RECONSTRUCTION OF URBAN INTERSECTIONS USING PORTLAND CEMENT CONCRETE PAVEMENT

Jeff S. Uhlmeyer, P.E., Pavement Design Engineer
Linda M. Pierce, P.E., State Pavement Engineer
Washington State Department of Transportation
PO Box 47365, Olympia, WA 98504-7365

ABSTRACT

As of 1994, the Washington State Department of Transportation (WSDOT) began replacing selected asphalt concrete (AC) intersections with full depth Portland cement concrete pavement (PCCP). This decision was made due to the high visibility of urban intersections and the high rate of rutting that was occurring in a short period of time (eight years or less). Though costs to remove and replace just the rutted asphalt layer will always have a lower initial cost than remove and replacement with full depth PCCP, the life cycle cost and the disruption to the traveling public indicates that reconstruction with PCCP is an appropriate and viable option. With continued experience within WSDOT and the contracting community in PCCP intersection construction, and the use of partial and full road closures, lengthy construction periods are no longer warranted or necessary.

INTRODUCTION

In 1994, the Washington State Department of Transportation (WSDOT) began replacing selected asphalt concrete (AC) pavement intersections with full depth Portland cement concrete pavement (PCCP). These originally built asphalt concrete (AC) intersections were severely rutted and distressed due to loads from slow moving trucks and warm temperatures. Statewide, rut depths of two inches or more occasionally occurred. Rehabilitation to restore these intersections to an acceptable level occurred at intervals of eight years or less. In some cases, rut depths as deep as four inches or greater occurred within two years of paving and required immediate rehabilitation. The high cost of maintenance of AC pavements at intersection locations has made the use of PCCP an attractive and feasible alternative. This study documents the removal and replacement of AC with PCCP at several intersections in Washington State. Areas of interest include WSDOT's experience, construction costs, life cycle cost analysis, traffic management and finally the review of a recent project where three major intersections were reconstructed with full-depth PCCP using accelerated construction techniques.

WASHINGTON'S EXPERIENCE

WSDOT has considered PCCP at urban intersections for some time as a solution to eliminate asphalt rutting. However, because budget constraints have often dictated the choice of construction, AC has often been the choice, largely due to its lower initial cost. An additional reason for not considering PCCP reconstruction has been related to constructibility and concerns

about accommodating high traffic flows through urban intersections. Rehabilitating urban intersections with AC requires rotomilling and inlaying with AC to remove wheel rutting. This work can typically be done at night, in a short period of time, and with minor inconvenience to the public. Rehabilitating intersections with PCCP, on the other hand, can involve the complete disruption of the intersection, as construction for specific areas sometimes must be staged over several days. The concern within WSDOT has been that the inconvenience to the traveling public is too great to reconstruct urban intersections with PCCP. One Washington concrete contractor commented that even if a concrete intersection contract were awarded, the construction fears related to traffic control would result in very high unit prices.

However, since 1994, WSDOT has shown that PCCP intersections are constructible, and the former construction and traffic control concerns have been overcome. The first two projects, the intersections of Pines Road/Sprague Avenue, and Broadway Avenue/Thierman Street, in Spokane, Washington, were reconstructed with PCCP despite the less expensive AC rehabilitation of rotomilling and inlaying with AC. Nearly 1,600 trucks use Pines Road daily. Both approach legs on Pines Road were down hill, and 75 mm (3 in) ruts formed within two years following rehabilitation. The Broadway Avenue and Thierman Street intersection was reconstructed adjacent to a truck stop where daily truck counts numbered approximately 2,800. After two years, the ruts on Broadway Avenue were 100 to 125 mm (4 to 5 in) deep. Rutting may have been due to a number of factors, including insufficient structural depth and/or unstable mix; regardless, reconstruction of these intersections was necessary.

WSDOT was faced with either more inlay/overlay cycles with AC or reconstructing with PCCP and eliminating the rutting potential. Selecting to reconstruct with PCCP provided a valuable learning tool and allowed additional PCCP intersection projects to progress relatively problem free. As will be discussed in this paper, reconstructing with PCCP can be cost effective in comparison to AC alternatives.

An advantage with PCCP is the 40-year design life the PCCP provides with minimal or no rehabilitation required. The construction user costs and disruption to traffic that are necessary with future AC overlays are eliminated when PCCP is used. The major disadvantage with PCCP intersections is the initial construction cost. However, a life cycle cost analysis of PCCP intersections versus AC reconstruction and future inlays shows that PCCP intersection construction competes with and can be less expensive than rebuilding with AC.

Table 1 lists the average daily traffic (ADT), percentage of trucks, and the corresponding 40-year equivalent single axle loads (ESALs) for each of the reconstructed intersections.

