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SPECIAL PROJECT
SP-2054-SHR

REVIEW OF AIRFIELD PAVEMENT CONSTRUCTION FALLON NAVAL AIR STATION

by
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EXECUTIVE SUMMARY

This report documents the results of the investigation by the Naval Facilities Engineering Service Center on the performance of pavement types and economic analysis of pavement alternatives for airfield pavements at Naval Air Station, Fallon, Nevada. This investigation was sponsored by the Commander-in-Chief Pacific Fleet by Document Number N0000709099P00039D.

This study was initiated because of the premature cracking that occurred on Runway 13R-31L almost immediately after the application of the 2-inch asphalt concrete (AC) overlay during May-September 1997. The primary objectives of the investigation were to:

1. Review the long-term repair program for the AC portion of the runway and determine if this is the best repair alternative for that pavement.
2. Evaluate replacing the AC portion with new Portland cement concrete (PCC) pavement.
3. Evaluate constructing a new all PCC runway to the east of the existing runway 13L-31R.
4. Evaluate AC versus PCC pavement performance for applicability at NAS Fallon.
5. Review existing Taxiway "A" construction project and assess constructability.
6. Review condition of the runway shoulders and prepare cost estimates to upgrade the shoulders to meet requirements of Military Handbook 1021/1.

This investigation also included the performance of economic analysis of the alternatives and the calculation of life-cycle costs for the different alternatives.

The investigation revealed that low-temperature thermal cracking occurs in asphalt concrete pavements constructed in the NAS Fallon area. The cracking present in Runway 13R-31L is due to reflection of the existing cracks in underlying layers. Such cracks were initially caused by cyclic exposure to low temperatures. Similar thermal cracks are present in the pavements at Reno-Tahoe International and Reno-Stead Airports and Amedee Air Strip at the Sierra Army Depot. Such cracking can be minimized by cutting newly constructed AC pavements into 25 feet square slabs as demonstrated at Reno-Stead Airport.

While both AC and PCC pavement materials have their technical advantages and disadvantages, the propensity for thermal cracking of asphalt concrete in the Fallon environment and the accompanying maintenance requirements for AC suggest that PCC might be a better choice of pavement material for future airfield pavement at NAS Fallon.

Analysis of an AC slab sample from Runway 13R-31L showed that the material composition and compaction were marginal. Because the absorptive characteristics of the aggregates were not accounted for, the asphalt content was low by about 2 percent. Additionally, the void content was determined to be 10 percent. This indicates that the sample was under compacted, which would allow moisture and air to more readily enter the pores to promote oxidation of the asphalt cement. The lower than required asphalt content coupled with the high void content is causing the premature oxidation and weathering of the pavement.

Economic and life cycle cost analyses were performed on various candidate pavement alternatives. Calculations were made using Cumulative Net Present Value (NPV). The 25-year life cycle cost (LCC) for each alternative is:

ALTERNATIVE	INITIAL YEAR (NPV)	25-YR LCC (NPV)
Maintain Existing Asphalt Concrete Overlay (Status Quo)	$320,000	$6,750,164
New Asphalt Concrete Overlay	$2,640,776	$8,898,349
New Asphalt Concrete Pavement	$32,950,437	$39,284,692
New Asphalt Concrete Pavement With Sawed Joints	$33,825,073	$38,067,351
New Portland Cement Concrete Pavement	$38,684,159	$40,067,488
Replacement of Runway 13R-31L	$75,518,950	$77,638,798
Repair Runway 13R-31L Shoulders	$7,192,906	$7,454,533

The alternative to maintain and repair the existing pavement to keep it serviceable is the least cost alternative to the government with a 25-year life cycle cost of $6.75M (NPV).

The repair or replacement of the AC pavement is not required at this time because the pavement is technically adequate based on the current condition rating and determined load carrying capacity. Additionally, the construction history as shown in Table 1 coupled with the fact that the previous overlays were cracked as shown in Figures 1 through 3, further indicate that the present cracked overlay will perform satisfactorily. Hence, for the near term, the following recommendations are made:

1. Rout and seal cracks that are 1/4 inch wide or wider as they appear.
2. Apply a fog seal every three years beginning in 1999 to retard oxidation and inhibit raveling. (A fog and other surface seals will affect the frictional characteristics. Therefore, care must be taken to insure skid resistant levels are maintained.)
3. Upgrade runway and taxiway shoulders to meet requirements of MIL-HDBK 1021/1.

Continue maintaining the pavement until such time that the PCI falls below 70 (estimate around year 2006) at which time a global repair or replacement procedure needs to be implemented.

Long term recommendations include re-evaluation of the economics when global repair procedures are needed and to evaluate foreign object damage (FOD) to engines relative to rock, sand and pavement debris as foreign objects resulting in FOD. Considering FOD data, economics and potential for restrictions on operational requirements, select rebuilding the asphalt concrete portion of Runway 13R-31L with Portland cement concrete if warranted.

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INTRODUCTION

This report is to document the results of the investigation from the project "NAS Fallon Runway Study". This project was funded by the Commander-in-Chief Pacific Fleet by Document N00007099P00039D. The objective of this study is to review the airfield pavement construction program at Naval Air Station (NAS) Fallon to identify areas where pavement performance and utility can be enhanced. The areas to be studied were established jointly by Engineering Field Activity (EFA) West and NAS Fallon. The Naval Facilities Engineering Service Center (NFESC) was selected to perform the study.

The proposed study initially consisted of seven tasks. The tasks consisted of the following requirements:

<u>Task 1</u>. Work Plan

a. Prepare a Work Plan detailing the proposed methods and procedures for the different tasks.

<u>Task 2</u>. Runway 13R-31L Alternatives

a. Review the long-term repair program for the AC portion and determine if this is the best repair alternative for that pavement.

b. Review the condition of the asphalt concrete (AC) portion of the runway.

c. Evaluate replacing the AC portion with new Portland cement concrete (PCC) pavement.

d. Evaluate constructing a new all PCC runway to the east of the existing runway 13L-31R.

e. Evaluate AC versus PCC pavement performance for applicability at NAS Fallon.

<u>Task 3</u>. Taxiway "A" Repair Constructability

a. Review existing construction project and assess constructability.

<u>Task 4</u>. Runway 13R-31L and Taxiway Shoulders

a. Review existing runway shoulder conditions and prepare cost estimates to upgrade shoulders to meet requirements of Military Handbook 1021/1.

b. Evaluate effect of large aircraft on taxiway shoulders

<u>Task 5</u>. Taxiway Clearances

a. Review the existing clearances on all taxiways for compliance with requirements of Military Handbook 1021/1.

b. Evaluate the effects of wing and engines of large aircraft and restriction on taxiway usage.

Task 6. Runway 13R-31L Electrical Wiring Upgrading

a. Provide a cost estimate to update electrical wiring.

Task 7. Taxiway D Upgrading

a. Prepare a cost estimate and determine life cycle cost to upgrade this taxiway to meet requirements of Military Handbook 1021/1.

Subsequently, Commander-in-Chief Pacific Fleet (CINCPACFLT), stated that they will support Tasks 1, 2, 3, and 4 and further stated that NAS Fallon is responsible for funding Tasks 5, 6, and 7 (Ref. U46433 – Brad Davis, e-mail message of 30 Jul 98, Subj: Fallon Study, Runway 13R-31L). In the kickoff meeting held on 5 August 1998, the NAS Fallon Operations Officer requested that Task 5 be removed from the study since the taxiway clearances are all known. Funding was not received from NAS Fallon to support the performance of Tasks 6 and 7. Hence, except for preliminary information generated in the site investigation during 5 and 6 August 1998, information relative to these two tasks is not included in this report. Funding for performance of Tasks 1 through 4 was faxed to NFESC on 19 November 1998.

TASK 1. WORK PLAN

The kick-off meeting was held on 5 August 1998 at Public Works Engineering, NAS Fallon, Nevada. The purpose of the meeting was to review and approve the work planned by NFESC. In attendance were the following:

NAS Fallon

CDR Chris Lindberg, Executive Officer
CDR Thor Jensen, Operations Officer
Del Pursel
Bob Finley
Bud Zanger

EFA West

Chuck Heron
Eldon Jemtrud

NFESC

Mel Hironaka
Charlie Schiavino
Yutaka Sugiyama

A briefing was presented by NFESC in which the following topics were discussed relative to the work plan:

1. Work Plan Tasks (including problem definitions, approaches, and products)
2. Project Team
3. Milestones and Deliverables

The most significant visuals that were used in the discussions are included as Appendix A. Chuck Heron, Eldon Jemtrud, and Del Pursel edited the original views used in the briefing to reflect what NAS Fallon and EFA West desired from the conduct of the study. Their review and modifications constitute approval of the work plan. Their input are included in the Appendix A printout of the visuals. As discussed in the previous section, Task 5 was deleted at the request of the Operations Officer and NAS Fallon elected to not fund Tasks 6 and 7.

