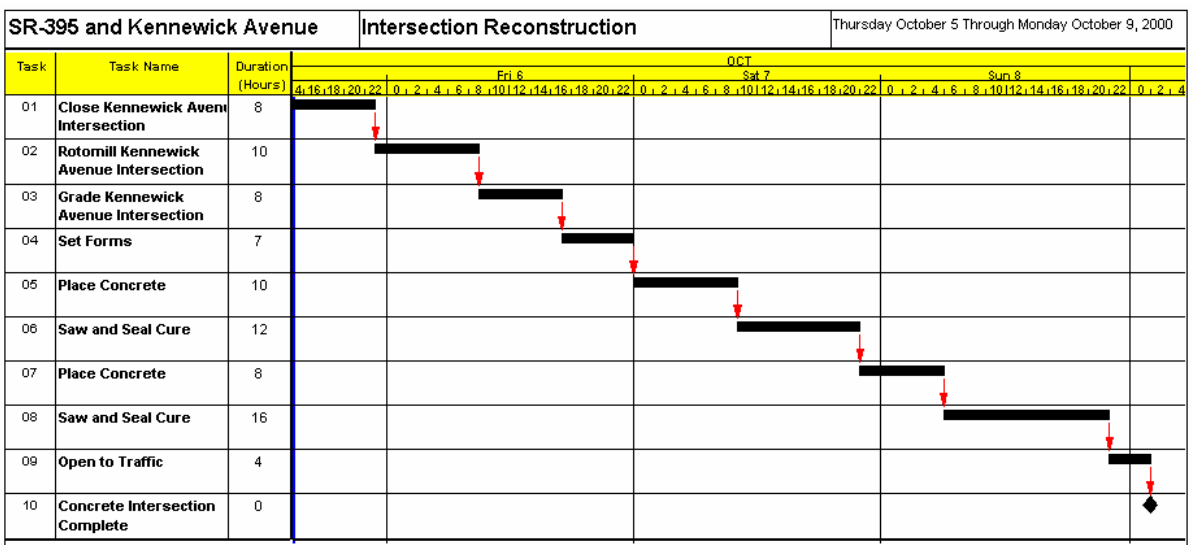


Figure 17 *– Contractor's CPM schedule*

The CPM schedule was straight forward, as most activities have "start-to-start" or "start-to-finish" relationships.

Table 5 is a summary of the CPM schedule showing the main activities of the construction with start times, finish times, and duration.

Table 5 – Contractor's estimated CPM schedule for Kennewick Avenue intersection weekend closure

Sequence	**Work Activity**	**Start**	**Finish**	**Duration (hrs)**
1	Close Kennewick Ave. Intersection	10/5/00 3 PM	10/5/00 11 PM	8
2	Rotomill Kennewick Ave. Intersection	10/5/00 11 PM	10/6/00 9 AM	10
3	Grade Kennewick Ave. Intersection	10/6/00 4 AM	10/6/00 12 PM	8
4	Set up Forms	10/6/00 7 AM	10/6/00 3 PM	8
5	Place Concrete	10/6/00 11 AM	10/6/00 9 PM	10
6	Saw and Seal Cure	10/6/00 9 PM	10/7/00 9 AM	12
7	Set up Forms	10/7/00 7 AM	10/7/00 10 AM	3
8	Place Concrete	10/7/00 10 AM	10/7/00 6 PM	8
9	Saw and Seal Cure	10/7/00 6 PM	10/8/00 10 AM	16
10	Open to Traffic	10/8/00 10 AM	10/8/00 2 PM	4
	Concrete Intersection Complete	10/5/00 3 PM	10/8/00 2 PM	71

The contractor's actual CPM schedule is shown in Table 6. The chronology of construction events at the intersection of SR 395 and Kennewick Avenue reconstruction is shown in Appendix C.

Table 6 – Contractor's actual CPM schedule for Kennewick Avenue intersection weekend closure

Sequence	Work Activity	Start	Finish	Duration (hrs)
1	Close Kennewick Ave. Intersection	10/5/00 4:00 PM	10/5/00 7:00 PM	3:00
2	Rotomill Kennewick Ave. Intersection	10/5/00 8:07 PM	10/6/00 3:10 AM	7:03
3	Grade Kennewick Ave. Intersection	10/6/00 3:30 AM	10/6/00 11:30 AM	8:00
4	Set up Forms	10/6/00 7 AM	10/6/00 3 PM	8:00
5	Place Concrete	10/6/00 11:40 AM	10/6/00 9:00 PM	9:20
6	Saw and Seal Cure	10/6/00 3:00 PM	10/7/00 6:30 AM	15:30
7	Set up Forms	10/7/00 7 AM	10/7/00 10 AM	3:00
8	Place Concrete	10/7/00 8:00 AM	10/7/00 4:15 PM	8:15
9	Saw and Seal Cure	10/7/00 6:00 PM	10/8/00 11:30 AM	17:30
10	Open to Traffic	10/8/00 9:00 AM	10/8/00 4:45 PM	7:45
Concrete Intersection Complete		10/5/00 4 PM	10/8/00 2 PM	≅ 70 Hrs

The breakdown of the time actually spent on each activity during the reconstruction of the Kennewick Avenue intersection is listed in table 7.

Table 7 – Breakdown of time consumed by each activity during the reconstruction of the intersection of SR 395 and Kennewick Avenue

Activity	Time (Minutes)
Closing Roadway	60
Excavation	395
Grading	260
Conduit Repair	60
Form and Place Concrete	1290
Sawcutting	570
Cure Concrete	720
Clean Joints	240
Joint Seal	240
Clean Roadway	60
Prep Roadway for Opening to Traffic	165
Delay	95
Total	4155 Min. ≅ 70 Hrs

Figure 18 is a pie chart of the activities shown in Table 7.

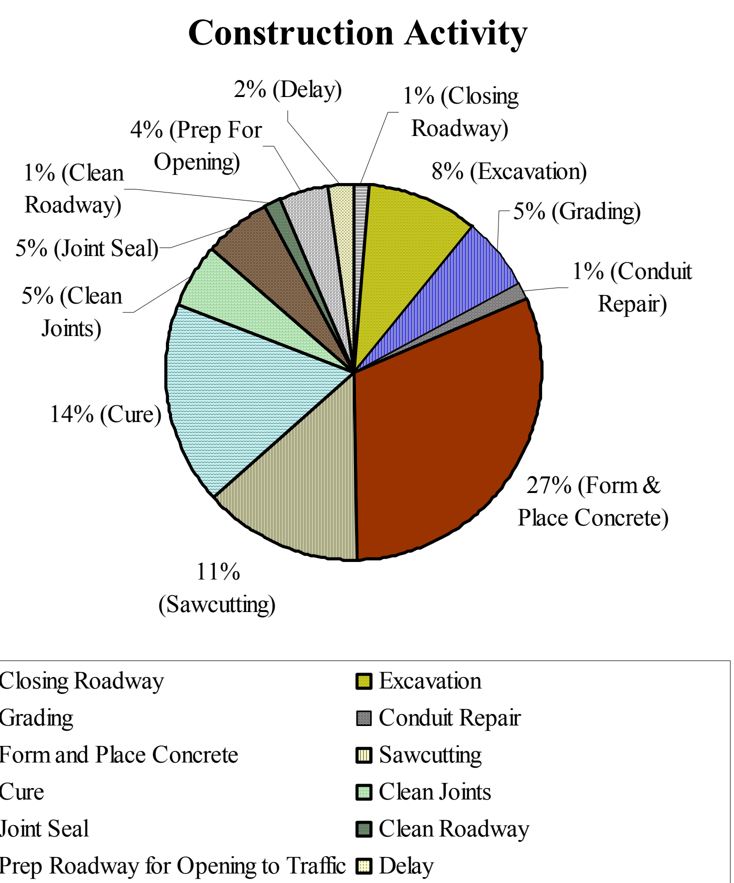


Figure 18 *– Components of typical turn-around time for a PCCP intersection reconstruction*

Special equipment is not necessary for rapid construction of concrete pavement. Because the time for placement can be shorter than with conventional paving, however, accelerated paving requires well-planned construction sequencing.

The construction began at 7:00 PM on Thursday, October 5th, 2000. The construction sequence from removal of the existing pavement to opening to traffic on Sunday, October 8th is outlined in the following sections.

Figure 19 shows an aerial photo of the construction of the SR 395 and West Kennewick Avenue on the Friday of the three-day closure.