CONSTRUCTION COSTS

To investigate costs for PCCP intersections, six intersections were analyzed [1]. Three of the six intersections were complete PCCP projects, while three were included on larger AC resurfacing projects. The complete PCCP intersection projects were simpler to analyze, as all costs on the

project were directly tied to the contract. The PCCP intersection costs for the AC resurfacing projects were developed by isolating pay groups or summarizing construction pay notes.

Once the PCCP costs were summarized, calculations were made to estimate the costs of a comparable reconstructed AC pavement structure. The PCCP thickness used to rebuild the intersections ranged from 230 to 300 mm (9 to 12 in.). The comparable flexible AASHTO design ranged from 215 to 245 mm (8.5 to 9.6 in) of AC over approximately 250 mm (10 in) of crushed stone base to meet frost depth design criteria. The total existing pavement structure (AC and aggregate base) for the intersections reviewed in this study ranged from 381 to 460 mm (15 to 18 in) thick. The price used for AC was based on unit bid prices that would be expected for the AC quantity represented. All other items for the PCCP or AC reconstruction remained the same. Finally, cost estimates for future inlays were computed on the basis of a typical 60 mm (2.4 in) depth. A summary of PCCP or asphalt concrete intersection reconstruction costs, as well as future inlay costs, is shown in Table 2. These costs include labor, materials, preliminary and construction engineering, change orders, and taxes. The initial PCCP intersection costs ranged from $455,500 to $982,200, whereas the initial AC intersection costs ranged from $349,800 to $728,600.

The range of PCCP reconstruction costs resulted primarily from the size and variability in unit bid prices for each intersection. In general, initial PCCP intersection construction ranged from $79 to $177 per square meter ($66 to $148 per square yard). AC intersection costs ranged from $61 to $130 per square meter ($51 to $109 per square yard). The PCCP reconstruction costs were less when intersections were reconstructed as part of a larger AC resurfacing project

Table 3 compares cement concrete pavement prices for PCCP thicknesses of 225, 250, and 300 mm (9, 10, and 12 in). The concrete for all the intersections required opening to traffic within 24 hours and used approximately 418 kg/m^3 (705 lb/yd^3) of Type III cement. The cement concrete pavement price included both placing and finishing the PCCP. The average bid price for the four projects with a 250 mm (10 in) section was $46.44 per square meter ($38.83 per square yard). The 300 mm (12in) thick intersection was slightly higher at $50.49 per square meter ($42.22 per square yard), and the 225 mm (9 in) section, was less at $40.99 per square meter ($34.28 per square yard).

AC pavement unit bid prices for the different classes of asphalt used on the intersections are also shown in Table 3. The unit prices for the Sprague Avenue/Pines Road and Broadway Avenue/Thierman Streets intersections were $88 and $66 per tonne ($80 and $60 per ton), respectively. These prices were high because AC was a relatively minor item on these projects. Four of the remaining intersections were included on larger resurfacing projects, and the unit bid price reflected project prices for mainline paving ranging from $30.80 and $46.34 per tonne ($27.94 to $42.04 per ton). The price for the 19th Avenue intersection was $40.50 per tonne ($36.74 per ton) because the four intersections included in the contract were combined, for a total of 3,516 tonnes (3,876 tons) for the project. The remaining contracts involved inlays from the larger resurfacing projects abutting the reconstructed PCCP intersections.

Table 4 provides a summary of the average unit bid prices for the major items of cement concrete pavement, crushed surfacing base course, roadway excavation, and AC pavement. The final

comparison for total contract prices is of major traffic items. Table 5 summarizes traffic control labor, vehicle, and supervisor costs for each of the intersections. The contract totals for Sprague Avenue/Pines Road and Broadway Avenue/Thierman Street were obtained from the final contract totals, as these were individual intersection contracts. The contract totals for the 19th Avenue Intersection on SR 395 were obtained by isolating the pay groups. The remaining contract totals were reconstructed as best as possible from available information such as pay notes and inspectors daily reports.

Table 6 shows the total cost for traffic items as a percentage of the contract subtotal. The range as shown is 4.0 to 16.9 percent. The 11.9 percent for the Broadway Avenue/Thierman Street intersection can be explained because of the extra traffic control labor needed for flaggers at the many entrances to the intersection in combination with the high truck volumes at the Broadway Avenue Truck stop. Upwards of 250 trucks a day entered the truck stop. The percentage for the Sprague Avenue/Pines Road intersection can be explained by the early learning curve with concrete intersection construction in the Eastern Region. An additional factor was that AC pavement was constructed as the base material beneath the PCCP, and additional time and exposure to traffic was necessary. An example of reducing traffic control costs occurred on the Pines Road/Sprague Avenue intersection. The project was originally estimated to require 24-hour traffic control. Both the Eastern Region and the prime contractor, Inland Asphalt of Spokane, Washington, desired to keep traffic impacts to a minimum. As a result, Inland Asphalt scheduled the major portion of the preparation work to be done at night. The traffic item "Labor for Traffic Control" under ran the estimated amount by $18,000, or 25 percent of the estimated quantity. To control costs, traffic signals were used during the day, and flaggers were used at night. A comparison between estimated traffic control labor dollars and actual contract dollars for traffic control labor is seen in Table 7. In the three cases where precontract estimates were available, the estimated contract total versus the actual contract total was 30 to 53 percent less than the engineer's estimate.