TASK 2 – RUNWAY 13R-31L ALTERNATIVES

Problem

The asphalt concrete (AC) overlay installed on Runway 13R-31L during 5 May 1997 through 5 September 1997 developed premature cracking. The cracks appeared during the first winter season and have grown progressively worse. This prompted an investigation led by Engineering Field Activity West. This effort culminated in a report titled "Fallon Runway Overlay Assessment" [1]. This investigation is a follow on effort directed to maintenance and repair and alternatives to this same cracked pavement.

Alternatives for AC Portion of Runway 13R-31L

The following are considered to be the most feasible alternatives for the maintenance and repair of the existing cracked asphalt pavement or replacement of that portion of the runway with other pavement alternatives.

1. ***Maintain Existing Asphalt Concrete Overlay (Status Quo)***. Seal the cracks and maintain the pavement until such time in the future when the Pavement Condition Index (PCI) falls below the critical PCI of 70 (estimated to be around year 2006). At that time, select one of the alternatives below based on re-evaluated economic conditions at that time and operational concerns for implementation.

2. ***New Asphalt Concrete Overlay.*** Install a two-inch asphalt concrete overlay using the proper SHRP [2] performance grade of asphalt cement for the temperature conditions at NAS Fallon. Expect this asphalt cement to retard reflection cracking somewhat but expect the existing cracks to reflect through eventually. Seal the cracks and maintain the pavement as in Alternative 1.

3. ***New Asphalt Concrete Pavement.*** Remove the entire pavement structure including the base and install a new base and AC surface course using proper SHRP [2] performance grade of asphalt cement for the temperature conditions at NAS Fallon and expect cracks to appear eventually. Seal the cracks and maintain the pavement as in Alternative 1.

4. ***New Asphalt Concrete Pavement With Sawed Joints.*** Remove the entire pavement structure including the base and install a new base and AC surface course using proper SHRP [2] performance grade of asphalt cement for the temperature conditions at NAS Fallon. Saw cut joints in both longitudinal and transverse directions to obtain 25 foot square slabs. Seal the joints and maintain the pavement as deemed necessary.

5. ***New Portland Cement Concrete Pavement***. Remove the existing asphalt concrete pavement structure and replace with new Portland cement concrete pavement.

Replacement of Runway 13R-31L

In addition to investigating the treatment or alternatives to the AC portion of the Runway as discussed above, investigation of an all-new parallel runway was required. This alternative is:

- ***New Portland Cement Concrete Pavement Parallel Runway***. Construct an entirely new all Portland cement concrete parallel runway to the east of Runway 13L-31R and abandon the existing Runway 13R-31L when complete.

Review of Long Term Repair Program for AC Portion of Runway 13R-31L

Cracking of the AC pavement on Runway 13R-31L has been a common occurrence throughout the history of this pavement. Figures 1 through 4 illustrate the history of the occurrence of largely spaced transverse reflective cracking which are indicative of initially induced low temperature thermal cracking (details discussed later in this report). The following describes the views in these figures:

Figure 1. NAS Fallon Runway R13-31, Crack Sealed (August 1970) [3]. Note transverse cracking of the pavement spaced at large distances which is indicative of thermal cracking. Such cracking has been recognized for a number of decades and has been studied extensively.

Figure 2. NAS Fallon Runway R13-31, Existing Cracks and New Overlay (lower right) (26 August 1986). Note existing crack pattern, which is very similar to that present in 1970. Alligator cracking due to aircraft loading is absent. Only cracking due to environmental conditions are visible. A new overlay being installed can be seen in the lower right corner.

Figure 3. NAS Fallon Runway R13-31, Existing Cracks with Sealant and Cracking in New overlay (26 August 1986). Overlay being installed in August 1986 cracked almost immediately.

Figure 4. NAS Fallon Runway R13R-31L, Cracking Pattern in Present Overlay (22 April 1999). Cracking pattern in the present overlay is very similar to that present in 1970 and after two overlays prior to 1986. The occurrence of the cracks is almost certain to be due to reflection of existing cracks in the underlying pavement layers.

These figures illustrate the fact that if an AC overlay is installed on previously thermally cracked pavements, the existing cracks will reflect through the overlay. Regardless of treatments made to the cracks prior to applying the overlay, the cracks reflect through. As examples:

1. Reinforcing fabric was used in 1980 prior to a 3-inch overlay [4,5]. Another overlay was required after six years in 1986. This information suggests that the fabric may have accelerated the occurrence of the cracking by introducing a "slip" plane on which the overlay can move more easily. (Low temperature thermal cracking originates from the surface downward).

2. Stress Absorbing Membrane Interlayer (SAMI) was used in 1997 prior to the 2-inch overlay at that time [6]. One hundred percent of the cores taken from transverse cracked areas showed that the cracks reflected through regardless of whether or not a SAMI was used [6].

Although esthetically unpleasant, previously cracked AC overlays have functioned satisfactorily. The previous overlays were maintained with crack sealing procedures and global applications of surface treatments as shown in Table 1. These procedures have sustained the operational integrity of the pavement until such time when it was deemed necessary to implement a repair project. The same maintenance procedures could be followed for the present cracked overlay until such time that the pavement requires application of a global repair (or replacement) procedure. In addition, the application of fog seals periodically (e.g., every 3 years) should prolong the life of the pavement.

Based on the worldwide accepted system for assessing the condition of airfield and airport pavements, the average Pavement Condition Index (PCI) [7] of the AC portion of Runway 13R-31L at the time of the last survey in October 1998 was determined to be 95. This equates to the pavement having a condition rating of "excellent." The only distresses present on this pavement were low severity longitudinal and transverse cracking and small areas of raveling. Such cracking is the result of environmental factors on the asphalt cement. There were no load-related distresses observed during the survey.

Review The Condition Of The Existing Asphalt Concrete

Field Inspection of Runway 13R-31L

Runway 13R-31L was visually inspected for general crack patterns and any other pavement distresses in April 1999. Figure 5 shows a typical crack observed during this inspection. The runway was constructed using approximately 17' widths for each pass or lane. The longitudinal construction joint between paving lanes has the appearance of not being "tight," resulting in longitudinal cracking. Based on observations at several locations along the longitudinal joints, it appears that the roller rolled too close to the edge of the paving lane. This caused the outer edges of the paving lane to be depressed resulting in longitudinal "bird baths" at many locations, some of which are visible in Figure 4. Some of these joints now exhibit low severity raveling.

Surface wear has also occurred within the center 100 feet of the runway, which appears to be the result of raveling. There are several small locations that could be considered near high severity. This is only apparent in the main gear wheel path and is more apparent towards the south end of the runway. One of these areas with exposed aggregate is shown in Figure 6. The occurrence of exposed aggregate suggests that stripping or asphalt deficiency may be the cause.

Transverse cracks resembling thermal cracking were observed throughout the Runway. In general the cracks are contained within each paving lane. However, at approximately every 150 feet, the cracks travel across multiple paving lanes. Crack widths were measured at random locations along the entire length and width of the runway using a crack comparator. Crack widths measured between 0.01 inch to 0.20 inch with the vast majority between 0.06 inch and 0.12 inch (1/16 inch and 1/8 inch). The larger cracks are beginning to have aggregate dislodged from the crack opening. The dislodging appears to be more common under areas with aircraft traffic. Although it appears dislodgment of aggregate from the cracks have occurred, no loose aggregate was observed along the entire length of the runway during this inspection.

An arbitrarily selected 1,500 feet section of pavement was measured for crack characteristics. The section measured was in the second paving lane along the west edge of the runway, beginning at construction station 45+25 and ending at approximately station 60+50. Measurements were taken and the distance between cracks was calculated by taking the numerical difference between continuous measuring wheel readings for the location of each crack. The average distance was computed to be 42.5 feet. The results of these measurements and calculated values are shown in Column 1 of Table 2.