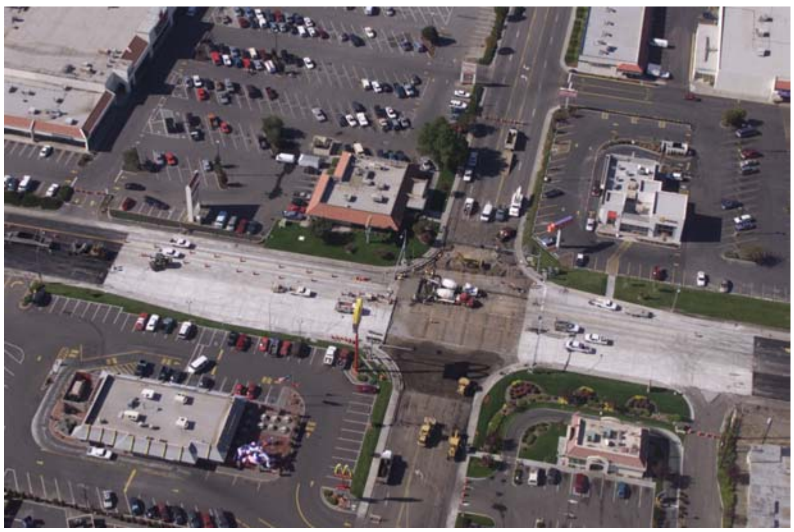


Figure 19 *– Aerial photo of Kennewick intersection, ready for concrete placement*

5.1 Removal of the Existing Pavement

Removal of the existing pavement and preparation of the grade to support the new material is critical in the reconstruction process. A rotomill was used to remove the existing pavement and base to a depth of 12 inches in a single pass (Figure 20). To ensure that the schedule was maintained, the contractor had a second rotomill standing by. The total amount of the existing AC pavement removed was 998 Tons (detail shown in Appendix D).

Figure 20 *– Wirtgen W2200 Rotomill*

Figure 21 *– Replacing broken electric conduit*

During removal of the existing pavement, electrical conduit was encountered in two locations (Figure 21). This required a change order to relocate these conduits and replace the wiring. This emphasizes the necessity to have decision makers onsite to address unexpected problems. The WSDOT and contractor immediately agreed to relocate the utility and address the change order at a later date.

5.2 Grade Preparation

In an intersection, while the surface area to be graded is not large, it can still be a difficult job due to the size of the equipment and the confined working area. Obtaining uniform support demands the same construction practices and attention to detail that any newly constructed roadway requires. A poorly compacted base layer will lead to pavement performance problems, such as settlement and cracking. Figures 22 through 25 show some of the grading operations at the Kennewick Avenue intersection.

Attention must be paid to the compaction around all utility installations. They are especially vulnerable to soft spots, which lead to excess settling and jeopardize the useful life of the intersection.

***Figure 22** – Surveying the grade*

***Figure 23** – Grade preparation*

***Figure 24** – Rolling grade*

***Figure 25** – Subgrade compaction*

5.3 Setting Forms, Dowel Bar Baskets and Tie Bars

Construction of PCCP intersections requires some type of fixed-form construction to accommodate short paving segments, varying paving widths, and curved paving areas. The forms were placed to allow placement of the PCCP with roller screeds. Figure 26 shows the erection of forms. Dowel bar baskets were pre-fabricated with ten epoxy coated dowel bars per joint. Figure 27 shows the dowel bar baskets placed between the forms.

***Figure 26** – Setting forms*

***Figure 27** – Installation of dowel bar baskets*

The dowel bar baskets were placed at the proper transverse joint locations according to the plan shown in Figure 28.

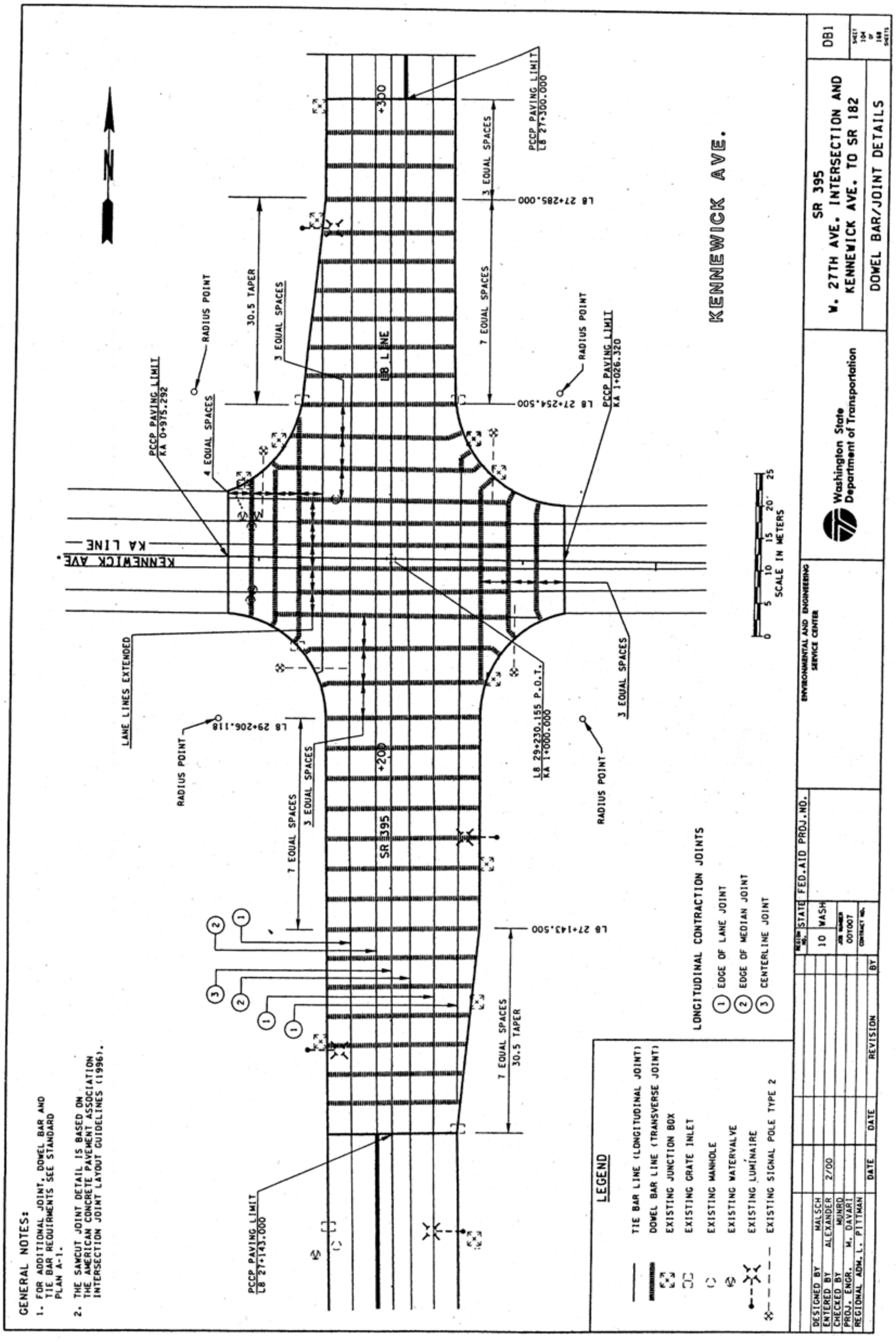


Figure 28 *– Design criteria for installation of dowel bars and joint details*

Tie bars for longitudinal construction joints and dowel bars for construction joints were inserted into holes along the sides of the fixed forms. The dowel baskets for transverse joints were clearly referenced before concrete placement. Dowel and tie bars were properly aligned within WSDOT specifications and tolerances (Figure 28). The dowel bar baskets were not anchored to the base, however, the contractor placed concrete directly on them to prevent movement during other placing operations. All dowel and tie bars were epoxy coated and the dowels were coated with non-bonding agent for their entire length to prevent bonding with PCCP.

5.4 Placing the Concrete

Concrete was placed in alternate sections (Figure 29) to eliminate the use of forms for the interim sections. The alternate sections 1 through 4 were placed on Friday, October 6, 2000.