LIFE CYCLE COST ANALYSIS

A life cycle cost analysis was performed for each intersection to compare PCCP reconstruction and AC reconstruction options [1]. In addition, analyses were performed to compare reconstruction with PCCP and rehabilitation using traditional inlays at four-, six-, and eight-year intervals to rehabilitate rutted surfaces. Assumptions used in the analyses include the following:

- A 40-year design period was used to compare PCCP reconstruction versus AC reconstruction or inlay options
- Four, six, and eight years were used for AC inlay cycles
- Analyses were performed with and without user delay costs
- Analyses reflect total construction costs for PCCP, AC reconstruction, or AC inlays
- A 4 percent discount rate was used.

Tables 8 and 9 show the 40-year annualized cost analysis (including user delay costs) for the six selected intersections. Table 8 compares PCCP reconstruction with AC reconstruction followed by AC inlays at four-, six-, and eight-year cycles. In almost every case the cost of PCCP

reconstruction was lower than that of the AC reconstruction alternative. In only one project was AC reconstruction cheaper, and then only for an eight-year inlay cycle. Table 9 compares PCCP reconstruction with rehabilitating the existing AC structure with 60 mm (2.4in) AC inlays at four-, six-, and eight-year cycles. When PCCP reconstruction is compared to inlaying with AC, Table 9 shows that inlaying at four-, six-, or eight-year cycles will provide the lowest 40-year annualized cost. However, an argument against inlaying only the existing pavement once distress becomes intolerable is the inconvenience to the traveling public. Not only does excessive rutting compromise user safety, but also users must endure resulting traffic delays caused by rehabilitation or maintenance operations. Often times, as WSDOT has experienced, repairs are needed within two years of the inlay.

TRAFFIC CONTROL AND CONSTRUCTION STAGING

Traffic control and construction staging is typically the primary issue associated with the construction of PCCP intersections. While some delay to the traveling public is unavoidable, the delay has proved to be tolerable, with a maximum delay during peak hours, on occasion, of about 15 to 20 minutes. An important design element 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, fire and police agencies, 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 minimized. For instance, during construction of the Broadway Avenue/Thierman Street intersection, an open invitation was provided to any party affected by or interested in the construction. Weekly meetings, initiated by the project engineer, were held. At these meetings concerns were voiced about 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. Weekly meetings were of major importance in moving heavy truck traffic to an adjacent truck stop.

A Customer Focus Highway Construction Workshop [2], held in Seattle in January 1999, noted that the traveling public is a lot more tolerant during construction when people are kept informed. With widespread publicity to keep the public informed, WSDOT has noticed upwards of a 30 percent reduction in the ADT for intersection reconstruction projects. The 30 percent reduction represents people who have found alternative routes or have adjusted their schedules to avoid the construction project.

Staging options for PCCP intersection construction include the following

- complete closures with detours
- partial closures with detours
- construction under traffic
- complete closures during limited time periods
- combination of the above.

WSDOT has used complete closures, partial closures with detours and construction under traffic. The primary focus in this paper will be complete closures.

The ideal construction situation is to completely close the roadway. Complete closures allow the contractor to remove and replace more roadway in a continuous and safe operation. Interaction with traffic is avoided, as complicated work zone lane configurations are eliminated. However, closing a major urban arterial 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, and so they are unpopular for that reason. Full depth reconstruction with PCCP at urban intersections has typically taken up to 30 to 40 days where closures have not been used. Intersections that have used some type of closure such as closing the minor legs of the intersection have reduced this time in half.

KENNIWICK AREA – ACCELERATED CONSTRUCTION

Complete closures were used in the city of Kennewick for the reconstruction of the Clearwater Avenue, West Kennewick Avenue, and Yelm Street intersections. Traditionally, rehabilitation of intersections with PCCP required several weeks and in most cases mandated complete disruption of the intersection and resulted in traffic management problems. By constructing the approach and leave legs of the three intersections while under traffic and constructing the intersection square area (radius return to radius return) during the three day closures (one weekend for each intersection), WSDOT was able to considerably reduce the construction time necessary to reconstruct these urban intersections. The contract specified closing each intersection by 7:00 pm Thursday evening and opening to traffic by 6:00 am the next Monday morning. Local traffic was detoured to adjacent streets while state highway traffic was detoured to surrounding highways.