Additional data on pavement cracking at NAS Fallon was collected from information for Runway 7-25. The data was obtained by scaling from an arial photograph that was part of the 1990 construction project titled: Asphalt Repairs, Runway 7-25. The arial photo was used in the plans (Site Plan) to indicate location where each type of construction detail was to be performed. The cracks present at that time in the pavement were highlighted. A 1500' section was randomly selected to measure crack frequency both in the second paving lane from the south edge and along the centerline of the runway. The results of these measurements and calculated values are shown in Column 2 and 3 of Table 2. Data were scaled from the photograph for cracks appearing between stations 18+00 to 33+50. A very brief visual inspection of this runway was performed during the site visit described above. Measurements were not taken; however crack occurrence appear to be very similar in dimensions to both the arial photos from 1990 and the present cracks on runway 13R-31L.

Asphalt Concrete Pavement Sample and Mix Design

Sampling of the asphalt concrete pavement was performed on April 22, 1999. The sample was taken from Station 48+09, 25 feet from the west edge of the runway pavement. The 24-inch by 24-inch sample was removed (with underlying layers attached) and shipped to the Waterways Experiment Station (WES) for testing.

WES was tasked by NFESC to conduct a laboratory evaluation of the asphalt concrete slab surface layer in accordance with prescribed test instructions. Tests and measurements were conducted on the slab specimen with results forwarded in "Laboratory Evaluation of Asphalt Concrete Samples from Fallon NAS Runway Pavement" (Appendix B). The "approved" job mix formula submitted by the paving contractor was used for comparison in this evaluation.

Test results indicate the extracted aggregate gradation has an excessive amount of fines passing the No. 4 sieve and a significantly high amount passing the No. 200 sieve. The significance of these excessive fines usually means the asphalt mixture should have low air voids if compacted properly. However, this is not the case with this specimen. The asphalt concrete represented by the slab specimen contained an excessively high percent of air voids. High voids indicate the asphalt mix may have been under-compacted during placement. Past experience has shown excessive fines and under-compaction of material may lead to rutting, or the problem of oxidation and premature raveling can be accelerated if the asphalt cement content is too low.

Results from material property tests indicate the Marshall flow value was high. A high flow value could be caused by an excessive amount of either fines or asphalt cement. However, the stability measurements made by the gyratory testing machine detected no unstable asphalt mixtures and indicated an excessive amount of asphalt cement was not used. Therefore, the Marshall flow property, although high which is attributed to the excessive amount of fines, does not seem to detrimentally effect other material properties.

Test results from this evaluation were then compared with the project specifications and also with the job mix formula and specifications from the 1986 overlay project. The only significant difference in the two projects specifications involved asphalt content. The 1986 specification indicated that if absorption of the combined aggregates is greater than 2.5%, use bulk-impregnated (effective) specific gravity for determining asphalt cement content. The 1986 job mix formula used an effective asphalt cement content of 5.6% (7.5% by total weight of mix). Although this statement was not in the 1997 specification, the job mix formula was to be designed using procedures contained in the Asphalt Institutes Mix Design Methods for Asphalt Concrete (MS-2) which indicates using effective asphalt cement content when absorption into the aggregate is present. If the 1997 job mix formula was not designed using effective specific gravity, the effective asphalt cement content of the mix would be approximately 2 percent less, which is significantly low.

Aggregate gradation indicated on the submitted and approved job mix formula for the 1997 overlay did not comply with project specifications. The job mix formula is to be designed within the project specification gradation band. Once the mix is designed within the specification and is accepted, the tolerance indicated in the specification is applied to the job mix formula, hence creating the acceptable variation during the project. Table 3 compares the gradations in the specification, submitted mix design and results from tests indicated above.

Although the laboratory test results show that the pavement sample was marginal, the in-place asphalt concrete material appears to be performing acceptably. However, at an undetermined future time, the airfield pavement may experience premature weathering and raveling problems. An increased possibility of moisture damage resulting from the higher than normal percentage of air voids is a concern that could accelerate the weathering and raveling conditions. In addition, excessive amount of fines and the apparent low effective asphalt cement content will contribute to premature raveling.

Replacement of AC Portion of Runway 13R-31L with PCC

A design to replace the existing AC portion of Runway 13R-31L with PCC was prepared in accordance with MIL-HDBK-1021/4 [8]. The RAD version 1.0 Rigid Pavement Design Program developed by the Army Waterways Experiment Station was used to design the pavement. The portion of the runway considered for replacement is shown in Figure 7. The dimensions of this portion of the runway are 200 feet wide by 9,000 feet long. The results of this effort are shown in Table 4 completed DD Form 1391. The pavement thickness was designed to be 14 inches. The cost to remove the existing AC pavement and replace it with a new PCC pavement including new shoulders and lighting is estimated to be $39,800,000. Calculated life cycle cost values for this and the other alternatives are presented in a later section dealing with economic analysis of pavement alternatives.

Construction of a New all PCC Parallel Runway

A design for a new all-PCC Runway parallel to and outboard of Runway 13L-31R was prepared in accordance with MIL-HDBK-1021/4 [8]. The RAD version 1.0 Rigid Pavement Design Program developed by the Army Waterways Experiment Station was used to design the pavement. The location of the proposed runway relative to the two existing parallel runways is shown in Figure 8. The dimensions of this proposed runway are 200 feet wide by 11,000 feet long. The results of this effort are shown in Table 5 completed DD Form 1391. Typical cross section of the proposed runway is shown in Figure 9. As shown, the pavement thickness was designed to be 14 inches. The cost to construct this new runway with stabilized shoulders and lighting, overrun areas, blast pads and access taxiways is estimated to be $77,700,000. Calculated life cycle cost values for this and the other alternatives are presented in a later section dealing with economic analysis of pavement alternatives.

AC versus PCC Pavements at NAS Fallon

What type of pavement, asphalt concrete or Portland cement concrete, is more suitable for the environmental conditions at NAS Fallon? Information to answer this question along with life cycle cost data is presented in subsequent sections dealing with low temperature thermal cracking of asphalt pavements and economic analysis of pavement alternatives.

Solution

In summary, the repair or replacement of the AC pavement is not required because the pavement is technically adequate based on the current condition rating and determined load carrying capacity. Additionally, the construction history as shown in Table 1 coupled with the fact that the previous overlays were cracked as shown in Figures 1 through 3, further indicate that the present cracked overlay will perform satisfactorily. Routine procedures are recommended to maintain the pavement until such time that a global repair procedure needs to be implemented. This equates to the recommendation that the status quo alternative, which is to maintain the existing asphalt concrete overlay, be followed.

TASK 3 – TAXIWAY "A" PROJECT CONSTRUCTABILITY REVIEW

Problem: Is the project as designed constructable?

Answer: Yes, but the quality of the finished product would have been questionable.

Data: After a review of the available data concerning the taxiway, which included the pavement evaluation, condition survey, geotechnical data, and plans and specifications for the repair, a visual inspection of the taxiway was made. This visual inspection indicated that the first 1400 feet of taxiway was on a different soil formation which caused the pavement to be very uneven longitudinally as well as transversely. The plans and specifications called for the removal of only the center slabs leaving the outer slabs of the taxiway. This would not have repaired the impaired topography of the taxiway.

Design Coordination And Review Comments: Details of this effort is presented in Appendix C.

Solution: Remove the entire taxiway width for the first 1400 feet of taxiway and use the plans as prepared for the remainder of the taxiway. Suggested that paved shoulders would help to remedy the FOD problem along the edges of the taxiway since the vegetation is sparse.

TASK 4 - RUNWAY 13R-31L SHOULDERS

Problem: Does the existing shoulder conditions of Runway 13R-31L meet requirements of Military Handbook MIL-HDBK-1021/1?

Answer: No.

Requirements For Shoulders [9]:

Class B Runways : 150 feet on each side composed of the following:

1. First 10 feet – Paved
2. Remaining 140 feet
    - Clear, grade, and grub all stumps and other obstructions to minimum depth of 1 foot below finish grade.
    - Control dust and erosion by vegetative cover, liquid palliative, or combination of methods.

Taxiways for Class B Runways: 50 feet on each side

1. Shoulder treatment
    - Fixed-wing aircraft – same as outer 140 feet of runway shoulders
    - Rotary-wing aircraft – pave shoulders 25 feet on each side
    - Areas where turf is difficult to establish - pave shoulders 25 feet on each side

Data: Inspections of the shoulders on Runway 13R-31L and some of the taxiways showed that the shoulders are deficient. It was observed that the runway shoulders, where present, were deteriorated. There was loose gravel where shoulders should be paved in the inner 10 feet and low lying brush were present within the other remaining 140 feet of the shoulder. The taxiway shoulders did not have any turf nor were the inner 25 feet paved.