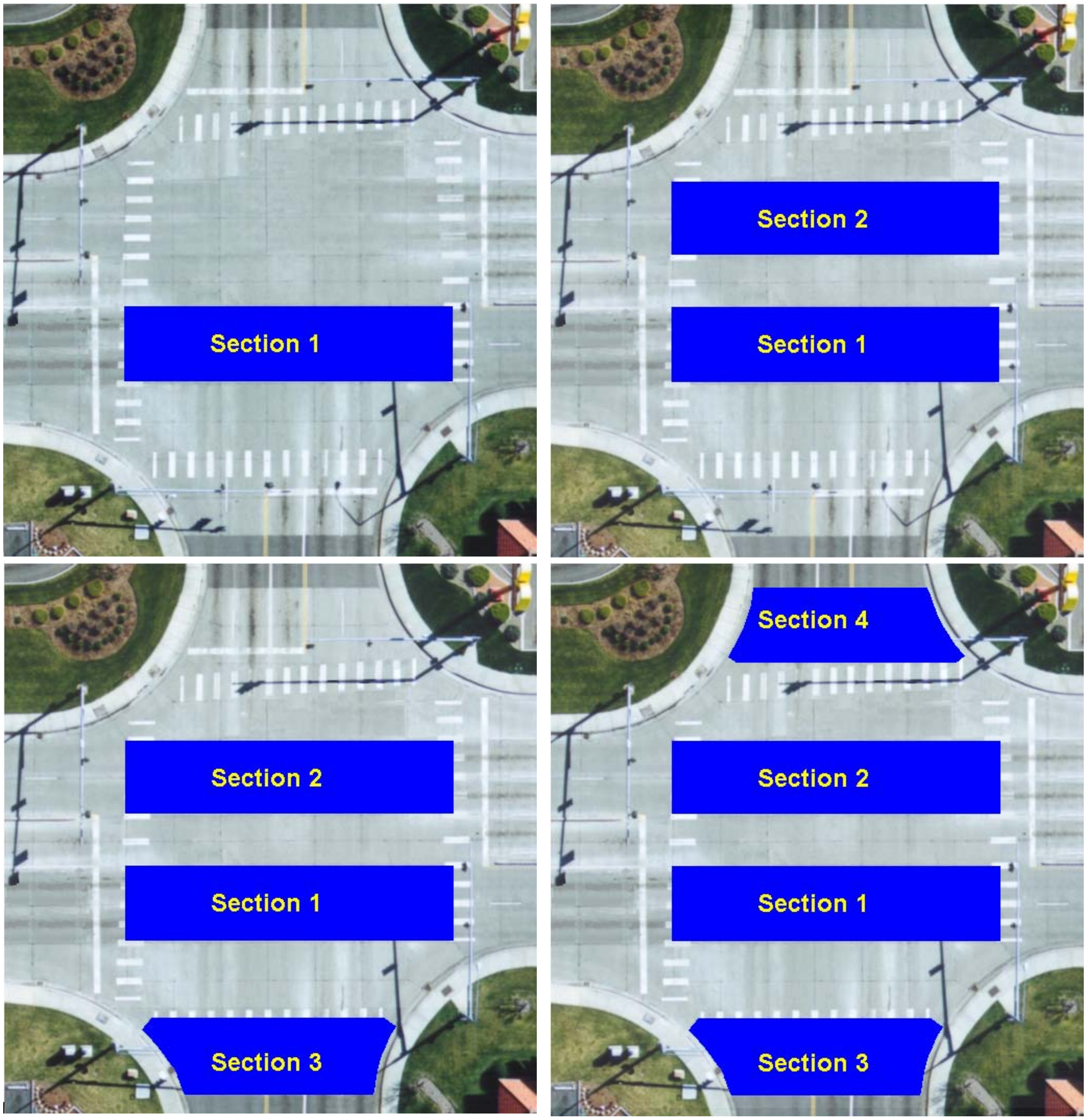


***Figure 29** – Concrete placement in alternate sections*

With the alternate sections in place (sections 1 through 4), on Saturday, October 7, 2000 the interim sections (sections 5 through 7) were placed, which did not require use of forms, since the sides of the newly placed pavement act as forms. This way a significant amount of time was saved by not erecting and removing side forms (Figure 30).

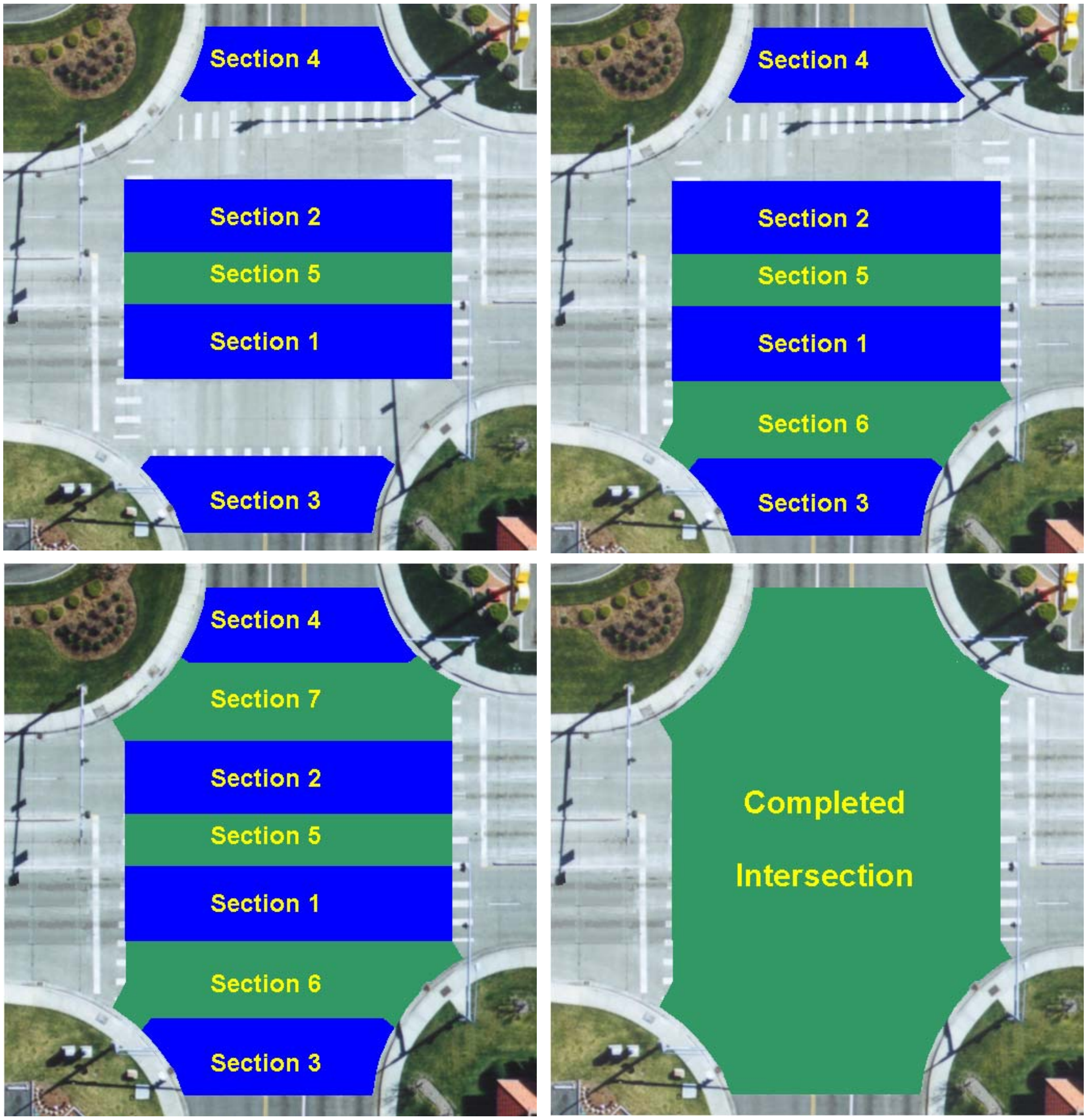


Figure 30 *– Concrete placement in interim Sections*

Concrete was delivered to the site in redi-mix trucks (Figures 31 and 32). Then, a roller screed and a Whiteman screed were used for finishing (Figures 33 through 35). Vibration was used to consolidate the concrete mix (Figure 36).

Figure 31 *– Two Trucks delivering concrete*

Figure 32 *– Concrete discharge and paving operation*

Figure 33 *– Roller screed*

Figure 34 *– Placement with roller screed*

Figure 35 *– Whiteman screed*

Figure 36 *– Vibrating concrete*

5.5 Use of Maturity Meter

Determination of the strength of in-place concrete is obviously important to contractors. Decisions such as when to strip forms and when to open the pavement to traffic are based on reaching a minimum level of concrete strength.

Waiting too long to perform these operations is expensive, but acting prematurely may cause the structure to crack or collapse. The maturity method is the technique that was used to estimate the strength of in-place concrete in this project. The maturity method is simply a technique for predicting concrete strength based on the temperature history of the concrete. The time-temperature numbers for the mix were determined in the laboratory prior to placement.

Maturity testing provides strength evaluation through monitoring of internal concrete temperature in the field. The temperature history is used to calculate a maturity index that accounts for the combined effects of time and temperature. The basis of maturity testing is that each concrete mixture has a unique relationship of strength to maturity index. Strength increases as cement hydrates. The amount of cement hydrated depends on curing time and temperature. Maturity is a measure of how far hydration has progressed. The most common expression used for maturity is the Nurse-Saul temperature-time factor $M(t)$:

$$M(T) = \sum (T_a - T_0)\Delta t$$

where

T_a = average concrete temperature during each time interval

T_0 = datum temperature, temperature below which cement hydration is assumed to cease (typically –10°C [14°F]).

Δt = time intervals, days or hours

Σ = summation of all the intervals of time multiplied by temperature

When using this equation, the maturity factor is expressed as degree-days or degree-hours. For example, a maturity of 400 degree-hours might be required before stripping forms. Direct reading maturity devices are preset for an assumed temperature below which cement hydration ceases.

As soon as practicable after concrete placement, temperature sensors were embedded into the fresh concrete. Sensors were connected to maturity instruments and the recording device was activated. Using the strength-maturity relationship developed in the laboratory, the value of compressive strength corresponding to the measured maturity index could be read from the instrument.

Maturity meters were used to determine form removal and time of opening to traffic. Figure 37 shows a commercial maturity meter and Figure 38 shows maturity meter sensors imbedded in fresh concrete and recording the internal temperature.

Figure 37 *– Maturity meter*

Figure 38 *– Maturity meter sensors imbedded in concrete*

Figures 39 and 40 show the maturity (time temperature factor) versus compressive and flexural strengths for a mix used by the contractor.