Prior to the weekend closures the approach and leave legs to the intersections were reconstructed under traffic. During the weekend closures, ACME Construction and Materials (ACME) of Spokane Washington, removed the entire structure within the intersection square and a portion of each approach or leave legs of the adjoining city streets. PCCP placement and curing proceeded well with the roadway being opened substantially ahead of the 6:00 am Monday morning target. For all three closures, the roadway was opened to traffic by 6:00 pm Sunday. Following the closure, WSDOT obtained very favorable comments from both businesses and residents.

Specific comments related to planning, public relations, construction, construction details, detour routes, and customer focused construction comments follow. Documentation of the West Kennewick Avenue intersection reconstruction is available through the Innovative Pavement Research Foundation [3].

Planning

The three-day closure (Thursday evening 6:00 pm to Monday morning 6:00 am) idea evolved between the City of Kennewick and WSDOT during the design phase of this project. The impetus for this decision was based upon a bad experience on a previous PCCP intersection construction project in the same area. During 1998, four intersections were constructed and complaints from the public were numerous, as staging requirements did not allow construction on consecutive intersections. Therefore traffic was "snaked" through the 3.2 km (2 mile) work area causing confusion. In addition the contractor could not open up and pour enough areas to keep construction flowing at a fast pace. The result was that the two intersections built at a time required over a month to complete. The overall impact to the traveling public and local businesses to reconstruct the four intersections extended for over two months.

WSDOT realized the construction process had to be shortened for future PCCP intersection work. WSDOT approached the City of Kennewick, discussed the issues, and the City agreed to allow a two-day weekend closure. However, a three-day closure was desired by contractors to deal with the uncertainties involved with a weekend closure. WSDOT approached the City of Kennewick with this proposal and a three-day closure for three separate weekends was approved (one intersection per weekend). Public input and buy in was also sought in the form of public meetings and direct business contact. Traffic issues were worked out between the City of Kennewick and WSDOT.

Public relations

The WSDOT (Pasco Project Engineers Office) provided excellent public relations prior to construction of the three-day closures. Specifically the following steps were taken:

- Numerous public meetings were held during the design phase for public input and agreement that the full closure option was acceptable.
- WSDOT contacted business owners prior to the actual construction. A designated individual contacted businesses a week and then again several days prior to construction. Flyers were handed out explaining the process and to remind the businesses that there would be detour routes.
- Weekly meetings were held by the project engineer to update the local media. An open door policy was in effect.
- WSDOT tried to make the closures as painless as possible. Mitigation measures included; a fully signed detour route, traffic staff on-site during the closure to make any necessary changes/refinements, aggressive scheduling to ensure a minimum timeline for closure, variable message signs, flyers, and media notices.

Media coverage was essential to the success of this project. Media coverage started a week ahead of the actual construction. During the first closure, Yelm Street intersection, television coverage was constant with the closure being the top story on the morning and evening news. The public was greatly exposed to the closures that were in effect. Local newspapers also provided excellent coverage. The short duration impact was large for the public, however, it was

generally agreed that the longer duration option would have caused a greater overall impact. WSDOT received great praise when the construction was completed.

Construction schedule

Prior to the weekend closures, WSDOT reconstructed under traffic, the approach and leave legs to the intersections with the following sequence:

- Construction of the left hand turn lane with traffic on both sides of the turn lane.
- Construction of the southern approaches with traffic pushed to the north.
- Construction of the northern approaches with traffic pushed to the south.

During the weekend closures, ACME removed the existing AC pavement within the intersection square and a portion of each approach or leave legs of the adjoining city streets. 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 certain activities had to occur by a certain time. The typical schedule maintained by the contractor for the three intersections included:

- **Thursday evening to Friday morning –** Excavate the existing roadway and prepare the grade for concrete.
- **Friday morning to late Saturday evening** – Formwork and pour concrete
- **Sunday** – Prep roadway for opening to traffic

Table 10 shows a detailed schedule for the actual work sequence for the West Kennewick Avenue intersection. Figure 1 provides a breakdown of the total time required for the various construction activities starting from 7:00 pm Thursday evening to 6:00 am Monday morning (83 hours total). The 13.8 hours noted as "no activity" is essentially the time the intersection was opened early.