Solution: Construct new shoulders for Runway 13R-31L and any taxiways requiring upgrading to meet criteria requirements of MIL-HDBK-1021/1. The cost estimate to construct the runway shoulders is $7,400,000. Details of this estimate are included as Table 6 in the completed DD Form 1391. Life cycle cost for the runway shoulders is computed to be $7,454,000 (details of this cost is presented in the economic analysis section).

TASK 5 – TAXIWAY CLEARANCES

Problem: Does the clearances on all taxiways comply with requirements of Military Handbook 1021/1? What are the effects of overhanging wing and engines of large aircraft on restriction on taxiway usage?

Answer: This task was requested to be deleted by the NAS Fallon Operations Officer and therefore was excluded from this study.

TASK 6 – RUNWAY 13R-31L WIRING SYSTEM UPGRADING
(Preliminary Study)

Problem: The runway lighting system fails during rainstorms.

Field Observations, Data and Notes including Description of Existing System

Kick-off Meeting (5 Aug 98):

- Modus Operandi – putting out fires
- Cable installed in the '50's
- New circuit/cable installed mid 90's
- Incident – new cable placed in same conduit as old cable, was burned when old cable failed/burned, requiring double the effort/splices to repair

Afternoon Site Survey (5 Aug 98):

- Met with Kevin Hargis, Air Terminal Manager, and Bob Fowkes, high voltage electrician, both with Day and Zimmermann Services, contracted maintenance/operations
- Old circuit/cable is 40's vintage – no longer manufactured.
- Old circuit has taped splices
- New conductor except for Mark 8 circuit
- One manhole had continuously running water – seepage into manhole was running across the floor to a sump, which had a continuously running pump
- One manhole had approx. three (3) feet of water in it, cables were submerged on cable racks, this hole was/is pumped weekly
- Nearly every handhole had standing water
- One area had conductors run on top of the ground for an active circuit.
- There are conductors abandoned in place
- Ancient 10KVA transformer in manhole, subject to submersion during rainstorms
- Open panel with "temporary" wiring in manhole
- Bob recommends above-ground low profile pad mount with cabinet.
- New conductor in same conduit as old – failure of old cable means fixing both circuits
- Ducts may get clogged by sand and sediments
- Use of molded splices now required

Meeting With PW (6 Aug 98):

- Gary Smith, EE and Earl McCarthy, EE
- FAA specified cable, might not be able to substitute/up-grade
- Late 50's circuit undergoing piecemeal replacement
- Policy to abandon in-place – cut costs by not paying for demo'
- Some conduit may be crushed/collapsed
- Funding not available to replace old cable

Discussions and Summary of Findings

The Runway 13R-31L cable and taped splices are approximately 40 years old. These taped splices are subject to failures when exposed to a wet or submerged environment. Such environments occur with each rainstorm. Because of the high water table, the manholes and handholes will fill with water and subsequently flow into the cable conduits and vice versa. We have been told that when an old circuit "blows" as a result of this adverse environment, it takes some of the new circuit with it. It was stated/deduced that the failures occurred at the splices and failure of the cable themselves were not mentioned. Never the less, this type of environment dictates the use of a moisture impervious/marine/submarine cable or one with an additional moisture barrier.

Conclusions and Recommendations

The combination of the age of the installed wiring system and adverse wet and submerged environment is causing the failures.

The following are recommended based on this investigation:

1. Compare FAA and MIL Standards and consider upgrading the runway wiring systems using the more suitable specification for the conditions at Fallon. (The cable and splices should be of the type suitable for the adverse environment being encountered at Fallon. For example, greater insulation value, jacketed cable, cable with a moisture barrier, moisture impervious cable, marine cable or submarine cable.)

2. Continue using molded splices but check for proper installation/quality control.

3. Run all circuits in ducts and with not more than one circuit per duct.

4. In manholes, place each circuit on its own hanger.

5. Use NEMA 6 enclosures and panels in areas subject to submergence and NEMA 4X elsewhere.

6. Use wall mounted transformer (dry type, resin filled or encapsulated) with waterproof connections.

7. Pack/seal ducts around cables to prevent water from entering the ducts. (Note: water tight integrity of conduit is required before sealing.) After ducts are sealed, seal manholes and maintain sump and sump pumps.

8. Add/clear drains in handholes.

9. Avoid abandoning old conductors in place. Require contractors to remove old cables for salvage value and recondition/re-bore/re-line/check/clear conduit for reuse or for spares. Plug/cap cleared spare ducts.

Participants

NFESC	NAS Fallon	Day and Zimmermann Services
Yutaka Sugiyama	Gary Smith	Kevin Hargis
	Earl McCarthy	Bob Fowkes

TASK 7 – TAXIWAY "D" UPGRADING

Problem: What is the cost to upgrade this taxiway to meet requirements of Military Handbook 1021/1 and what is the calculated life cycle cost.

Answer: This task was unfunded and therefore was excluded from this study.

ASPHALT PAVEMENT THERMAL CRACKING

Background

Low temperature thermal cracking of AC pavements have been recognized and studied extensively since mid 1960s [10]. Some examples of the results from these studies are incorporated in References 10 through 17. Thermal cracking in asphalt concrete pavements occurs in parts of the United States, Canada, Japan and Europe [13,17]. The cracking appears on the pavement surface in the form of transverse, longitudinal and block cracking [17]. The most common form is transverse cracking. Major factors that are responsible for causing thermal cracks are:

1. Very low temperatures that cause tensile stresses that exceed the tensile strength of the asphalt concrete.

2. Repeated large daily temperature excursions caused by high solar radiation resulting in fatigue failure of the asphalt concrete.

The occurrence of low temperatures has a detrimental effect on asphalt pavements [15]. The occurrence of low temperatures induces tensile stresses when the pavement matrix contracts. Because of its normal configuration (i.,e., length being many times longer than its width), the larger tensile stresses will occur in the longitudinal direction when the pavement contracts. The tensile stresses induced in the pavement by this contraction are relieved by the formation of cracks in the transverse direction. Hence, a thermally cracked pavement exhibits considerably more transverse cracks than longitudinal cracks. Often when longitudinal cracks are present in a pavement, they occur at the joints between paving lanes where compaction and bonding was not exceptionally good.

Low temperature induced cracks have been categorized into two broad types [15]. The first type of crack occurs through the entire pavement structure into the subgrade. It is generally believed that this type of crack occurs due to shrinkage of the subgrade associated with the effects of freezing. The second type is representative of thermal cracking which starts as microcracks as a result of contraction of the pavement surface. It was reported that cyclic temperature effects will result in a gradual increase in crack opening. The nominal crack spacing was in the range of 20 to 30 feet but spacings varied from several feet to several hundred feet. It was also reported that even though an overlay may initially restore the pavement serviceability to an acceptable level, the original transverse cracks will, with time, reflect through the overlay resulting in the original problem. This has been the previous experience with overlays on Runway 13R-31L at NAS Fallon.

A comprehensive list of possible contributing factors that affect low temperature cracking of asphalt pavements is shown in Table 7 [15]. In general, the mechanism and causative factors are more fully understood for the surface layer than for the lower pavement layers. The following information was presented regarding factors that influence low temperature cracking:

1. Although there are many external and component variables that influence low temperature cracking, the most significant variable is the consistency characteristics of the bitumen used in the surface layer.

2. Transverse cracking can be reduced or retarded by using a softer grade of asphalt (has lower temperature susceptibility and better flow properties at lower temperatures).

3. The occurrence of cracking increases as the environmental conditions become colder. (This is also shown in Reference 13)

4. Pavement age is a contributing factor for two reasons:

    a. The increase in stiffness of the asphalt binder with age and the resulting hardening causes the pavement to become more susceptible to thermal cracking.

    b. The probability of exposure to a low critical temperature increases with time.

5. From numerous field and test section evaluations, it has been observed, with all other conditions being equal, that the occurrence of transverse cracking is more severe on sandy soils than on clay subgrades.

