FINAL CONSTRUCTION REPORT: EXPERIMENTAL THIN BONDED CONCRETE OVERLAY PAVEMENT IN HOUSTON, TEXAS

Demonstration Project 561

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16. Abstract

An experimental thin bonded continuous concrete pavement was constructed in Houston, Texas, July - August 1983. It was monitored until 1990. The final evaluations of this TBCO test section in March and December of 1990 seem to confirm what earlier findings reported; the pavement is in very good condition and is expected to continue to provide excellent service for the foreseeable future. After more than seven years of continued heavy traffic of about 140,000 vehicles per day, the overall condition and appearance seem identical to any other typical CRCP of the same age in the Houston area, made from the same material and subjected to the same traffic load. The overall useful life expectancy of this TBCO test section is judged to be about 15 to 20 years from date of construction in 1983. After that length of time, increasing transverse and longitudinal pavement cracking will combine to form blocks and punchouts of varying sizes, leading eventually to the need for extensive repairs and maintenance.

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EXPERIMENTAL THIN BONDED CONCRETE OVERLAY PAVEMENT
IN HOUSTON, TEXAS

Project 561
(DTFH71-83-3952-TX-15)

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March 1991

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DISCLAIMER STATEMENT

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CHAPTER 1. INTRODUCTION

This report concerns the performance of a thin layer of portland cement concrete overlay used to rehabilitate an existing pavement. This chapter presents project background information and objectives, as well as organization and scope of the report.

A. BACKGROUND

In recent years, the highway industry in the United States has shifted its attention from construction of new pavements to maintenance, repair and rehabilitation of existing roadways. This shift occurred primarily due to two factors:

1. The Interstate Highway construction program is nearing completion. The basic highway network is now in place and future activities will be directed towards preserving this initial investment by resurfacing, restoring, rehabilitating and upgrading these highways.

2. Most of the pavement now in service is reaching its theoretical twenty-year design life and rehabilitation is needed before major expenditures become necessary.

In addition to these factors, there are cost, environmental, and time considerations contributing to this present trend towards maintenance, repair and rehabilitation.

In Houston, Texas, the freeway network includes many miles of continuous reinforced concrete pavements (CRCP). Overall at present, these pavements are in fair to good structural condition and are generally suitable for rehabilitation. However, these pavements eventually will have to be restored by rehabilitation or replacement. Consequently, a means of adding 20 or more years of maintenance-free life to these CRCP pavements needed to be discovered. As a result of a cooperative highway research program between the Center for Transportation Research, The University of Texas at Austin, the Texas Department of Transportation, and the Federal Highway Administration, an experimental thin bonded continuous concrete overlay was constructed in July and August of 1983 on the South Loop 610 in Houston.

Rehabilitating concrete pavements with thin bonded concrete overlay (TBCO) is feasible because of inherent structural and thermal compatibilities between the overlay material and the overlaid pavement. Bonded concrete overlays have been known for over 30 years. Construction methods of these overlays are similar to those used in standard concrete paving. As in standard practice, modern machinery and new materials such as superplasticizer have enhanced speed and ease of placement. Theoretical studies have shown that a TBCO will substantially increase the structural capacity of an existing concrete pavement and, as a result, will extend the fatigue life of the structure. The Houston Loop 610 experiment provided an excellent opportunity to test these studies under high traffic loading conditions. After about nine years of continued heavy use, the results of an ongoing performance and condition evaluation of this test section are being presented in this report.

Figure 1. Loop 610 before overlay. Note longitudinal cracking and surface spalling.

B. OBJECTIVES

The objectives of this final report of Research Study 561 are to document the following information:

1. Background and summary concerning construction of test section.

2. Summary of past performance evaluations and assessment of present condition after seven years of heavy use.

3. TBCO cost estimates

C. ORGANIZATION AND SCOPE

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CHAPTER 2. EXPERIMENTAL TEST SECTION CONSTRUCTION

This chapter introduces the field experiment in Houston, where various types of thin bonded concrete overlay pavements were installed. A brief summary of the original pavement history, as well as some design considerations and construction details of the five different test sections are discussed.

A. PAVEMENT HISTORY

The experimental test section is located on the eastbound mainlanes of the IH-610 South Loop between Cullen and the Calais Street overpass in Houston, Texas. It represents 1,000 feet of thin bonded concrete overlay, divided into five 200 foot sections.