Figure 2 provides a breakdown of the total time had there been an increase in production in various activities. For this example the formwork and concrete placement time was reduced 50 percent by hypothetically using two crews. In reality two crews would not get 50 percent efficiency but the figure illustrates that if any of the other activities had increased production, for instance, considerable time savings could have been realized. In this case the intersection could have been opened 24.5 hours early barring unforeseen problems. PCCP placement and curing proceeded well with the roadway being opened substantially ahead of the 6:00 am Monday morning target. For all three closures, the roadway was opened to traffic between 4:00 and 6:00 pm on Sunday. Liquidated damages ($1,200/hr for Yelm Street and Clearwater Avenue, $2,400/hr for West Kennewick Avenue intersections) for opening beyond 6:00 am Monday were avoided.

Construction details

On the first intersection, ACME geared up with extra crew to be sure the Yelm Street intersection went as planned. However, during the Yelm Street intersection the contractor learned there was no need to staff additional finishers and laborers to perform the work. ACME learned they could efficiently construct the intersections with their normal crew. The manpower required to construct the intersections consisted of the following:

- Rotomilling/Excavation 1 operator, 1 stake hop, 5 trucks and teamsters
- Grading Crew 4 laborers/operators
- Formwork and Pour Crew 9 finishers/operators
- Concrete Delivery 8 trucks and teamsters
- Electrician 1 electrician
- Traffic Control 6 to 8 flaggers

The pavement section used on the Kennewick area intersections consisted 300 mm (12 in) of PCCP placed on the existing crushed stone base. The PCCP used 418 kg/m^3 (705 lbs/cy) of Type III cement. WSDOT requires a concrete compressive strength of 17.2 MPa (2,500 psi) which was obtained in 10 to 12 hours. A maturity meter was used to monitor concrete strength. The quantities placed on the West Kennewick Avenue intersection were 233 m^3 (305 yd^3) on the Friday of the weekend closure and 179 m^3 (234 yd^3) on the Saturday. The total concrete typical to all three intersections including the approach legs was 1,262 m^3 (1,650 yd^3). Concrete delivery to the projects was a 9.6-kilometer (6-mile) haul.

Side form construction was used with paving widths approximately 3.6 to 7.2 meter (12 to 24 feet) in width. Both a Whiteman Screed and Bunyond Tube was used for concrete placement. The weak link noted in the Kennewick area intersections was the sawcutting. The tendency with accelerated construction is to sometime push the process and in this case sawcutting commenced earlier than should have, resulting in several rough joints.

Traffic/Detour routes

The full closure of the three intersections was possible primarily because of the availability of detour routes for local and through traffic. Traffic for the Kennewick area construction consisted of 30,000 average daily traffic with 30 percent trucks. The longest detour was 10.9 kilometer (13 miles), which necessitated good communication with truckers passing through the urban corridor. Car traffic was detoured on local streets. The longest detour was approximately five miles. Flaggers were placed at all key locations to keep the car traffic flowing. Truck traffic utilized signing placed on the state highways.

Customer focused construction comments

Following the SR 395 weekend closures interviews were taken from about 40 businesses surrounding the Clearwater and Kennewick Avenue intersections. The purpose of the interviews

was to ascertain the public's response to the three-day closures. A summary of selected questions with responses follows:

1. *Was your business affected by the closure?* Typical comments included: "It was a pain to get to the establishment." "People avoided the area." "Business slowed." "Some of our entrances were blocked off."

2. *Did you experience a loss in sales over the weekend closure?* The response was generally yes. Many of the businesses located near the intersections were restaurants. The estimated percentage in loss in sales ranged from 20 to 40 percent. A glass and silver collectable shop reported their total sales on the Friday of the closure was $1.50, however, some good sales over the weekend brought their total estimated percentage loss in sales to 50 percent. A car dealership reported the closure had no impact and the local Goodwill Store reported a 15 percent increase in sales. The typical range reported by most businesses was a 20 to 25 percent loss in sales.

3. *Did you hear comments from customers about accessibility due to construction?* All responses were yes. Typical responses were: "Out of town folks got lost in the detour." "What a mess, when will it be over?" "Took us extra time to get here." "It was a hassle to get to the business."

4. *Would you support a weekend closure in the future for reconstruction purposes rather than construction occurring over a longer period?* Despite the negative comments listed in the previous three questions every response to this question was surprisingly positive. Typical responses include: "We experienced a loss of business but it has not been too bad." "Get the construction over with." "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."

5. *Were you given the opportunity to express your views prior to the weekend closure?* Generally, Yes. Some employees were caught off guard but they blamed themselves for not reading the newspaper or listening to the news.

6. *Has the weekend closure caused a loss in income for your employees?* Generally, Yes. Typically less than $1,000 per business, some $1,000 to $2,000. Many of the food establishments sent people home with some volunteering to go home. Some businesses kept people on despite the slower business.