6. Increasing the thickness of the asphalt layer decreases the frequency of crack formation.

In the International State-of-the-Art Colloquium on Low Temperature Asphalt Pavement Cracking sponsored by the U.S. Army Corps of Engineers, The Asphalt Institute, Federal Aviation Administration, and the Ontario Ministry of Transportation and Communications, it was agreed that a wide variety of factors affect the degree of low temperature cracking [10]. The primary factor affecting the amount of low temperature cracking is the temperature susceptibility of the asphalt cement. Additionally, there are other secondary contributing factors, which include the asphalt concrete mix, mix components, pavement structure and environmental factors. The properties of the asphalt concrete mixture could also be contributing factors to low temperature cracking. Such properties as the type of aggregate, gradation of the aggregate, air void content of the mix, and the stiffness of the asphalt mix affect the amount of cracking that occur. The pavement structure, such as asphalt layer thickness, amount and severity of existing cracks, type and thickness of base and subbase layers, type of subgrade soil, and amount of traffic also affect the amount of cracking. Environmental factors that influence the degree of cracking include air temperature, pavement temperature, rate of temperature change, frequency of freeze-thaw occurrence, and amount of precipitation.

Analytical and empirical methods have been developed to predict cracking behavior in asphalt pavements. Examples of such methods are described in Reference 14 and 16. With appropriate data on pavement age, minimum air temperature, and asphalt mix fracture temperature and strength properties, the spacing between low temperature induced thermal cracks can be calculated. An example of an empirical equation to predict crack spacing is [14]:

$$S = 994.11 - 127.69(A)^{0.1} + 43.89(T) + 0.5954(T)^2 - 0.665(FT_o) - 0.0249(FS)$$

Where:
- S = Crack spacing, meters
- A = Pavement age, years
- T = Minimum air temperature at the site (50% reliability), °C
- FT_o = TSRST fracture temperature of original unaged mix, °C
- FS = TSRST fracture strength, kPa
- TSRST = Thermal stress restrained specimen test

In this reference containing the empirical relationship to calculate the crack spacing, the average spacing of the thermal cracks was 95 feet for conventional mix pavements. Although the above equation was developed for highway pavements in Alaska, similar relationships can be developed for airfield pavements subjected to low temperature conditions through laboratory tests and data from field performance. The presentation of the above information is to demonstrate that the occurrence of thermal cracking was known for many decades and various studies have been conducted on this subject to the point where spacing of the cracks can be predicted.

New and modified formulations of asphalt cements have been developed to counteract the effect of low temperature susceptibility and thermal cracking [12,14]. These formulations include the addition of additives and extenders to the asphalt cements. The additional material includes sulfur, fibers, carbon black, high-float emulsions, rubber and polymers. The effect of the additives and extenders on inhibiting thermal cracking is variable but have been shown to be effective to various degrees. In a comparison of the performance of conventional versus asphalt-rubber pavement on a street in Fairbanks, Alaska, the asphalt-rubber section had a crack density that was 1/6 th of the conventional. The average spacing of the cracks in the conventional section was about 20 feet.

The Strategic Highway Research Program (SHRP) was established by Congress in 1987 to develop and evaluate techniques and technologies to combat the deteriorating conditions of the nation's highways and to improve their performance, durability, safety and efficiency. The research under this Program was concentrated in four areas:

- Asphalt
- Concrete and structures
- Highway operations (maintenance and work zone safety)
- Pavement performance (long-term pavement performance study)

The development of the Superpave System directed to asphalt pavements was the most expensive item in the program. This System enables designers to select materials and design a mix to meet specific ***weather*** and traffic conditions at the project site. The Superpave System consists of the following components:

- Asphalt binder specification
- Design and analysis system based on the volumetric properties of the asphalt mix
- Mix-analysis tests and performance prediction models

Asphalt binder properties have a direct impact on the performance of an asphalt mix and its ability to resist permanent deformation (e.g., rutting) and low temperature cracking. Because of the importance of binder properties, a new asphalt binder grading system was developed. This system is called Performance Graded (PG) Asphalt Binder System [2]. Selection of the correct asphalt binder grade for use in a project is based on design pavement temperatures (high and low) and types of traffic loading. Again, the above information is presented to emphasize that low temperature thermal cracking mitigation procedures have been developed for highway pavements. The Army Corps of Engineers has validated the applicability of this SHRP developed technology to airfield pavements in research conducted for the Federal Aviation Administration [18].

The Colorado Department of Transportation conducted a laboratory and field investigation on low temperature thermal cracking in hot mix asphalt concrete [19]. Based on the results of the study, they concluded that the most important factor that improves resistance to thermal cracking is the use of a softer grade of asphalt cement. If rutting is a concerns, the use of polymer modified asphalt cement is recommended. It was also recommended that the bending beam rheometer test on the asphalt cement be used as a specification to improve resistance to thermal cracking of the hot mix asphalt concrete.

In summary, thermal cracking of asphalt concrete pavements has been recognized for a number of decades. It has been observed to occur in parts of the Untied States, Canada, Japan and Europe. There have been many studies and investigations on this phenomenon. Analytical and empirical methods have been developed to predict the occurrence and spacing of the cracking. Thermal cracks usually run transverse to the longitudinal direction of the pavement and are spaced from several feet to several hundred feet apart. The most important factor that influence the occurrence of thermal cracking is the consistency characteristics of the asphalt binder. To counteract the effect of low temperature susceptibility of the binder, new and modified formulations have been introduced. The most important contribution in this area has been from the Strategic Highway Research Program in which performance graded asphalt binders have been developed. The application of this technology to airfield pavement has been validated by research performed by the Corps of Engineers for the Federal Aviation Administration [18].

Asphalt Pavement Thermal Cracking at NAS Fallon

From all indications, the premature cracking of the asphalt overlay on Runway 13R-31L (and the cracking of other asphalt concrete pavements at NAS Fallon for that matter) can be attributed initially to low temperature thermal cracking. Subsequent cracks that occur in overlays are generally due to reflection of previous thermally cracked pavement but this does not preclude the occurrence of new thermal cracks as the asphalt cement hardens with pavement age. The contributing factors, symptoms, and confirmation of thermal cracking at NAS Fallon are:

1. The occurrence of large daily temperature excursions (i.e., large differences between daily minimums and maximums).

2. The abundance of transverse cracks on the runway spaced at somewhat uniform and large intervals indicative of thermal cracking.

3. The appearance of the cracks during the first winter after the installation of the overlay.

4. The presence of similar cracking prior to previous overlays on this same runway.

5. The almost duplicative crack density on the cross runway (Runway 7-25) prior to the most recent overlay.

6. The history of the occurrence of cyclic low temperature thermal cracking of the asphalt pavement at NAS Fallon is illustrated in Figures 1 through 4.

7. The occurrence of thermal cracking was confirmed by Mr. Bob Campbell, Senior District Engineer, The Asphalt Institute [20]. His area of responsibility includes the state of Nevada among others. Mr. Campbell stated that thermal cracking occurs in northern Nevada and that he has observed its occurrence in the Fallon area.

Thus, it is certain that low temperature thermal cracking occurs at NAS Fallon. Hence, if asphalt concrete pavements are constructed in this area, particular concern should be made to minimize the occurrence of thermal cracking by using the appropriate asphalt cement for that area.

Las Vegas and Reno Airport Inspections

Inspections were conducted at Las Vegas McCarran International, Reno-Tahoe International and Reno-Stead Airports to determine the presence of thermal cracking of their asphalt pavements due to cyclic exposure to low temperatures [21,22]. Thermal cracked pavement was not observed at McCarran International Airport, which is at an elevation of 2,140 feet. The only distresses observed were block cracking, rutting and bleeding as defined in the Pavement Condition Index survey procedure [7]. Asphalt pavements (taxiway and drainage ditch) that were constructed in 1992 showed no signs of thermal cracking and would otherwise be rated as in excellent condition if the rutting was not present. A photograph of the AC paved ditch is shown in Figure 10. (Note block cracking on taxiway shoulder in the background.) However, all new pavements that were constructed since have been with Portland cement concrete because of problems that were being encountered with the local aggregates when used in asphalt pavements. Rutting (Figure 11) and bleeding problems were experienced when the local aggregates were used. It was also mentioned that the volcanic aggregates available had thermal expansions that were twice that of limestone aggregate.

Thermal cracking was observed at Reno-Tahoe International and Reno-Stead Airports. The elevation of these airports are 4,412 and 5,046 feet respectively (NAS Fallon is at 3,934 feet). Reno-Stead Airport is located approximately 15 miles to the northwest of Reno, Nevada. The distance between cracks and the width of the cracks were measured at both of these locations. These measurements were taken along a path parallel to and within 15 feet of the centerline of the runways. The distance between cracks was calculated by taking the numerical difference between continuous measuring wheel readings for the location of each crack. The width of each crack was measured using a retractable tape. The results of the measurements are summarized in Table 2 along with the data from NAS Fallon. The data was also plotted in crack frequency diagrams for comparison with the data for NAS Fallon. This information is shown in Figures 12 and 13.