The original concrete pavement was completed in June, 1970, and served as the riding surface until the thin bonded concrete overlay (TBCO) was constructed in the summer of 1983. Figure 2 shows the original pavement is an 8-inch-thick, continuous reinforced concrete pavement (CRCP) with 0.5 percent longitudinal steel reinforcement. The CRCP rests on a 6-inch layer of cement-treated subbase of gravel screenings and another 6-inch layer of compacted subgrade.

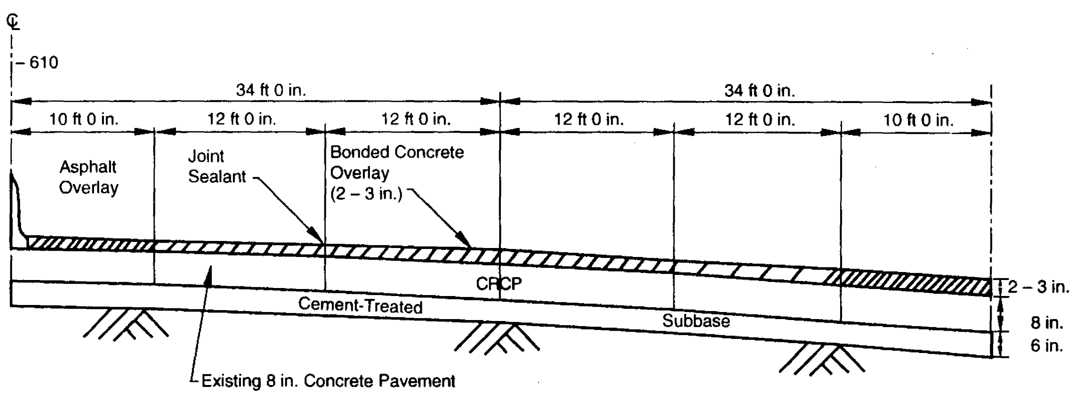

Figure 2. Typical cross section showing detail elements and their dimensions.

An estimated 23.6 million 18 kip equivalent, single axle loads were applied to the pavement from 1970 to 1983, representing an averaged annual daily traffic (AADT) count, excluding access road traffic, of about 140,000, including about 5 percent heavy truck traffic.

Pavement defects were selectively repaired prior to placing of the overlay, using polymer concrete as patching material. Additionally, uncontrolled longitudinal cracks were routed out 3/4 inch wide and about one inch deep, filled with dry sand, and covered with a liquid monomer.

Defects in the original CRCP surface consisted primarily of spalled transverse cracks, longitudinal cracks and punchouts of varying dimensions. Although these defects were not considered an immediate threat to the life and load carrying capacity of the structure, they required increasing amounts of maintenance and caused increasing disruptions and inconveniences to heavy traffic. When it became obvious that something had to be done and that some form of rehabilitation would be necessary in the near future, the decision was made to place an experimental thin bonded concrete overlay on the structure.

B. DESIGN CONSIDERATION OF THE OVERLAY

Two main factors, thought to have a significant influence on the performance of TBCOs, were the type of concrete reinforcement and the overlay thickness. Using principles of statistics, a factorial two by three matrix experiment was devised, based on fiber and welded wire fabric reinforcements and two- and three-inch overlay thicknesses as follows:

1. Two-inch plain concrete overlay
2. Two-inch, steel welded wire fabric concrete overlay
3. Three-inch, steel welded wire fabric concrete overlay
4. Three-inch, fiber-reinforced concrete overlay
5. Two-inch, fiber-reinforced concrete overlay

It is to be noted that the factorial matrix design did not include a three-inch plain concrete overlay section and is, therefore, only a partial factorial.

Figure 3 illustrates the factorial design matrix used in the experiment.

Overlay Thickness \ Concrete Reinforcement	Non – Reinforced	Steel – Mat Reinforced	Steel – Fiber Reinforced
2 in.	X	X	X
3 in.		X	X

X = Test Sections

Figure 3. Factorial design for the south Loop 610, Houston experimental project.

While the efforts in the experiment were centered on assessing the effects and possible interactions of the primary factors, an attempt was made to factor out possible undesirable secondary effects and interactions. Two such secondary effects were varying traffic level and differences in thermal expansion for the overlay and original pavement.