CONCLUSIONS

Initial construction costs for full depth PCCP reconstruction at urban intersections costs approximately 25 to 30 percent more than full depth AC construction. Lower construction costs have been experienced when urban intersection construction is included as part of larger AC resurfacing projects.

The 40-year annualized costs for intersections (with user costs) show that full depth PCCP intersection reconstruction is typically less than full depth AC reconstruction with future AC inlays when intersection reconstruction is necessary. This study showed the 40-year annualized costs for PCCP reconstruction for five of the six intersections was six to fourteen percent less than AC reconstruction. The 40-year annualized cost for reconstructed PCCP intersections (with user costs) compared to AC inlays at four-, six-, and eight- year cycles show the AC inlay will always be less than reconstruction with PCCP at an urban intersection. However, with AC inlays, the state or local agency must decide whether inlays meet the expectations of the public. The public view of an agency rehabilitating the same section of roadway at four-, six- or eight-year cycles does not reflect well on the agency even if the section needs rehabilitation due to the distress present. In addition, user delays incurred by the public are not received well during roadway rehabilitation.

WSDOT has experienced faster reconstruction of PCCP intersections where some type of closure has been used. Intersection projects with minimal or no detours have required 30 to 42 days for the PCCP reconstruction. Allowing at least some type of closure (such as closing minor legs) during construction has reduced the number of days in half. Full closure of the intersection has facilitated the fastest construction period. On the Kennewick area intersection construction, three separate intersections were reconstructed utilizing weekend closures. The approach legs were reconstructed under traffic on the days preceding the weekend closure and the intersection square was reconstructed during the weekend closures. A total of 8.5 days per intersection was required (three days of which were the weekend closure).

The closure of a state highway is a mindset. 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 of closing an intersection 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.

Weekend closures allow the public to see constant production. Weekend closures allow more efficiency for the contractor and their operations. In addition complete closures allow a safe environment for state and contract workers. As contractors become familiar with intersection reconstruction the construction time should decrease. The closure period depends on traffic management strategies, how many resources the contractor is willing to use during construction, and ultimately how much an agency is willing to pay to reconstruct urban intersections.

REFERENCES

1. Uhlmeyer, Jeff S., "PCCP Intersection Design and Construction in Washington State," Washington State Department of Transportation, WA-RD 503.1, Olympia, WA, May 2001.

2. Customer Focus Highway Construction Workshop, Discussion Comments from the Workshop, Seattle, WA, January 1999.

3. Innovative Pavement Research Foundation, "Accelerated Construction of Urban Intersections with Portland Cement Concrete Pavement," Draft Report, May 2001.

Table 1. Average Daily Traffic (1997) and Associated ESALs for typical WSDOT intersections.

SR	Intersection	Major Leg			Minor Leg	
		ADT	Percent Trucks	40 Year ESALs	ADT	Percent Trucks
27	Pines Rd and Sprague Ave	24,596	6.5	20,000,000	24,596	7.5
90	Broadway Ave and Thierman St	17,000	17.0	30,000,000	2,500	30.0
2	Division St and Francis Ave	36,726	2.6	10,000,000	31,768	2.8
291	Francis Ave with Maple/Ash St	31,768	2.8	9,000,000	15,884	2.0
27	Pines Rd and Broadway Ave	25,608	6.5	20,000,000	12,804	6.5
395	SR 395 and 19th Ave	13,370	19.0	53,000,000	10,000	5.0

Table 2. Initial AC and PCCP Construction Costs and Future AC Inlay Costs.

SR	Intersection	Quantity (m^2)	Initial PCCP Cost	Initial ACP Cost	Future Inlay Cost
27	Pines Rd and Sprague Ave	3,441	$531,300	$403,900	$72,900
90	Broadway Ave and Thierman St	5,566	$982,200	$728,600	$95,900
2	Division St and Francis Ave	8,603	$675,100	$519,000	$151,200
291	Francis St/Maple and Ash St	5,061	$466,200	$361,800	$91,900
27	Pines Rd and Broadway Ave	4,808	$455,500	$349,800	$89,700
395	SR 395 and 19th Ave	5,322	$546,400	$441,600	$91,900

Table 3. Portland Cement Concrete Pavement and Asphalt Concrete Pavement Unit Bid Prices.