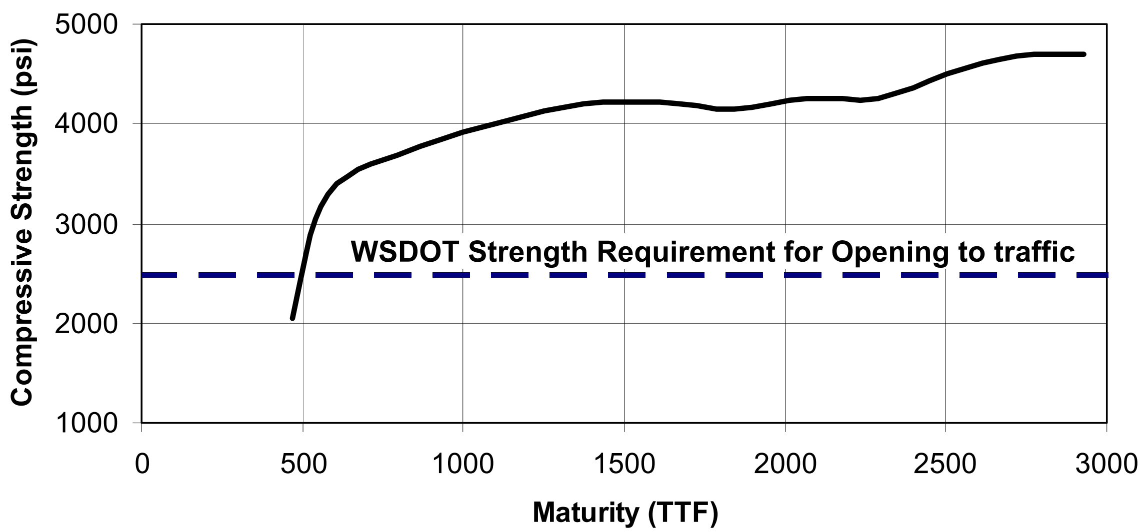


Figure 39 *– Maturity vs. concrete compressive strength*

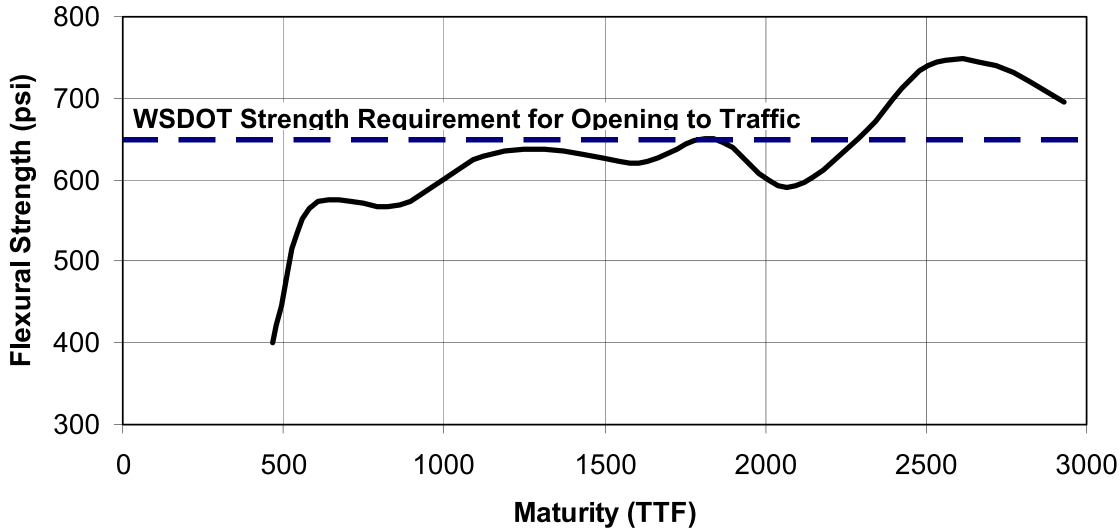


Figure 40 *– Maturity vs. concrete flexural strength*

Figure 41 shows the strength gain versus time from the maturity meter.

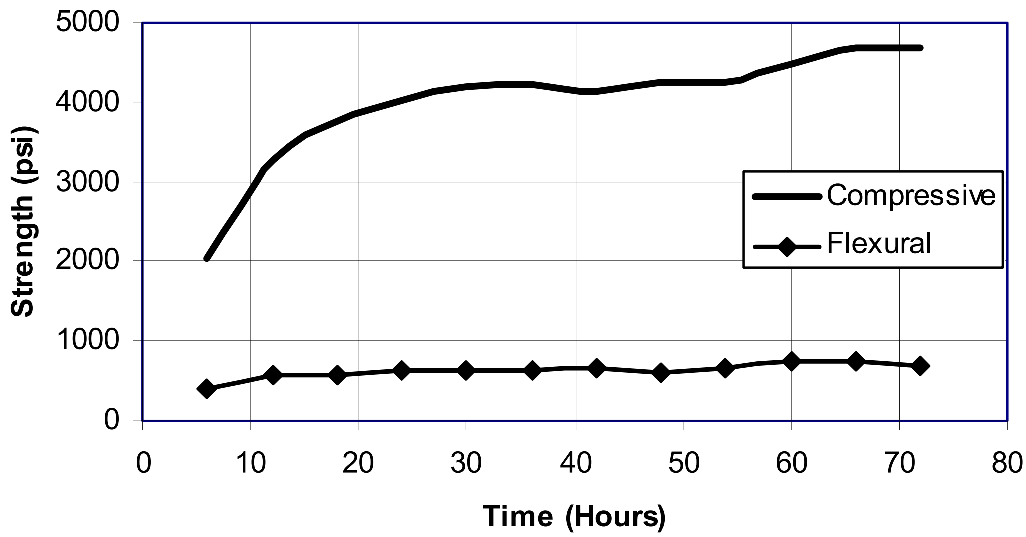


Figure 41 *– Concrete compressive and flexural strength gain vs. time*

5.6 Finishing and Texturing of Concrete

Hand finishing was kept to a minimum through proper operation of the Whiteman and roller screeds. Where hand finishing was necessary, it was accomplished with standard hand tools. Figures 42 and 43 show finishing, and Figures 44 and 45 show floating operations.

Figure 42 *– Finishing concrete*

Figure 43 *– Finishing concrete*

Figure 44 *– Floating behind Whiteman screed*

Figure 45 *– Floating*

Tines were used to texture the surface of freshly placed PCCP. Figures 46 and 47 show the texturing operation and a textured concrete surface.

Figure 46 *– Manual texturing of the pavement*

Figure 47 *– Tines of freshly placed concrete*

5.7 Curing of Concrete

Proper curing is necessary to maintain a satisfactory moisture condition in the concrete to ensure proper hydration. Internal concrete moisture directly influences both early and ultimate concrete properties. Therefore, initiating curing immediately after placing and finishing activities is important. Even more so than with standard concrete, curing is necessary to retain the moisture necessary for hydration during the early strength gain of accelerated concrete pavement.

In this project a liquid membrane curing compound was utilized which met ASTM C 309 material requirements. This compound was a white-pigmented compound applied to the surface and exposed edges of the concrete pavement at a rate of one gallon per 150 ft^2. The curing compound creates a seal that minimizes evaporation of mixing water and contributes to thorough cement hydration. The white color also reflects solar radiation during bright days to prevent excessive heat build up in the concrete surface. Class A liquid curing compounds used in this project are sufficient for accelerated-concrete paving under normal placement conditions when the application rate is sufficient.

Curing compound was sprayed on the surface immediately after finishing and texturing. Curing compound was applied in two passes at 90 degrees to each other, to ensure complete coverage and offset wind effects. Figure 48 shows application of the curing compound.

Figure 48 *– Curing compound being applied manually*

5.8 Sawing and Sealing Joints

After paving and curing of concrete, control joints must be sawn into the new pavement. Monitoring heat development in the concrete enables the contractor to adjust curing measures to influence the rate of strength development, the window for sawcutting, and the potential for uncontrolled cracking. Maturity testing allows field measurement of concrete temperature and correlation to concrete strength.

The sawing window is a short time period of time after placement when the concrete can be cut successfully without cracking. Sawing can begin when the sawcut operation does not produce excessive raveling along the sawcut. Sawing must be completed prior to the shrinkage stresses exceeding the tensile strength of the concrete, which causes uncontrolled cracking to begin.

There are many factors which can affect the length of the sawing window. These include the rate of concrete hydration, base type, and weather conditions. While experience is the most important factor in deciding when to saw, the surface hardness and concrete temperature can also be used to monitor the sawing window. Sawing should be completed before the pavement temperature drops significantly. The sawcutting at the Kennewick Avenue intersection typically began within 6 hours of concrete placing. Figures 49 through 51 show sawcutting operations.

Figure 49 *– Sawcutting freshly placed PCCP*

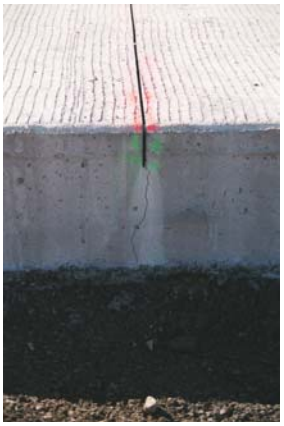


Figure 50 *– Traverse crack at form edge*

Figure 51 *– Joint at PCCP*

The joint sealing in this intersection was in accordance with standard WSDOT specifications which require that sawed contraction joints be from 3/16” to 5/16” in width and 1/3 the depth of placement. The joints are then cleaned, dried, and sealed with a hot-poured asphaltic joint filler. Figures 52 through 54 show Joint cleaning and sealing operations.