To overcome the effects of varying traffic levels, the project location was chosen such that no entry or exit ramps existed for the entire 1,000 - foot length of the test section. Therefore, if it is assumed that only relatively few lane changes occur and that weaving is at a minimum, any of the four lanes in each of the five design sections can be assumed to receive essentially the same number of load applications. The performance data analysis can therefore be a two-way design, where lane is the blocking variable.

To avoid the effects of different thermal expansion and thereby reduce any thermally induced differential movement of the overlay and underlying pavement, the same type of coarse aggregate, from the same source, was used, in this case Colorado River quartzite gravel. Since the type of coarse aggregate significantly affects concrete strength and thermal expansion, using the same type and source will leave only the effects of the inherent variability within the gravel pits. However, since this variability is conceivably of the same order of magnitude now as it was when the original pavement was constructed, the chances for thermally induced differential movement of the pavement and overlay, with resultant debonding and shear failure, are considerably reduced.

Finally, an important part of the experiment design considerations was simplicity in construction methods. It was thought that any reasonably experienced concrete paving contractor could easily accomplish this task with readily available equipment and materials.

C. PROJECT INFORMATION SUMMARY

The Loop 610 CRTBC experiment consisted of overlaying a 1000-foot section of IH-610, a major, heavily traveled, urban freeway, which encircles central Houston. The site selected is located on South Loop 610 eastbound mainlanes between Cullen and the Calais Street overpass, approximately 3.5 miles east of the Astro World/Water World amusement park complex. At this location the roadway is an eight-lane divided highway with four through lanes in each direction and a concrete median barrier. Main lane widths are 12 feet with 10-foot shoulders. In this experiment, only the four eastbound lanes were overlaid.

Figures 4 and 5 show the plan view and longitudinal profile of the roadway. Figure 5 illustrates the slight (+3.60 percent) upward grade for the 3-inch steel-reinforced, 3-inch fiber-reinforced and 2-inch fiber-reinforced sections.

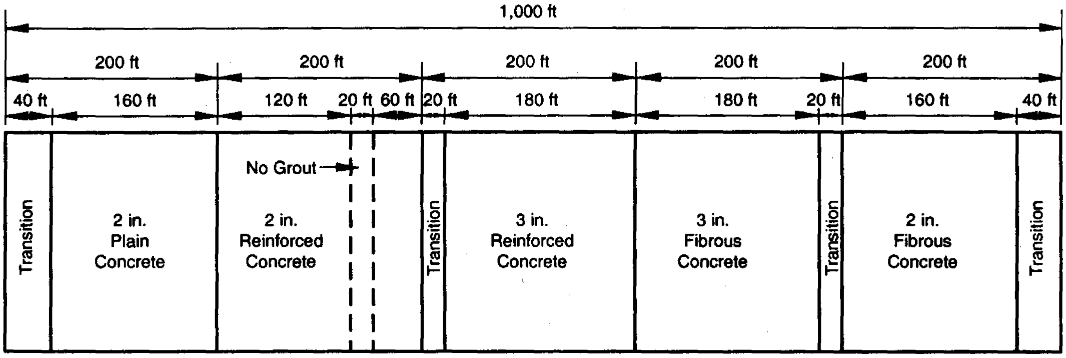

Figure 4. Plan view of the Loop 610, Houston test sections, showing details of design and layout.

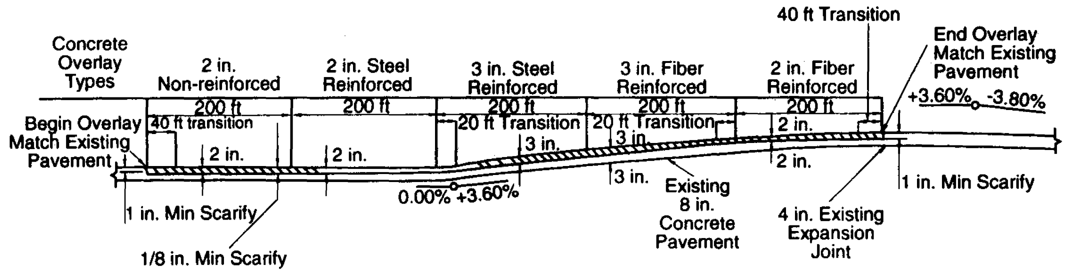

Figure 5. Profile of experimental section.