SR	Intersection	PCCP			ACP	
		Thickness (mm)	Quantity (m^2)	Unit Price	Quantity (Tonne)	Unit Price
27	Pines Rd and Sprague Ave[2]	250	3,441	$51.42	25	$88.18
90	Broadway Ave/Thierman St[2]	250	5,566	$47.83	433	$66.14
2	Division St and Francis Ave[3]	250	8,603	$41.50	[1]	$46.40
291	Francis Ave/ Maple and Ash St[3]	225	5,061	$41.00	[1]	$46.40
27	Pines Rd and Broadway Ave[3]	250	4,808	$45.01	[1]	$30.80
395	SR 395 and 19th Ave[3]	300	5,322	$50.49	0	$40.50

[1.] Asphalt used on these contracts were from the larger asphalt surfacing project and was inlayed adjacent to the concrete intersections.
[2.] Pines Road/Sprague Ave. - 1994 construction. Broadway Avenue/Thierman St. – 1996 construction
[3.] 1998 construction

Table 4. Summary of Average Unit Bid Prices for Major Bid Items.

Bid Item	Unit	Average Unit Bid Price
Cement Concrete Pavement – 10 inch	Square Meter	$46.44
Crushed Surfacing Base Course	Tonne	$17.94
Roadway Excavation	Cubic Meter	$14.91
Asphalt Conc. Pavement	Tonne	$77.16[1]

[1] The $77.16 per ton price reflects the SR 27, Pines Rd and Sprague Ave and SR 90, Broadway Ave and Thierman St intersections where the asphalt was not part of a larger resurfacing project.

Table 5. Total Costs for Traffic Control Items.

SR	Intersection	Labor	Vehicle	Supervisor	Total
27	Pines Rd and Sprague Ave	$52,304	$945	$12,300	$65,549
90	Broadway Ave and Thierman St	$76,083	$1,935	$10,750	$88,768
2	Division St and Francis Ave	$9,680	$1,750	$9,240	$20,670
291	Francis Ave/ Maple and Ash St	$8,250	$1,450	$7,656	$17,356
27	Pines Rd and Broadway Ave	$8,700	$1,500	$7,680	$17,880
395	SR 395 and 19th Ave	$14,355	$800	$4,800	$19,955

Table 6. Traffic Control Items Expressed as a Percentage of Contract Subtotal.

SR	Intersection	Project Subtotal	Total for Traffic Items	Percent of Subtotal
27	Pines Rd and Sprague Ave	$387,418	$65,549	16.9
90	Broadway Ave and Thierman St	$748,104	$88,768	11.9
2	Division St and Francis Ave	$520,436	$20,670	4.0
291	Francis Ave/ Maple and Ash St	$359,734	$17,356	4.8
27	Pines Rd and Broadway Ave	$351,101	$17,880	5.1
395	SR 395 and 19th Ave	$422,807	$19,955	4.7

Table 7. Estimated Traffic Control Labor versus Actual Traffic Control Labor.

SR	Intersection	Estimated Traffic Control Labor	Actual Traffic Control Labor	Percent Under Estimate
27	Sprague Ave and Pines Rd	$75,000	$52,304	30.3
90	Broadway Ave and Thierman St	$162,500	$76,083	53.2
395	SR 395 and 19th Ave	$29,000	$14,355	50.5
395	SR 395 and 7th, 10th, 19th, and 27th Aves[1]	$121,800	$63,336	48.0

[1] This estimate combined four intersections built on the contract.

Table 8. 40-Year Annualized Costs for PCCP Reconstructing versus ACP Reconstruction with Future Inlays.

SR	Intersection	PCCP Reconstruction	ACP Reconstruction With 4-Year Inlays	6-Year Inlays	8-Year Inlays
27	Pines Rd and Sprague Ave	$33,000	$45,400	$38,400	$34,800
90	Broadway Ave and Thierman St	$54,500	$64,300	$55,800	$51,500
2	Division St and Francis Ave	$72,100	$100,500	$87,600	$80,500
291	Francis Ave/Maple and Ash St	$32,900	$50,800	$42,200	$35,500
27	Pines Rd and Broadway Ave	$34,200	$51,000	$42,700	$38,500
395	SR 395 and 19th Ave	$30,100	$46,700	$38,500	$34,300

Table 9. 40-Year Annualized Costs for PCCP Reconstruction versus AC inlays.

SR	Intersection	40 Year Annualized Costs			
		PCCP Reconstruction	4-Year Inlay	6-Year Inlay	8-Year Inlay
27	Pines Rd and Sprague Ave	$33,000	$22,900	$15,900	$12,300
90	Broadway Ave and Thierman St	$54,500	$27,600	$19,200	$14,900
2	Division St and Francis Ave	$72,100	$45,500	$31,600	$24,500
291	Francis Ave/Maple and Ash St	$32,900	$28,200	$19,600	$15,200
27	Pines Rd and Broadway Ave	$34,200	$26,900	$18,700	$14,500
395	SR 395 and 19th Ave	$30,100	$26,700	$18,500	$14,400

Table 10. Construction Schedule for West Kennewick Avenue.