Figure 52 *– Cleaning the joint reservoir*

Figure 53 *– Joint sealing of sawed construction joint*

Figure 54 – Joint sealing

Figures 55 and 56 show examples of proper and poor sawcutting and sealing.

Figure 55 *– Example of Proper sawcut and sealing*

Figure 56 *– Example of poor sawcut and sealing*

5.9 Bond Breakers between PCCP and Existing Concrete and Isolating Utilities

In order to prevent transverse cracking in newly placed PCCP caused by existing concrete surfaces, it is important to isolate two structures. In this project a 30 lb. roofing felt was attached to the face of the existing curb and gutter to provide this isolation. Without this isolation, the freshly placed concrete can bond to existing surfaces. Excessive cracking can then be developed from the stresses created in the new concrete from its inability to expand and contract and from developing a mechanical bond to the existing concrete. Figure 57 shows the roofing paper placed on the interface of the old and new material.

Figure 57 *– Placement of roofing paper sheet as a bond breaker between existing curbing and new concrete slab*

Manholes and other utilities should be isolated in order to prevent uncontrolled cracking around these utilities. The utilities were encased in a box out, effectively isolating them from the main concrete slab to minimize the impact of differential movement. The box out was left imbedded in the concrete slab. As the result of this operation, no visible cracks were observed around these utilities after concrete was cured and hardened. Figures 58 through 61 show details of this operation.

***Figure 58** – Encasing existing utility*

***Figure 59** – Boxed out manhole*

***Figure 60** – Placing concrete inside and out side of the box out*

***Figure 61** – Finished surface with imbedded encasement*

5.10 Placing Asphalt Concrete Adjacent to New PCCP

The final step to completing the intersection is to place the asphalt concrete pavement (ACP) adjacent to the concrete approach, leave legs, and the ends of the PCCP intersection. The area adjacent to the newly placed PCCP was excavated 2 to 3 feet and the excavated area was replaced with concrete to the level of the inlay that abuts the PCCP. ACP is then placed above the new concrete to the level of the PCCP.

Figures 62 through 64 show placement of concrete for backfill and Figure 65 shows paving with ACP over concrete backfill.

Figure 62 – Placing concrete for backfill

Figure 63 – Placing concrete at pourback area

Figure 64 – Completed concrete backfill

Figure 65 – Brooming preparation for ACP

5.11 Surface Preparation and Opening to Traffic

Before opening to traffic, the intersection was thoroughly cleaned using a water truck, as shown in Figure 66. Figure 67 shows the cleaned intersection.

Figure 66 – Cleaning the roadway with water truck

Figure 67 – Cleaned intersection

Cores were taken from the newly paved intersection for depth measurement (Figure 68).

Figure 68 – Coring concrete

The next step was to place striping prior to opening to traffic. Figures 69 and 70 shows this operation.

Figure 69 – Placing striping

Figure 70 – Placing stopbar and lane striping

5.0 Construction Costs

Full-depth PCCP reconstruction at urban intersections costs approximately 25 to 30 percent more than full-depth ACP construction (Reference 1). According to the Federal Highway Administration (FHWA), PCCP has an average life of 30 to 35 years, requires less annual maintenance, and therefore, less time is lost in traffic jams caused by road repairs. Life-cycle cost analysis is a tool that brings together all of the information needed to make an educated choice: initial investment, anticipated service life, overlay and maintenance costs over the roadway's life, the value of money saved as well as spent. The 40-year annualized costs for intersections with and without user delay costs show that full-depth PCCP intersection reconstruction typically costs less than full-depth ACP reconstruction with future ACP inlays when intersection reconstruction is necessary (Reference 1).

The area of the approach legs at the SR 395 and Kennewick Avenue intersection was 30,013 ft^2 (2,788 m^2), and the area of intersection square (radius return to radius return) itself was 14,559 ft^2 (1,353 m^2) as tabulated in Table 8 for each segment paved. In Table 8, the corresponding segment map is shown in Figure 71.

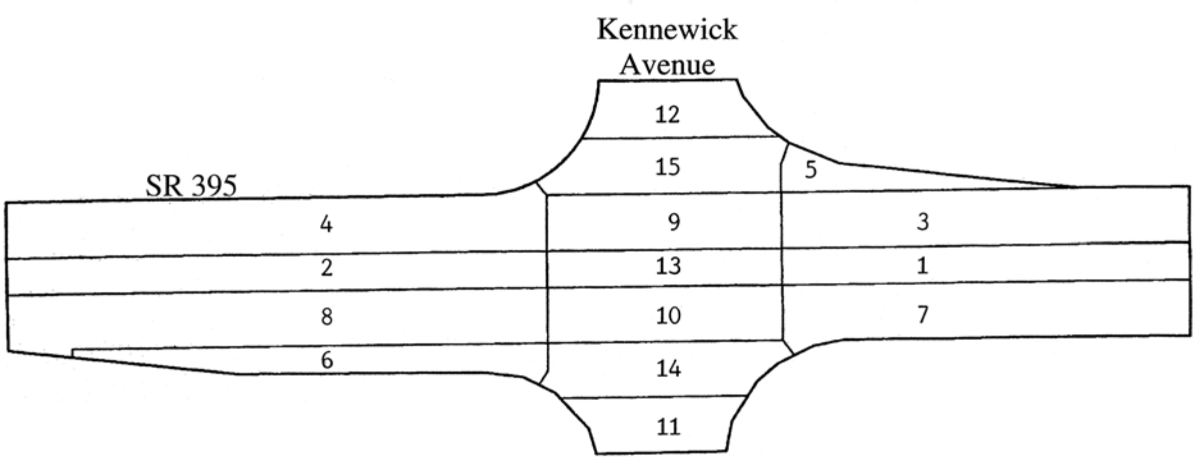


Figure 71 – Paved segment numbers at Kennewick intersection

Table 8 – Segment areas of the approach legs and intersection at SR 395 and Kennewick Avenue

Segment No.	Location	Date	Area, m^2	Area, ft^2
1	Approach	21-Sep-2000	264	2837
2	Approach	22-Sep-2000	352	3784
3	Approach	27-Sep-2000	395	4255
4	Approach	27-Sep-2000	537	5779
5	Approach	28-Sep-2000	97	1044
6	Approach	03-Oct-2000	208	2242
7	Approach	04-Oct-2000	404	4345
8	Approach	04-Oct-2000	532	5728
Total Approach Area			**2,788**	**30,013**
9	Intersection	06-Oct-2000	227	2443
10	Intersection	06-Oct-2000	227	2443
11	Intersection	06-Oct-2000	149	1603
12	Intersection	06-Oct-2000	163	1757
13	Intersection	07-Oct-2000	151	1628
14	Intersection	07-Oct-2000	217	2332
15	Intersection	07-Oct-2000	219	2353
Total Intersection Area			**1,353**	**14,559**
Total Approach and Intersection Area			**4,141**	**44,572**

The cost of the reconstruction of the intersection at Kennewick Avenue and SR 395 was $226,830. The cost breakdown is shown in Table 9. The unit price for reconstruction of the intersection at SR 395 and Kennewick Avenue is $15.58 per square foot.

Table 9 – Construction cost for Kennewick Avenue and SR 395 intersection reconstruction

DESCRIPTION	UNIT BID PRICE	UNIT	QUANTITY	EXTENDED PRICE
Removing Traffic Curb	$35.00	Meter	118.00	$4,130.00
Cement Concrete Pavement	$247.00	M^3	547.00	$135,109.00
Epoxy-Coated Tie Bar With Drill Hole	$0.10	Each	1187.00	$118.70
Planing Bituminous Pavement 300mm - 345 mm Depth	$3.22	M^2	1753.00	$5,644.66
Type C Block Traffic Curb	$32.00	Meter	181.00	$5,792.00
Plastic Gore Stripe	$6.20	Meter	17.00	$105.40
Plastic Crosswalk Stripe	$32.50	M^2	97.00	$3,152.50
Plastic Stop Bar	$17.50	Meter	59.00	$1,032.50
Plastic Traffic Arrow	$70.00	Each	1.00	$70.00
Temporary Pavement Marking	$0.16	Meter	200.00	$32.00
Traffic Signal Display And Detection System 1 Revision	$44,490.00	Lump Sum	1/3	$14,830.00
Portable Changeable Message Sign	$6,500.00	Each	1.67	$10,833.33
Operation of Portable Changeable Message Sign	$3.00	Hour	83.00	$249.00
Traffic Control Labor	$29.00	Hour	607.00	$17,603.00
Traffic Control Vehicle	$50.00	Day	4.00	$200.00
Traffic Control Supervisor	$34.00	Hour	29.50	$1,003.00
CL A Signs (for Detours)	$45.00	M^2	51.53	$2,318.85
C.O. #2 - Portland Cement Concrete Compliance Adjustment	$247.00	0.016	547.00	$2,161.74
C.O. # 5 - Intersection Closure Added Flagging Hours	$17,371.00	L.S.	0.33	$5,790.28
C.O. #3- Signal System Repair	$33,307.26	L.S.	0.50	$16,653.63

INTERSECTION TOTAL **$226,829.59**

6.0 Summary and Conclusions

1. The reconstruction of the intersection at SR 395 and Kennewick Avenue using accelerated construction techniques and complete weekend closure was completed successfully. In fact the intersection was opened to traffic 16 hours ahead of the scheduled opening time. As contractors become more familiar with intersection reconstruction the construction time and cost per unit volume should decrease.