Figure 6 shows the location and horizontal alignment, as well as the fact that no entry or exit ramps are within the cross-hatched 1000-foot test section. Figure 3 shows the details of the geometric layout and sequence of the individual test sections.

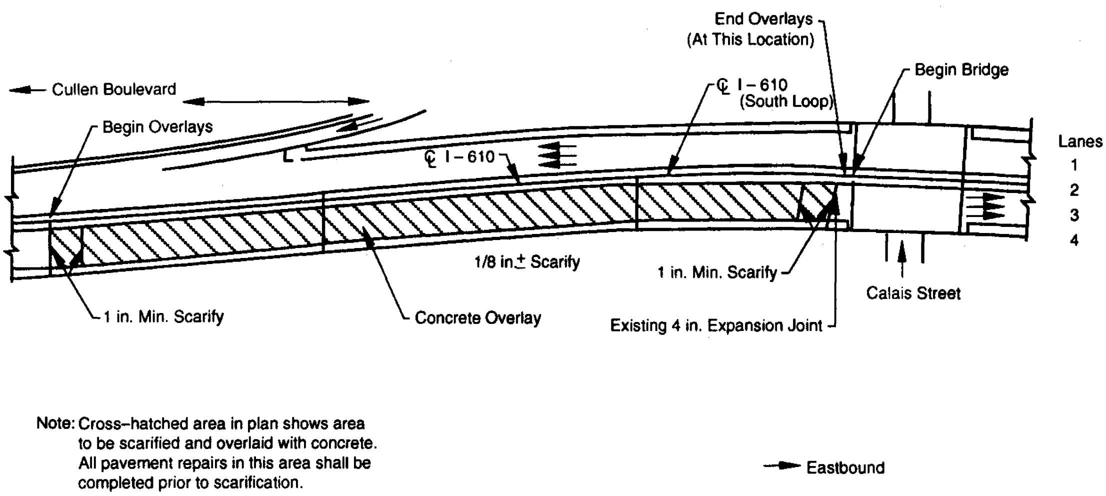

Figure 6. View showing the Houston Loop 610 project location, horizontal alignment, and depth of scarification.

The original pavement structure is a continuous reinforced concrete pavement (CRCP) with 0.5 percent longitudinal steel and five sacks per cubic yard cement factor. The CRCP rests on a six-inch-thick cement treated subbase. The material comprising the subgrade is a silty clay (Fig. 1). Bonded overlay construction was completed on this section of roadway on June 4, 1989. It now carries an estimated average annual daily traffic (AADT) of 140,000 vehicles with eight percent trucks.

An inspection immediately prior to the bonded overlay construction showed minor surface defects consisting primarily of closely spaced transverse cracks, spalled transverse cracks, longitudinal cracks and small asphalt and polymer concrete patches.

D. CONSTRUCTION

1. General

Construction of the experimental overlay sections began on July 22, 1983 and was completed August 27, 1983. Source delay was encountered due to the passage of a hurricane and a shortage of crushed ice used to control concrete placement temperatures. Construction proceeded in two major phases: Phase 1, the placement of overlays on the inside two lanes and Phase 2, the placement of overlays on the outside two lanes.

2. Surface Preparation

Surface preparation consisted of Roto-milling to a universal depth of 1/4 inch, which proved to be the minimum attainable level with the type of equipment and material used. After milling, the surface was broomed with a stiff bristle broom to remove all loose material. Thereafter, the longitudinal joint sealer was removed using jack hammers.

Finally, the surface was thoroughly sandblasted to remove all contaminants.

The original concrete paving appeared clean and sound. Transverse cracks appeared tightly closed, indicating that the original CRCP was structurally adequate. It also became evident that the original polymer concrete patching material had indeed penetrated deeply into the cracks.

The final step in pavement surface preparation consisted of air blasting as close as possible to the grouting and paving operations. Following air blasting, double layers of polyethylene sheeting were used to prevent truck tire imprints and oil drippings from contaminating the surface. No surface repair, such as joint or crack sealing, deep patching or slab jacking, was necessary, as the prepared CRCP surface appeared in good condition.

Immediately before paving, a water-cement grout was uniformly broomed over the full width of the prepared surface. The water-to-cement ratio was about 0.62 by weight, or seven gallons of water per sack of cement. A water-reducing plasticizer gave the bonding grout an easily workable, creamy consistency. The concrete was batched at a central plant and hauled in ready-mix trucks loaded with six cubic yards each, or less than 80 percent capacity.