Date	Time	Construction Activity
Thursday, October 5th	7:00 pm	Shut down SR 395 and entrances to West Kennewick Ave.
	8:00 pm	Rotomill rolled into place with rotomilling beginning at 8:07 pm
	8:50 pm	Rotomill hit conduit
Friday, October 6th	12:00 am	Surveying took place throughout the night
	12:30 am	Loader began removing isolated corners from existing intersection – approximately sever or eight loads were removed to about 4:00 am
	3:10 am	Rotomilling completed – last truck loaded
	3:30 am	Grading and rolling began and continued through the night
	7:30 am	Begin excavation for conduit repair
	7:30 am	ACME crews show up
	8:30 am	Forming began for pour #1-4
	11:40 am to 1:20 pm	Concrete for pour #1
	1:35 pm to 3:40 pm	Concrete for pour #2
	3:40 pm to 5:50 pm	Concrete for pour #3
	5:50 pm to 9:00 pm	Concrete for pour #4
	3:00 pm	Start saw cutting
Saturday, October 7th	6:30 am	Finish saw cutting
	8:00 am to 9:40 am	Concrete for pour #5
	9:40 am to 12:35 pm	Concrete for pour #6
	12:35 pm to 4:15 pm	Concrete for pour #7
	4:30 pm to 8:00 pm	Asphalt work, brooming, tack coat and asphalt placement
	6:00 pm	Start saw cutting
	11:30 pm	Finish saw cutting
Sunday, October 8th	5:00 am to 9:00 am	Clean joints/blow joints 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 misc. details
	4:45 pm	Open to traffic

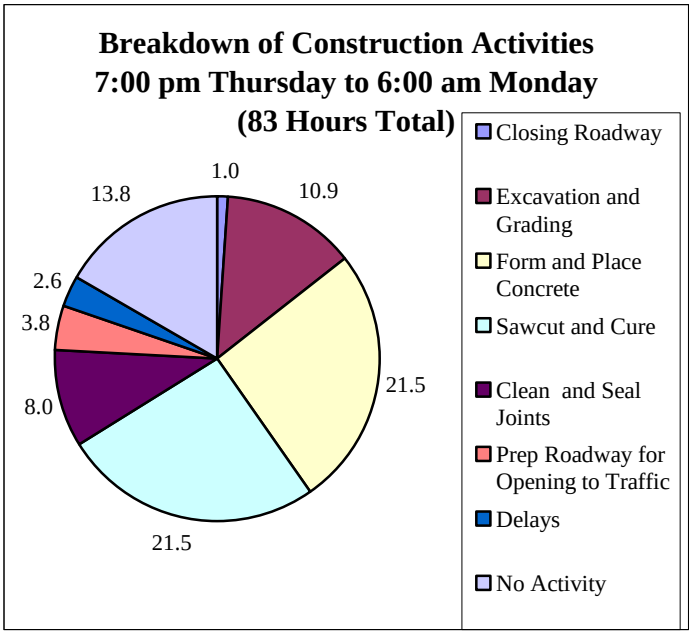

Figure 1. Construction times for individual activities for the three-day closure

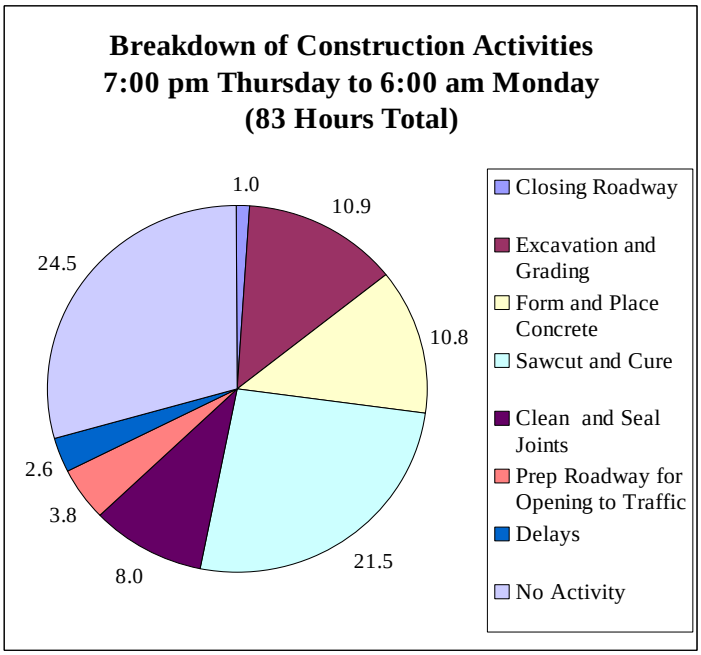

Figure 2. Construction times for individual activities showing hypothetical increased production for the three-day closure