2. The closure of state highways is possible. Once people are well informed of the closure details they are more willing to accept it. The customer focused construction comments show that the overall effect is negative (that is, the inconvenience and loss of sales). However, with the alternative of extending construction the public would much rather be inconvenienced for a short period as long as the work gets done.

3. Weekend closures allow the public to see constant production. Concrete is placed daily and completion can be seen. The long-term service life of concrete pavement out weighs the one-time inconvenience to the public.

4. Weekend closures allow more efficiency for the contractor and their operations. Because the contractor had control of the entire intersection, and because the approaches were completed prior to the weekend closure, it was possible to move efficiently and place the concrete in the intersection.

5. The complete closure of the intersections allows a safe environment for state and construction workers.

6. With the appropriate planning and preparation, and the use of an experienced crew, placement of the paving material became routine. The batch plant was able to easily meet the production demands of the contractor's schedule. This, combined with the contractor's experience, resulted in a smooth and continuous operation.

7. The concrete mix design was critical in maintaining the accelerated schedule. Placing, consolidation, and finishing operations were consistent with typical paving operations, and in accordance with standard WSDOT requirements. Maturity meters were used to verify adequate strength prior to opening the intersections to traffic.

8. A detour plan was implemented that provided local access, access to commercial sites, and special routes for heavy trucks passing through the area. The detour plan made it possible to modify the reconstruction of the intersection approaches and complete this work in the week prior to the intersection closure.

9. Many individuals, especially business owners in the affected areas, were contacted personally by Washington State DOT personnel. Pre-construction meetings were held with the City council and the public to encourage active involvement of all the affected parties.

10. Public information served a vital role in the success of the project. The media was utilized to alert the public to the upcoming construction and to keep them up to date on the schedule. Informed local drivers avoided the area entirely, reducing traffic delays. As a result, complaints from the public were reduced by over 70% compared to the project constructed two years before.

11. The contractor's schedule required a concrete mix design that would allow for opening to traffic within 24 hours. The contractor believed that the project goals could have been accomplished using Type I/II cement for the approach and departure legs. However, the use of Type III cement may be necessary for rapid strength gain during the closure period.

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4. American Concrete Institute "Accelerated Techniques for Concrete Paving," ACI 325.11R-01 Reported by ACI Committee 325, Farmington Hills, Michigan, March 2001.

5. American Concrete Pavement Association, Concrete Paving Technology, "Fast-Track Concrete Pavements," Skokie, Illinois, 1994.

6. Washington State Department of Transportation, "2000 Standard Specifications for Roads, Bridges and Municipal Construction, Manual 41-10, Olympia, Washington, January 2000.

7. American Society of Testing and Materials, Annual Book of ASTM Standards, 2001.

APPENDIX A
WSDOT Closure notices for Kennewick Avenue Intersection

Washington State
Department of Transportation

Intersection Closure Notice

SR 395 & Kennewick Ave.

The intersection of SR 395 and Kennewick Avenue
in Kennewick will be closed for concrete paving

Thursday, October 5th at 7:00 p.m.

Through

Monday, October 9th at 6:00 a.m.

Through traffic will be detoured via SR 240, Edison Street and 10th Ave.

Trucks with a GVW of 26,000 lbs. or greater must detour via I-182 & I-82.

Only local deliveries may use the local detours.

Updates on the status of this project can be obtained by calling 545-2381 or at our website http://www.wsdot.wa.gov/regions/southcentral/constdefault.htm.

APPENDIX B
Labor and Equipment Used in the Project

Excavation

Rotomill:	Wirtgen W2200
	1 Operator
	1 Grade checker
End Dumps:	3 Belly Dumps - 22 Ton Capacity
	2 End Dumps - 14 Ton Capacity
	5 Teamsters

Grading

Loader:	Catepillar 950F
Grader:	Catepillar 40G
Roller:	Ingersol Rand Roller
Backhoe	Catepillar 416
	Grade Crew – 4 on the grade crew
Surveying	2 Surveyors

Conduit Replacement – Change Order Work

Backhoe:	Cat 536C
	1 Operator
	2 Electricians

Induction Loops

Electrician:	1 Electrician (loops)

Form and Concrete Crew

Formwork and Pour Crew:	1 Foreman
	5 Finishers
	4 Laborers
Sawcutter:	1 Sawcutter
8 Concrete Trucks	8 Teamsters

Joint Sealing

Pickup with Hot tank	1 Laborer
	1 Laborer

Miscellaneous

Water Truck	1 Teamster
2 Pickups for Temp Striping	3 laborers
Air compressor	1 Laborer

Flaggers – 3 Shifts

	1 Foreman
	6 Flaggers

APPENDIX C
Chronology of construction events at the intersection of SR 395 and Kennewick Avenue

Time	Activity
Thursday October 5th	
7:00 PM	Shut down SR 395 and entrances
8:00 PM	Rotomill rolled into place with rotomilling beginning at 8:07 PM
8:50 PM	Rotomill hit an electric conduit
Friday October 6th	
12:00 AM	Surveying took place through the night
12:30 AM	Loader began removing isolated corners from existing intersection –approximately seven or eight loads were removed to about 4:00 AM
3:10 AM	Rotomilling complete – last truck loaded
3:30 AM	Grading and rolling began and continued through the night
7:30 AM	Begin excavation for conduit replacement
7:30 AM	ACME crews begin placing forms
11:40 AM to 1:20 PM	Concrete for segment #1
1:35 PM to 3:40 PM	Concrete for segment #2
3:40 PM to 5:50 PM	Concrete for segment #3
5:50 PM to 9:00 PM	Concrete for segment #4
3:00 PM	Start sawcutting
Saturday October 7th	
6:30 AM	Finish sawcutting
8:00 AM to 9:40 AM	Concrete for segment #5
9:40 AM to 12:35 AM	Concrete for segment #6
12:35 PM to 4:15 PM	Concrete for segment #7
4:30 PM to 8:00 PM	Asphalt work, brooming, tacking and asphalt placement
6:00 PM	Start sawcutting
Sunday October 8th	
11:30 AM	Finish sawcutting
5:00 AM to 9:00 AM	Clean cracks/blow cracks dry
9:00 AM to 1:00 PM	Joint seal
1:00 PM to 2:00 PM	Clean roadway
2:00 PM to 4:45 PM	Prep roadway – temporary striping and miscellaneous details.
4:45 PM	Open to traffic

APPENDIX D
Removal of Existing AC Pavement Quantities

Truck ID	Arrival Time	Loading Time	Departure Time	Capacity Tons
76 C	8:00 PM	8:07 PM	8:14 PM	22
36 I	8:00 PM	8:15 PM	8:25 PM	22
62	8:00 PM	8:25 PM	8:27 PM	14
323	8:00 PM	8:27 PM	8:31 PM	14
323	8:36 PM	8:36 PM	8:41 PM	14
62	8:37 PM	8:41 PM	8:43 PM	14
76 C	8:45 PM	8:45 PM	9:05 PM	22
36 I	8:50 PM	9:05 PM	9:24 PM	22
2 PR	8:50 PM	9:38 PM	9:40 PM	22
323	8:50 PM	9:40 PM	9:43 PM	14
62	8:55 PM	9:43 PM	9:46 PM	14
76 C	9:44 PM	9:46 PM	9:54 PM	22
36 I	9:48 PM	9:54 PM	10:15 PM	22
2 PR	9:50 PM	10:15 PM	10:23 PM	22
76 C	10:19 PM	10:23 PM	10:26 PM	22
323	9:47 PM	10:26 PM	10:29 PM	14
62	9:49 PM	10:29 PM	10:33 PM	14
323	10:35 PM	10:35 PM	10:39 PM	14
62	10:39 PM	10:39 PM	10:52 PM	14
323	10:44 PM	10:56 PM	11:00 PM	14
36 I	10:30 PM	11:00 PM	11:05 PM	22
2 PR	10:50 PM	11:05 PM	11:07 PM	22
76 C	10:52 PM	11:07 PM	11:12 PM	22
323	10:58 PM	11:12 PM	11:14 PM	14
62	11:06 PM	11:28 PM	11:33 PM	14
323	11:20 PM	11:33 PM	11:35 PM	14
2 PR	11:33 PM	11:35 PM	11:37 PM	22
76 C	11:34 PM	11:37 PM	11:39 PM	22
36 I	11:35 PM	11:40 PM	11:45 PM	22
62	11:39 PM	11:45 PM	11:52 PM	14
323	11:40 PM	11:52 PM	11:54 PM	14
62	11:58 PM	12:00 AM	12:05 AM	14
323	12:02 PM	12:05 AM	12:08 AM	14