3. *Paving Operations*

The concrete was dumped onto the grouted pavement surface and manually finished to grade using a transverse concrete finisher guided by rails. Suitable surface texturing consisted of transverse metal tine finishing, or wire combing, by hand from a working bridge. Following surface texturing, a white pigmented, impervious curing powder was spread manually from a second working bridge.

After 24 hours, pavement edges and centerline longitudinal joints were cut to one-inch depths and sealed with hot-poured asphalt material. A minimum of six days of curing were allowed before returning the lanes to traffic.

CTR research report 3-8-83-357-2F gives additional construction detail concerning this experimental project.

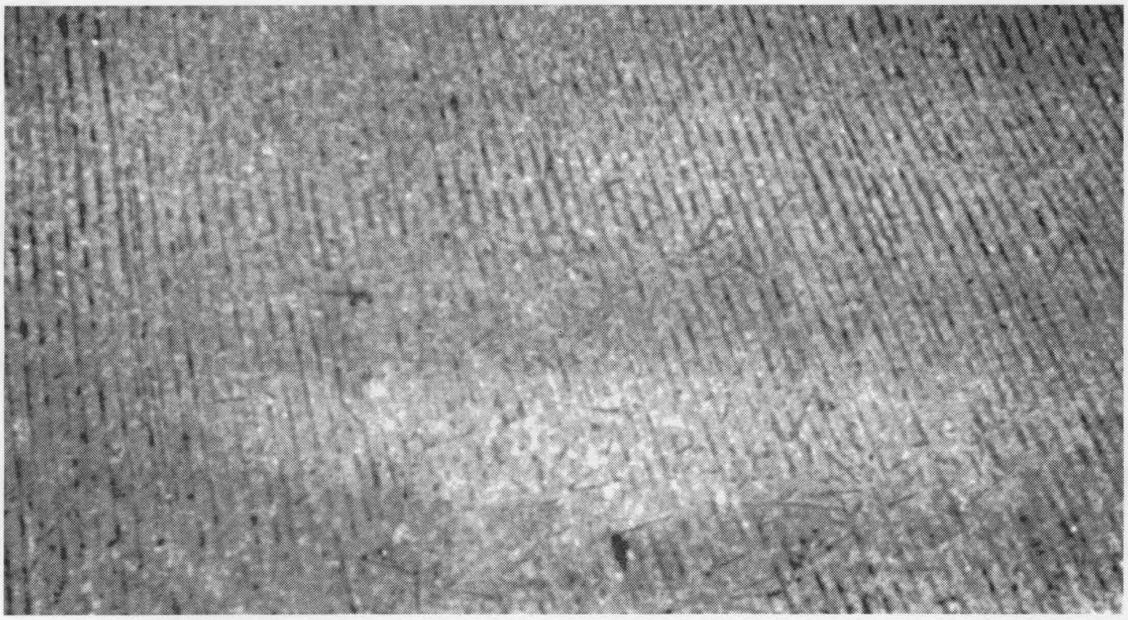

Figure 7. Loop 610 after overlay. This is the surface of a section using steel fiber reinforcement.

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CHAPTER 3. TBCO COST SUMMARY

This chapter provides TBCO cost summary figures as estimates and general guidelines to be used where several construction alternatives are being considered during initial planning stages of a rehabilitation project. These figures are not to be considered fixed and absolute, or even typical, for any other urban or even rural area in the state of Texas.

A. CONSTRUCTION COST

In general, construction cost figures include items for material, labor, equipment procurement or rental, taxes, bonds, licenses and insurance, as well as a number of indirect and miscellaneous expenditures.

Material items include concrete, reinforcement, water reducers, curing compounds, joint sealer, saw blades, scarifier teeth, blasting sand and grout mix.

Major indirect and miscellaneous cost items include project management and engineering, office personnel and expenses, timekeeper, inspections, ice, sanitation and field supplies, as well as freight, tools, repairs and safety items.

Table 1 includes construction costs for each of the five 200-foot test sections as submitted by the low bidder, as well as averaged three lowest bids received and the agency's engineer's estimate.

B. TRAFFIC HANDLING COST

The total cost for controlling and handling traffic during construction is estimated at $1,000 per day by Houston District Office engineers. Total traffic handling time was 36 days for overlay construction and 6 days for curing, totaling 42 days.