The thermal cracked AC pavement on Runway 7-25 at Reno-Tahoe International Airport was constructed in 1984. Figure 14 shows the typical condition of the AC runway pavement. Transverse thermal cracks are visible in several locations in this figure: (a) in the foreground in the paving lanes to the left and (b) straddling several paving lanes in the middle. Figure 15 is an example of a typical thermal crack present on this runway. The condition and thermal cracks are similar in characteristics as that occurring on Runway 13R-31L at NAS Fallon. The average crack density was calculated to be 36 feet/crack with an average crack width of 3/8 inch.

There are two asphalt concrete runways at Reno-Stead Airport, Runway 14-32 and 8-26. Runway 14-32 was constructed in May 1986 and now exhibits large low temperature thermal cracks. Figure 16 is an overall view of the runway showing typical condition of the pavement. Figure 17 is an example of the large cracks, which has been maintained with crack seal. The Pavement Condition Index for this pavement was determined to be 56 during the last survey conducted in April 1998. This low value is primarily due to the thermal cracking and the rutting in one of the wheel paths. The average crack density for this runway was calculated to be 52 feet/crack and average crack width of 3 inches. Reference 23 documents similar crack patterns and widths at the Sierra Army Depot, Amedee Air Strip evaluated in 1980.

Runway 8-26 at Reno-Stead Airport, which was constructed in November 1993, has no visible thermal cracks. The average PCI for this runway at the time of the last survey in 1998 is 89. The primary reason for the absence of the thermal cracks is that the pavement was saw cut into smaller pieces (25 feet squares). Details of the saw-cut joint specifications (FAA Item P-605) are shown in Appendix D. The saw-cut joints appear to have relieved the thermal stresses. The pavement was also grooved transversely at 2 inches on center for the length of the runway. Figure 18 shows a view of the runway with the saw-cut joints. Figure 19 is a close-up view of a joint and the grooved pavement surface. At the time of this survey, the saw-cut joint widths measured approximately 5/8 inch in the transverse direction and 3/4 inch in the longitudinal direction.

In summary, thermal cracking as a result of exposure to cyclic low temperatures was not observed at Las Vegas McCarran International Airport but was observed at both Reno-Tahoe International and Reno-Stead Airports. The crack density at Reno-Tahoe and Reno-Stead Airports were respectively, 36 feet/crack and 52 feet/crack. At Reno-Stead airport, saw cutting of the asphalt pavement into 25-foot squares prevented the occurrence of low temperature thermal cracking. The grooving of this same pavement may also have provided some stress relief and thereby inhibiting the formation of thermal cracks.

Sierra Army Depot Amedee Air Strip Inspection

Thermal cracking was observed at Amedee Air Strip at the Sierra Army Depot during an inspection on 28 June 1999. The Sierra Army Depot is located approximately 50 miles northwest of Reno, Nevada. The elevation of the airfield is 4,001 feet. The runway was constructed in two phases: keel section in summer of 1995 and the outer portions in summer of 1996. The distance between cracks and the width of the cracks were measured in the keel section, which was approximately four years old at the time of the inspection. These measurements were taken along a path parallel to and within 15 feet of the centerline of the runway. The distance between cracks was determined by pacing, and the width of each crack was measured using a scale. The results are similar to the measurements that are summarized in Table 2. Actual measurements indicate the average distance between cracks is 48 feet (34 cracks in approximately 1500 feet). The crack widths were hairline to approximately 3/16". Similar thermal cracking was reported in a condition survey performed in November 1980 at this same location [23].

ECONOMIC ANALYSIS OF PAVEMENT ALTERNATIVES

Pavement Alternatives Analyzed

Economic analysis for pavement alternatives was performed using ECONPACK for Windows 1.02 [24] and following the policy and guidance of OMB Circular No. A-94 [25], DODINST 7041.3 [26], SECNAVINST 7000.14B [27] and NAVFAC P-442 [28]. Based on Navy Policy, the 30-year real discount rate of 2.9% which is located in OMB Circular No. A-94 Appendix C (revised January 1999) was used to discount constant dollars. A real discount rate has been adjusted from a nominal discount rate to eliminate the effect of expected inflation. The economic life of airfield pavements is 25 years which was obtained from Appendix A, Reference Code A1 of the NAVFAC Economic Life Analysis Consolidated Report (dated 24 February 1999).

Construction and design criteria and source and derivation of costs used in this analysis are described in detail in Appendix E. Cost of pavement replacement of the initial construction cost for each alternative was obtained and inserted in the DD Form 1391 which was developed for the new Portland cement concrete pavement alternative. The results of this effort are shown in Tables 4, 8 and 9 of the completed DD Form 1391s. Frequency for major maintenance and repair and costs for operations and maintenance are both a function of the Pavement Condition Index (PCI). Predicted PCI for the 25 year economic life is based on straight line prediction models using actual data from NAS Fallon (asphalt and concrete surfaces) and Stead Airport (asphalt pavement with sawed joints). Figures 20, 21 and 22 represent the prediction models used. Data points used in the prediction models signify actual PCI survey results unless indicated otherwise on the figure.

Economic analysis and life cycle cost is calculated using Cumulative Net Present Value (NPV). The life cycle cost for each alternative is shown in Table 10 and is summarized as follows

ALTERNATIVE	INITIAL YEAR (NPV)	25 YR LCC (NPV)
Status Quo	$320,000	$6,750,164
New Asphalt Concrete Overlay	$2,640,776	$8,898,349
New Asphalt Concrete Pavement	$32,950,437	$39,284,692
New Asphalt Concrete Pavement With Sawed Joints	$33,825,073	$38,067,351
New Portland Cement Concrete Pavement	$38,684,159	$40,067,488

The status quo alternative is the least cost alternative to the government with a 25 year life cycle cost of $6.75M (NPV), followed by a new asphalt concrete overlay at $8.9M (NPV). All remove and replace alternatives are between $38.1M and $40.1M (NPV). Life cycle cost is graphically represented in Figure 23.

Cost Sensitivity Analysis was performed on expense items which have the greatest potential for variation. If the analysis indicates the result to be "insensitive" it is indicating that alternatives will not change ranking of least cost given the parameters of the specific analysis. Performing the analysis on this expense item, the status quo is insensitive to all alternatives except the alternative for a new asphalt concrete overlay. If the expense of the initial overlay is reduced by more than 35.8%, the least cost alternative would be the overlay instead of the status quo. Figure 24 is a graphical representation of the cost sensitivity between the status quo and the new asphalt concrete overlay alternatives. If the remove and replace alternatives are considered in the future, the three alternatives change rankings as the least cost alternative within themselves and should be re-evaluated at the time these alternatives are considered.

Discount Rate Sensitivity Analysis was performed using all alternatives. The status quo alternative is insensitive to all other alternatives. Figure 25 is a graphical representation of the discount rate sensitivity analysis.

The results of this analysis indicate that the status quo is the least cost alternative. At the time this pavement falls below a PCI of 70 (anticipate around FY2006) a new alternative should be selected based on re-evaluated economic conditions at the time and operational concerns for implementation.

Replacement of Runway 13R-31L

Economic analysis for the replacement of runway 13R-31L with a new all Portland cement concrete runway parallel and outboard to Runway 13L-31R was performed using ECONPACK for Windows 1.02 and following the policy and guidance stated above.

Construction and design criteria and source and derivation of costs used in this analysis are described in detail in Appendix F. Cost of initial construction was developed with the results of this effort shown in Table 5 of the completed DD Form 1391. Frequency for major maintenance and repair and costs for operations and maintenance are both a function of the Pavement Condition Index (PCI). Predicted PCI for the 25 year economic life is based on a straight line prediction model using actual data from NAS Fallon. Figure 22 represents the prediction model used. Data points used in the prediction models signify actual PCI survey results.

Economic analysis and life cycle cost is calculated using Cumulative Net Present Value (NPV). The 25 year life cycle cost for replacing runway 13R-31L is $77.7M (NPV).

Repair Runway 13R-31L Shoulders

Economic analysis for the repair of runway 13R-31L asphalt concrete shoulders was performed using ECONPACK for Windows 1.02 and following the policy and guidance stated above.