Truck ID	Arrival Time	Loading Time	Departure Time	Capacity Tons
2 PR	12:02 AM	12:08 AM	12:10 AM	22
76 C	12:02 AM	12:10 AM	12:20 AM	22
36 I	12:06 AM	12:20 AM	12:23 AM	22
62	12:10 AM	12:23 AM	12:29 AM	14
323	12:32 AM	12:32 AM	12:34 AM	14
62	12:38 AM	12:38 AM	12:42 AM	14
323	12:40 AM	12:42 AM	12:53 AM	14
2 PR	12:40 AM	12:53 AM	12:55 AM	22
36 I	12:42 AM	12:55 AM	1:00 AM	22
76 C	12:44 AM	1:00 AM	1:08 AM	22
62	12:47 AM	1:31 AM	1:41 AM	14
36 I	1:30 AM	1:41 AM	1:44 AM	22
76 C	1:38 AM	1:44 AM	1:49 AM	22
2 PR	1:30 AM	1:49 AM	1:56 AM	22
62	1:46 AM	1:56 AM	2:14 AM	14
62	1:21 AM	2:21 AM	2:26 AM	14
323	2:22 AM	2:26 AM	2:28 AM	14
62	2:33 AM	2:33 AM	2:36 AM	14
323	2:36 AM	2:36 AM	2:46 AM	14
62	2:43 AM	2:46 AM	2:49 AM	14
2 PR	2:52 AM	2:52 AM	2:56 AM	22
323	2:54 AM	2:56 AM	3:00 AM	14
62	2:55 AM	3:00 AM	3:04 AM	14
323	2:59 AM	3:06 AM	3:09 AM	14
Total				**998**

APPENDIX E
Kennewick Intersections Concrete Delivery Report

Date	Location	Truck No.	Leave Plant	Arrive At Site	Start Discharge	Finish Discharge	Discharge Duration (Minutes)	Load Size (Yd^3)
6-Oct-00	Segment 1	924	11:25	11:35	11:50	11:57	7	10
6-Oct-00		975	11:25	11:40	11:46	11:55	9	10
6-Oct-00		222	11:30	11:47	11:58	12:05	7	10
6-Oct-00		88	11:35	11:50	11:58	12:06	8	10
6-Oct-00		86	11:49	12:05	12:10	12:23	13	10
6-Oct-00		440	11:52	12:10	12:12	12:25	13	10
6-Oct-00		939	12:05	12:20	12:30	12:37	7	10
6-Oct-00		439	12:08	12:28	12:48	1:00	12	10
6-Oct-00		975	12:25	12:42	1:05	1:13	8	10
6-Oct-00	Segment 2	924	12:30	12:45	1:15	1:40	25	10
6-Oct-00		222	12:37	12:53	1:37	1:55	18	10
6-Oct-00		88	12:40	12:25	1:50	1:55	5	10
6-Oct-00		86	1:00	1:22	2:05	2:10	5	10
6-Oct-00		440	1:05	1:20	2:00	2:12	12	10
6-Oct-00		221	1:48	2:10	2:20	2:28	8	10
6-Oct-00		975	2:00	2:24	2:28	2:35	7	10
6-Oct-00		443	2:24	2:43	3:00	3:10	10	10
6-Oct-00		439	2:27	2:42	2:48	3:02	14	10
6-Oct-00		440	2:57	3:17	3:25	3:35	10	10
6-Oct-00		939	3:41	4:00	4:02	4:40	38	10
6-Oct-00	Segment 3	115	3:43	4:08	4:45	4:52	7	10
6-Oct-00		918	3:53	4:19	4:45	4:55	10	10
6-Oct-00		909	-	4:30	5:00	5:15	15	10
6-Oct-00		79	4:20	4:40	4:55	5:10	15	10
6-Oct-00		440	4:28	5:12	5:20	5:48	28	10
6-Oct-00	Segment 4	88	5:05	5:25	5:44	6:35	51	10
6-Oct-00		63	6:00	6:17	6:30	6:42	12	10
6-Oct-00		115	6:30	6:50	6:55	7:07	12	10
6-Oct-00		79	6:39	7:00	7:50	8:00	10	10
6-Oct-00		166	6:46	7:04	7:27	7:37	10	10
6-Oct-00		440	7:00	7:20	7:25	7:55	30	10
6-Oct-00		63	8:04	8:22	8:28	8:47	19	10

Date	Location	Truck No.	Leave Plant	Arrive At Site	Start Discharge	Finish Discharge	Discharge Duration (Minutes)	Load Size (Yd^3)
7-Oct-00	Segment 5	106	7:50	8:10	8:15	8:30	15	10
7-Oct-00		939	8:04	8:18	8:34	8:40	6	10
7-Oct-00		88	8:35	8:50	9:00	9:07	7	10
7-Oct-00		440	8:42	8:58	9:07	9:15	8	10
7-Oct-00		71	8:10	-	9:20	9:25	5	10
7-Oct-00		222	8:58	9:15	9:26	9:35	9	10
7-Oct-00		63	9:05	9:25	9:30	9:40	10	10
7-Oct-00		106	9:10	9:25	9:50	10:20	30	10
7-Oct-00	Segment 6	939	10:21	10:39	10:45	11:15	30	10
7-Oct-00		113	10:17	10:35	10:45	10:55	10	10
7-Oct-00		923	10:30	10:47	10:57	11:15	18	10
7-Oct-00		88	10:35	10:50	11:18	11:29	11	10
7-Oct-00		440	10:45	10:58	11:20	11:30	10	10
7-Oct-00		71	10:46	11:00	11:33	11:50	17	10
7-Oct-00		437	10:53	11:08	11:42	11:50	8	10
7-Oct-00		106	10:55	11:10	11:55	12:08	13	10
7-Oct-00		222	11:23	11:38	12:12	12:35	23	10
7-Oct-00	Segment 7	113	11:43	11:58	12:25	1:25	60	10
7-Oct-00		923	11:54	12:10	1:25	1:38	13	10
7-Oct-00		78	-	1:20	1:30	1:50	20	10
7-Oct-00		88	1:10	1:25	1:40	1:50	10	10
7-Oct-00		440	1:20	1:38	1:50	2:15	25	10
7-Oct-00		437	1:25	1:40	1:46	2:00	14	10
7-Oct-00		106	1:32	1:49	2:20	2:27	7	10
7-Oct-00		222	1:47	2:04	2:28	2:40	12	10
7-Oct-00		923	2:31	-	2:58	3:10	12	10
7-Oct-00		440	3:17	3:34	3:38	3:48	10	10

APPENDIX F
2002 WSDOT Standard Specification for Acceptance of Portland Cement Concrete Pavement

5-05.3(4)A Acceptance of Portland Cement Concrete Pavement

Acceptance of Portland cement concrete pavement shall be based on statistical evaluation for air content and strength per section 1-06.2(2). The point of acceptance will be per Western Alliance for Quality Transportation Construction (WAQTC) TM 2 or at the point of discharge when a pump is used.

Acceptance of Concrete. The concrete producer shall provide a certificate of compliance for each truckload of concrete in accordance with Section 6-02.3(5)B.

For the purpose of acceptance sampling and testing, a lot is defined as the total quantity of material to be used that was produced from the same operation. All of the test results obtained from the same material shall be evaluated collectively and shall constitute a lot. The quantity represented by each sample will constitute a sublot. Sampling and testing for statistical acceptance shall be performed on a random basis at the frequency of one sample per sublot. Sublot size shall be determined to the nearest 10 cubic yards to provide not less than three uniform sized sublots with a maximum sublot size of 500 cubic yards.

The Engineer will furnish the Contractor with a copy of the results of all acceptance testing performed within 2 working days after testing. The Engineer will also provide the Composite Pay Factor (CPF) of the completed sublots after three have been tested.

Acceptance testing for compliance of air content and 28 day compressive strength shall be conducted from samples prepared according to WAQTC TM 2. Air content shall be determined by conducting WAQTC FOP for AASHTO T 152. If the contractor fails to provide the Aggregate Correction Factor per WAQTC FOP for AASHTO T 152 with the mix design, one will not be applied. Compressive Strength shall be determined by conducting AASHTO T 22.

The quality limits as defined in section 1-06.2(2)D shall be as follows. The lower quality limit for Air Content shall be 3.5 percent. The upper quality limit for Air Content shall be 6.5 percent. The lower quality limit for compressive strength shall be 1000 psi less than that established in the mix design as the arithmetic mean of the five sets of 28 day compressive strength cylinders, or 3000 psi, whichever is higher. These compressive strength cylinders are to be cast at the same time as the flexural beams that were used to prequalify the mix design under section 5-05.3(1). There is no upper quality limit for 28 day compressive strength.

The price adjustment factor defined in section 1-06.2(2)D shall be six (6) for compressive strength and four (4) for air content.

If either the air content or compressive strength is not measured in accordance with this section its individual pay factor will be considered to be 1.00 in calculating the Composite Pay Factor.

Rejection of Concrete:

1. Rejection by the Contractor. The Contractor may, prior to sampling, elect to remove any defective material and replace it with new material at no expense to the Contracting Agency. Any such new material will be sampled, tested and evaluated for acceptance.
2. Rejection without Testing. The Engineer may reject any load that appears defective prior to placement. Material rejected before placement shall not be incorporated into the pavement. No payment will be made for the rejected materials unless the Contractor requests that the rejected material be tested. If the Contractor elects to have the rejected materials tested, a minimum of three representative samples will be obtained and tested.

Payment for rejected material will be based on conformance with the statistical acceptance specification. If the CPF for the rejected material is less than 0.75, no payment will be made for the rejected material and in addition, the cost of sampling and testing, at the rate of $250.00 per test, shall be borne by the Contractor. If the CPF for the rejected material is greater than 0.75, the mix will be compensated at the new CPF and the cost of the sampling and testing will borne by the Contracting Agency.