C. USER COST

The cost to the user during construction includes traveling time delays, changes in vehicle operational characteristics, accident costs, and others.

Although some assumptions generally list user cost at about 2 to 3 times the total construction costs, no reliable user cost figures or estimates are available for this project.

TABLE 1. SUMMARY OF MATERIAL UNIT PRICE ON THE SOUTH LOOP 610 EXPERIMENTAL TBCO

Section	Successful Bidder	Average Three Lowest Bids	Engineer's Estimate
2"NR	$18.00/SY	$16.30/SY	$ 9.00/SY
2"R	20.00/SY	19.04/SY	12.00/SY
3"R	23.00/SY	21.57/SY	16.50/SY
3"F	29.00/SY	25.35/SY	16.50/SY
2"F	25.00/SY	21.00/SY	12.00/SY
Average	23.00/SY	21.00/SY	13.00/SY
Scarification of Base CRCP Surface	7.00/SY	5.82/SY	3.50/SY

D. TOTAL OVERLAY COST

The total overlay cost to the agency, excluding user cost estimates, is about $29/SY, plus an additional $8/SY for traffic handling, for a total of about $37/SY (Ref 5).

Additional cost information is given in CTR report 3-8-83-357-8F.

CHAPTER 4. PERFORMANCE EVALUATIONS

This chapter presents the results of performance evaluation of the thin bonded concrete overlay (TBCO) after five years in 1988 and after seven years in 1990.

After five years of heavy use, a condition survey was conducted in September 1988 by a four-man crew who walked over selected sections and recorded any cracking, spalls, punch-outs and repairs. In addition, a sounding survey for delamination was performed by using metal sounding bars. The results indicate no significant delamination was found on any portion of the test section. Only minor cracks of extremely narrow width, many of which were difficult to see, could be detected. Most of the cracks found were located on the welded wire fabric sections.

After a total of seven years of continued heavy use, another performance evaluation was conducted in March and December 1990. Condition and sounding survey results indicate that all five test sections were in excellent overall condition. Only minor debonding was encountered in the 3-inch welded wire fabric section near the longitudinal construction joint in Lane 2, which is the second lane over from the median. The percentage of debonding in this Section C was measured to be 0.6 percent. All other sections showed only negligible or no amount of debonding. In general, the characteristic appearance shows closely spaced (2- to 3-foot average, varying from 1 to 5 feet) transverse cracking and some uncontrolled longitudinal cracking adjacent to the longitudinal sawed joint in the middle of each 24 foot wide placement. Test sections 4 and 5 showed substantially fewer transverse cracks than sections 1, 2, and 3. Only four or five cracks were noticed in these two 200-foot sections. Some cracking in the steel fiber reinforced sections 4 and 5 showed the characteristic tightly closed appearance.

There was no spalling observed along the transverse cracks on any of the test sections, although any CRCP constructed in the Houston area from local siliceous river gravel often exhibits surface spalling along the transverse cracks. Overall, all cracks in all test sections appeared to be tightly closed.

The only visible surface defects noted, which are considered relatively minor, are some small delaminations or concrete layer separations about 2 or 3 inches wide along a sawed joint between the two outside lanes. These defects have been noted previously and may have been caused by the concrete sawing operations. However, they occur only for a foot in length. There are several small preformed instrumentation holes cast into the overlay at various locations. Since the testing and evaluation have been completed, these holes will be filled in with concrete material. (Ref 6)

CHAPTER 5. CONCLUSION

In general, the final evaluations of this TBCO test section in March and December of 1990 seem to confirm what earlier findings reported; that is the pavement is in very good condition and is expected to continue to provide excellent service for the foreseeable future. After more than seven years of continued heavy traffic of about 140,000 vehicles per day, the overall condition and appearance seem identical to any other typical CRCP of the same age in the Houston area, made from the same material and subjected to the same traffic load. For example, a similar urban freeway section of SH288 nearby of about the same age and comparable traffic loading, and constructed from the same material, showed actually slightly more wear and evidence of repair than the TBCO test section of this report. In view of the detailed past evaluations and the findings of this report, the overall useful life expectancy of this TBCO test section is judged to be about 15 to 20 years from date of construction in 1983. After that length of time, increasing transverse and longitudinal pavement cracking will combine to form blocks and punchouts of varying sizes, leading eventually to the need for extensive repairs and maintenance.

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