Construction and design criteria and source and derivation of costs used in this analysis are described in detail in Appendix G. Cost of initial construction was developed with the results of this effort shown in Table 6 of the completed DD Form 1391. Frequency for major maintenance and repair and costs for operations and maintenance are constant throughout the economic life. No overlays will be required. Crack sealing and application of fog seals is assumed at a frequency of every three years.

Economic analysis and life cycle cost is calculated using Cumulative Net Present Value (NPV). The 25 year life cycle cost for repair of Runway 13R-31L shoulders is $7.4M (NPV).

Non-Monetary Concerns – Disruption and Interruption to Airfield Operations

An estimate was made of the times the runway would not be available for operational use because of construction, maintenance or repair actions associated with each alternative. The intent was to develop time estimates that could be used in conjunction with the results from the economic analysis for decision-makers to select the most appropriate alternative. An attempt was made to develop estimates of construction times using the information in Richardson's General Construction Estimating Standards and Means Building Construction Cost Data for baseline data. However, meaningful estimates could not be developed from these references.

Since estimates could not be arrived with data from these references, it must be emphasized that these potential "down times" were estimates based on collective experience, knowledge of the processes involved and history of these types of actions. These times were developed with the intent to only provide another parameter for use by the activity and major claimant to assist in understanding the potential impact on the operational mission.

Several charts in Appendix H define the process in some detail such that the decision-maker will have an understanding of the type of work each process entails. It is not possible to determine the time precisely for the purpose of this study. The actual times will depend on numerous factors associated with the site, including availability and capability of contractors, weather, mission requirements and numerous other factors. This information is presented only as a general guide to the decision maker for use in conjunction with the life cycle cost figures and anticipated performance of these alternatives.

Table 11 indicates the number of occurrences of each type of action that will interrupt airfield operations for each alternative. Multiplying an estimated amount of time (such as the estimates indicated in Appendix H) with the number of occurrences for each action will provide a general guide for interruptions to airfield operations to be used in conjunction with the life cycle cost from the economic analysis.

AC OR PCC PAVEMENT AT NAS FALLON

An assessment of the performance of AC and PCC pavements in the environment at Fallon Naval Air Station was made. A summary of that assessment is included as Table 12. As can be seen in this table, the aggregates available for either AC or PCC pavements at Fallon is of inferior quality. For AC pavements, the absorptive characteristic of the aggregate requires a higher asphalt cement content. If this is not recognized, the asphalt content will be too low and hence cracking and other pavement distresses could be accelerated. Similarly, the tendency of the asphalt cement to strip from the aggregate will tend to accelerate the occurrence of these distresses. For PCC pavements, the reactive aggregate will cause damage to the concrete by degradation and cracking. Pavement distresses related to the aggregate problems described above in both asphalt and concrete pavements were observed in various inspections at NAS Fallon.

The most significant factor that makes PCC pavement performance superior to AC pavement performance at NAS Fallon is the resistant to low-temperature cyclic exposure. This exposure, as described previously, results in thermal cracking of new AC pavements or reflective cracking of AC pavement overlays.

The effect of aggregate quality, mix and construction deficiencies, environmental effects, and traffic loading are all reflected in the deterioration rate of the Pavement Condition Index (PCI). As shown in Table 12, the deterioration rate of the PCI for AC pavements at Fallon is five times higher than for PCC pavements. This high rate of deterioration is largely due to thermal cracking of new pavements and reflective cracking of overlays. The deterioration rates were determined by straight line prediction models using actual PCI data from NAS Fallon. Figures 20 and 22 represent the prediction models used. Data points used in the prediction models signify actual PCI survey results unless indicated otherwise on the figure.

Based on the information presented, Portland cement concrete would be considered a better material choice over asphalt concrete because of the inevitable thermal cracking of asphalt concrete pavement in the prevailing climate at Fallon. Therefore, when consideration is given for replacement of the existing asphalt concrete pavement and after considering FOD data, economics and potential for restrictions on operational requirements, select rebuilding the asphalt concrete portion of Runway 13R-31L with Portland cement concrete if warranted.

SUMMARY AND CONCLUSIONS

Runway 13R-31L Alternatives

The repair or replacement of the cracked AC pavement is not required at this time because the pavement is technically adequate based on the current condition rating and determined load carrying capacity. Additionally, the construction history, coupled with the fact that the previous overlays were cracked, further indicates that the present cracked overlay will perform satisfactorily.

Based on the test results of the laboratory evaluation, the in-place asphalt concrete material is acceptable for an airfield pavement. However, due to high air voids, high amount of fines and apparent low effective asphalt cement content, premature raveling may occur.

The cracking of the asphalt overlay on Runway 13R-31L can be attributed to low temperature thermal cracking and reflection of previous thermally cracked pavement. The contributing factors, symptoms, and confirmation of thermal cracking at NAS Fallon are:

1. The occurrence of large daily temperature excursions (daily minimum to daily maximum).

2. The abundance of transverse cracks on the runway spaced at somewhat uniform and large intervals indicative of thermal cracking.

3. The appearance of cracks during the first winter after the installation of the overlay.

4. The presence of similar cracking prior to previous overlays on this same runway.

5. The duplicative crack density on Runway 7-25 prior to the most recent overlay.

6. The history of the occurrence of cyclic low temperature thermal cracking of the asphalt pavement at NAS Fallon.

7. The confirmation of thermal cracking in the Fallon area by the Asphalt Institute representative for Nevada and the observation of thermal cracking at Reno International and Reno Stead Airports and Amedee Air Strip at the Sierra Army Depot all of which have similar climatic conditions as NAS Fallon.

Economic analysis and life cycle cost is calculated using Cumulative Net Present Value (NPV). The 25 year life cycle cost for each alternative is:

ALTERNATIVE	INITIAL YEAR (NPV)	25 YR LCC (NPV)
Status Quo	$320,000	$6,750,164
New Asphalt Concrete Overlay	$2,640,776	$8,898,349
New Asphalt Concrete Pavement	$32,950,437	$39,284,692
New Asphalt Concrete Pavement With Sawed Joints	$33,825,073	$38,067,351
New Portland Cement Concrete Pavement	$38,684,159	$40,067,488

The status quo alternative is the least cost alternative to the government with a 25 year life cycle cost of $6.75M (NPV).

Repair of Runway 13R-31L Shoulders

The existing shoulder conditions do not meet requirements of Military Handbook MIL-HDBK-1021/1. The 25-year life cycle cost to repair Runway 13R-31L shoulders is $7.4M (NPV).

RECOMMENDATIONS

Runway 13R-31L Alternatives

The following recommendations are made relative to the asphalt concrete portion of Runway 13R-31L.

1. Accept the status quo alternative as discussed, which includes the following to be performed in FY99:
   a. Rout and seal the cracks which have widths of ¼ inch or wider following the procedures described in NAVFAC MO-102.6, Asphalt Crack Repair Field Manual [29].
   b. Apply an asphaltic emulsion (same product used for the fog seal) over cracks which are less than ¼ inch wide.
   c. Apply a fog seal in accordance with NFGS –02786A (09/98) [30].

2. Maintain and repair the pavement as needed to keep it in serviceable condition. Major global procedures recommended are:
   a. Apply a fog seal every 3 years.
   b. Initially rout and seal the cracks when the widths are ¼ inch or wider following the procedures described in NAVFAC MO-102.6, Asphalt Crack Repair Field Manual [29].
   c. Every fall, rout and seal newly developed cracks that are ¼ inch or wider and inspect previously installed seals and repair/reseal as deemed necessary.

Also apply any localized maintenance and repairs as deemed needed during routine inspection of the pavement in between global procedures outlined above. Apply these global and localized procedures to maintain the pavement in serviceable condition until such time that the PCI falls below 70 (estimate around year 2006). At that time, reevaluate the economics of the alternatives as discussed in this report and select the most favorable alternative that fit operational requirements.

Repair of Runway 13R-31L Shoulders

The following recommendations are made relative to the repair of Runway 13R-31L shoulders.

1. Construct new shoulders on Runway 13R-31L and any taxiways requiring upgrading to meet criteria requirements of MIL-HDBK-1021/1.

2. Maintain and repair the pavement as needed to keep it in serviceable condition. Major global procedures recommended are:
   a. Apply a fog seal every 3 years.

b. Initially rout and seal the cracks when the widths are ¼ inch or wider following the procedures described in NAVFAC MO-102.6, Asphalt Crack Repair Field Manual [29].

c. Every fall, rout and seal newly developed cracks that are ¼ inch or wider and inspect previously installed seals and repair/reseal as deemed necessary.

