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

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ABSTRACT : 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. Three major AC intersections with severe rutting problems were reconstructed with PCCP. 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 paper discusses 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 and demonstrates that concrete pavements can be constructed efficiently and quickly.

Key words : Accelerated construction, PCCP ,maturity method.

1. 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. This paper will concentrate on the third intersection at Kennewick Avenue.

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, 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. They 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 1 depicts the level of severity of pavement rutting at an intersection. The purpose of this reconstruction with PCCP was to provide a quality long-life pavement with minimal user disruption which will result in safety improvements and a significant reduction in user costs.

Figure 1. Severity of pavement rutting at an intersection

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 [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. The objective of this research project was to document the rapid reconstruction of an intersection in where an AC intersection was reconstructed with PCCP over the weekend in a 70-hour period. The goal of this research project was to develop a body of knowledge and tools for reconstruction of intersections using PCCP.

2. 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 Washington State Department of Transportation (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 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 [2]. The contractor also benefited by increasing productivity.

2.1 Background

During 1998, four intersections 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 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 agreed on a three-day weekend closure for intersection reconstruction [3].

Late on, three more intersections 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 and WSDOT.

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. Weekly meetings were held by the project engineer to update the local media. Media coverage was essential to the success of this project. 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 intersection reconstruction to the following:

- WSDOT held preliminary meetings with the City 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
- 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.

3. 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.

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. 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.

Local traffic was detoured to adjacent streets, while state highway traffic was detoured over nearby interstate highway. 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 two of the three intersections concurrently.

4. 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 2,500 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.

Air-entraining admixtures meeting ASTM C260 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 C150 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 [4,5].

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 reconstruction:

Table 1. Concrete Mix Design

Material	Type	Quantity
Cement (lbs/yd^3)	ASTM C150 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 C260	11
Water-reducing admixture (oz/yd^3)	ASTM C494	30.3
Set-retarding admixture (oz/yd^3)	ASTM C494 / Delvo	17.6

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

Table 2. Concrete characteristics

Tasks	No. of Labor
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 [6]. 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 1,000 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.

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 [7].

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 2.

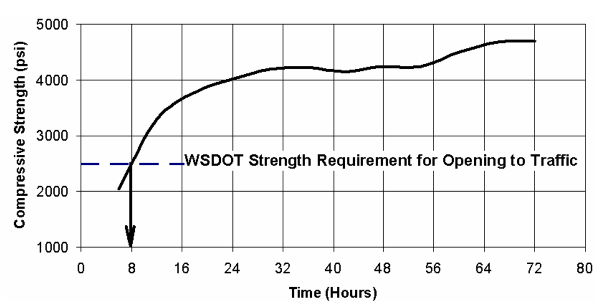

Figure 2. Compressive strength gain vs. time

5. CONSTRUCTION

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. 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. During removal of the existing pavement, electrical conduit was encountered in two locations. 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.

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. 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.

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 3 shows the erection of forms. Dowel bar baskets were pre-fabricated with ten epoxy coated dowel bars per joint and were placed between the forms.

Figure 3. Setting forms and installation of dowel bar baskets

Concrete was placed in alternate sections (Figure 4) to eliminate the use of forms for the interim sections.

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 4. Concrete placement in interim Sections

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. Tines were used to texture the surface of freshly placed PCCP.

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 C309 material requirements. This compound was a white-pigmented compound applied to the surface and exposed edges of the concrete pavement. 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.

After paving and curing of concrete, control joints must be sawn into the new pavement. 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.

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. 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.

Before opening to traffic, the intersection was thoroughly cleaned using a water truck. The next step was to place striping prior to opening to traffic.

6. CONCLUSION

1. The reconstruction of an intersection 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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