The maximum calculated Composite Pay Factor shall be 1.00.

APPENDIX G
Sample Media Coverage

FRIDAY
Oct. 6, 2000
50 cents

Tri-City Herald
www.tri-cityherald.com
Serving the Tri-Cities, S.E. Washington and N.E. Oregon

Road work continues on 395

Highway to be closed for 83 hours at Kennewick Avenue

By John Trumbo
Herald staff writer

Traveling on Highway 395 through Kennewick will be near impossible this weekend.

The project to lay down concrete on one of the city's busiest thoroughfares necessitates complete closure of the major highway at Kennewick Avenue for 83 hours straight.

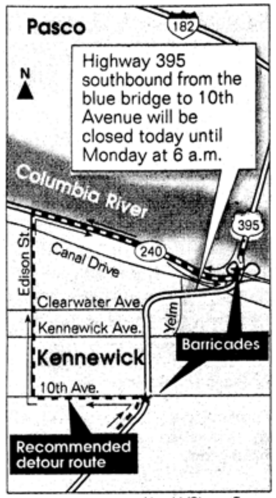
Blockades were set up on Highway 395 on Thursday night for northbound and southbound traffic.

By 10 a.m. today, construction workers expect to begin slathering concrete at the Kennewick Avenue intersection. The work will go on through the day and night until Monday morning, when the blockades will be removed.

Until then, southbound vehicles on Highway 395 will be directed to Highway 240 at the south end of the blue bridge, then on to Edison Street and east on 10th Avenue to return to Highway 395.

Northbound traffic on Highway 395 must go west at 10th Avenue, then north on Edison Street to Highway 240, and east to Highway

See **Road work,** Page A2



Herald/Sherry Emery

Road work: Closures in effect throughout weekend

Continued from A1

395 over the blue bridge.

All trucks weighing more than 26,000 pounds gross vehicle weight must detour via Interstate 182 and Interstate 82 to completely avoid city streets.

The reconstruction activity at Kennewick Avenue this weekend will be the third intersection makeover since the $3.6 million project began three weeks ago. The concrete paving in the intersections is expected to remove the chronic problem of having the asphalt lanes build up large bumps from heavy truck traffic.

The promise of a good road is some consolation to business owners near Kennewick Avenue and Highway 395, but it doesn't make up for lost business.

Sabrena Knight, manager of the Perfect Look hair-cutting salon, said roadwork and closures have hit sales there nearly 50 percent, and she expects a similar drop this weekend.

Getting to and from destinations on either side of the construction zone may be frustrating, but there is a way, if motorists have the will and the patience.

Paul Jensen of the Washington Department of Transportation said southbound traffic coming into Kennewick on Highway 395 may detour west on Clearwater Avenue then south on Morain Street, then go east on 10th Avenue to reconnect to Highway 395. Northbound traffic may use the reverse route.

The closures and designated detours will remain in effect throughout the weekend, 24 hours a day.

Jensen said paving and grinding will continue throughout the week in the construction zone, so motorists should expect delays and traffic backups.

Kamran Nemati, an associate professor in construction engineering at the University of Washington in Seattle, is documenting the process.

"This hasn't been done very often," Nemati said. With notebook and camera in hand, he plans to make a record for future reference on how well it works.

Nemati said the intersection demolition and rebuilding will follow a closely choreographed schedule. The closure was to begin at 7 p.m. Thursday, and the grinding equipment was to be on site by 8 p.m.

All the existing asphalt and road base was to be chewed up and hauled away by midnight Thursday, and new concrete was to be ready for spreading by 10 a.m. today.

Motorists may get to see a rebuilt Kennewick Avenue intersection, without those deep ruts, by Monday.

■ **Reporter John Trumbo can be reached at 582-1529 or via e-mail at jtrumbo@tri-cityherald.com.**

APPENDIX H
Sample Questionnaire

QUESTIONNAIRE

UNIVERSITY OF WASHINGTON

Dear business owner:

The following quick survey is intended to assist the Washington Department of Transportation and the University of Washington to assess the effect of the intersection closure at Kennewick Avenue and US 395 on businesses affected by the construction. Your cooperation in filling out the questionnaire is greatly appreciated.

Establishment's Name: ____________________________

Establishment's Address: ____

Questionnaire Filled by (optional): ___________________________ Position: ________________

1. Was access to you business affected? [ ] Yes [ ] No
   Explain:

2. Did you experience a loss in sales over the weekend closure? [ ] Yes [ ] No
   If so, how much?

3. Did you hear comments from customers about accessibility due to construction? [ ] Yes [ ] No
   Were they positive or negative?

   What were the comments?

4. Would you support a weekend closure in the future for reconstruction purposes rather than construction occurring over a longer period? [ ] Yes [ ] No
   Why?

5. Were you given the opportunity to express you views prior to the weekend closure decision?
   [ ] Yes [ ] No

6. Has your opinion of the Washington State Department of Transportation changed as a result of this construction? [ ] Yes [ ] No
   How?

7. Has the weekend closure caused a loss in income for your employees? [ ] Yes [ ] No
   If so, Approximately how much? [ ] $0 - $1,000
   [ ] $1,000 - $2,000
   [ ] > $2,000

8. Were Detour signage and routing effective? [ ] Yes [ ] No
   Explain:

9. Were you informed by the Washington State Department of Transportation in an accurately and timely manner with regards to the closure?

10. Do you have any suggestions for the Washington State Department of Transportation in regards to future closures?

APPENDIX I
Questionnaire Results

Following the SR 395 weekend closures interviews were taken from about 40 businesses surrounding the Clearwater and Kennewick Avenue intersections. A summary of the comments follows:

1. Was your business affected by the closure? Yes

   Comments: Could not get across the intersection
   It was a pain to get to the establishment
   Trucks, who are a large part of our business, could not get in
   Two of three entrances were blocked off
   Traffic from SR 395 was shut off
   Business slowed
   Local traffic found us Okay
   People avoided the area
   It was a hassle to get here
   People really wanted to eat here to go through all this

2. Did you experience a loss in sales over the weekend closure? Yes

   Comments: Percentage loss in sales and business type:

40%	fast food restaurant
30 – 40%	fast food restaurant
40%	restaurant
20 – 25%	ice cream shop
25%	restaurant
0%	car dealership
30%	pet store
50%	collectable shop – glass and silver

   15% increase in sales – Goodwill
   Typical range was 20 – 25 percent business loss

3. Did you hear comments from customers about accessibility due to construction? Yes

   Comments: It was a hassle to get to the business
   People were not going to come in until the work is done
   Out of town folks got lost in the detour
   Took us extra time to get here
   At least 15 people came in asking for directions
   Truck deliveries were difficult
   What a mess, when will it be over?
   I can't get here from there / Too hard to get here
   Too hard for out of town folks to get back to SR 395

4. Would you support a weekend closure in the future for reconstruction purposes rather than construction occurring over a longer period? Yes

   Comments: Loss of business but it has not been too bad
   Get it over with
   Weekend closure hurt but not too bad

Get it done with 24 hour a day work
Businesses will not be affected as long with closures
WSDOT will not have to come back for repaving
Will not interfere with as many people
Less impact overall
Hurts now but less disruption
Get it over with – more clogged with doing it during the week
We can endure one weekend as long as it is not constant
Affects us less
Its reality, it gets done quickly rather than a two-week problem
Over a weekend is great

5. Were you given the opportunity to express your views prior to the weekend closure? Generally, Yes

   Comments: Some employees were caught off guard but they blamed themselves for not reading the newspaper or listening to the news
   Owners were informed by WSDOT and had a chance to comment
   Most were aware the closure was going to happen

6. Has the weekend closure caused a loss in income for your employees? Generally, Yes

   Comments: Typically less than $1,000 per business, some $1,000 to $2,000
   Many of the food establishments sent people home – some volunteered to go home
   Some businesses kept people on despite the slower business

7. Were the detour signs effective? Generally, Yes

   Comments: Adequate, I understood where to go
   Some complained, message boards read too fast
   Effective at detouring people away from us
   There was a detour to Edison Street but folks who came into Kennewick did not know how to get back
   People have a hard time following detours
   Make signs big
   Clear, good job
   Out of town folks asked for local routes
   I saw no problems
   Local folks knew where to go

8. Were you informed by the WSDOT in an accurately and timely manner with regards to the closure? Generally, Yes

   Comments: Yes, a month ago and last week
   Owners knew what was going on

Saw the news

Yes, well informed, everything went like they said it would

Yes, the paper and news gave details

Yes, the morning paper and news

No idea as an employee, I do not read the paper

Yes, a flyer and the newspaper

Yes, owner knew

Yes, flyer by the DOT

9. Do you have any suggestions for the WSDOT in regards to future closures?

Comments: Why not connect between the intersections with concrete?

Why all the work at once with Pasco, Richland and Kennewick doing work?

Slow down the message boards

WSDOT did everything they could. Locals knew how to get around

Use clear signage

Best way to do it. Need to detour the trucks all the time

Good job

I like the 24-hour work

Cannot avoid the problem – If you got to do it you got to do it

Let us know ahead of time so we can staff up (some businesses increased business due to funneling effect of traffic control)

Great job, I liked the overnight thing, less disruptions from traffic

Allow construction in the early summer. People have more time as they do not have to worry about running kids around in traffic and dealing with detours