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Figure 1. NAS Fallon Runway R13-31, crack sealed (1970).

Figure 2. NAS Fallon Runway R13-31, existing cracks and new overlay (lower right) (26 August 1986).

Figure 3. NAS Fallon Runway R13-31, existing cracks with sealant and cracking in new overlay (26 August 1986).

Figure 4. NAS Fallon Runway 13R-31L, cracking pattern in present overlay (22 April 1999).

Figure 5. NAS Fallon Runway 13R-31L, close-up of typical crack (22 April 1999).

Figure 6. NAS Fallon Runway 13R-31L, close-up of surface with exposed aggregate due to stripping or asphalt deficiency.

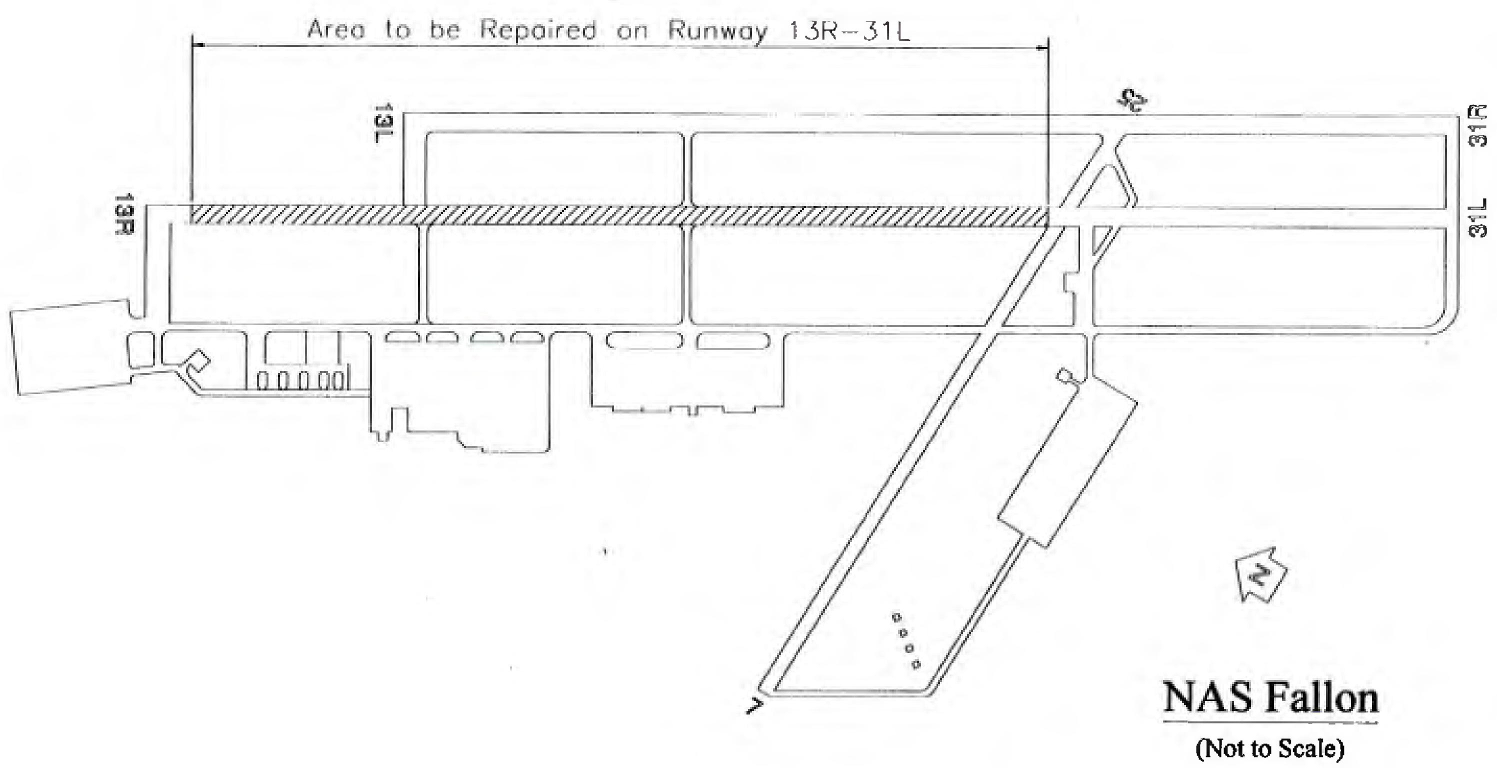

Figure 7. Area of Runway 13R-31L proposed for replacement with Portland cement concrete.

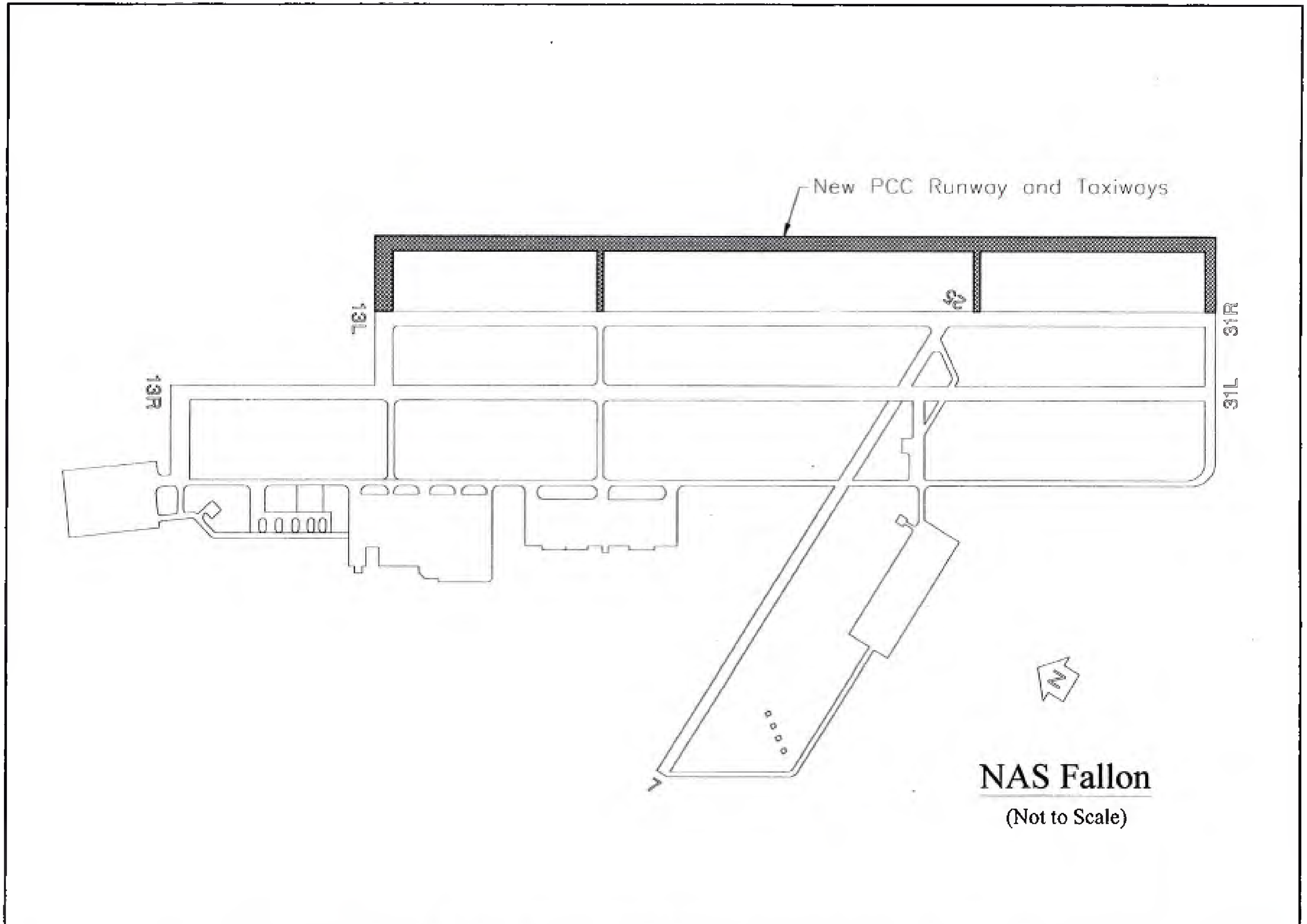

Figure 8. Layout of proposed new Portland cement concrete runway and taxiways.

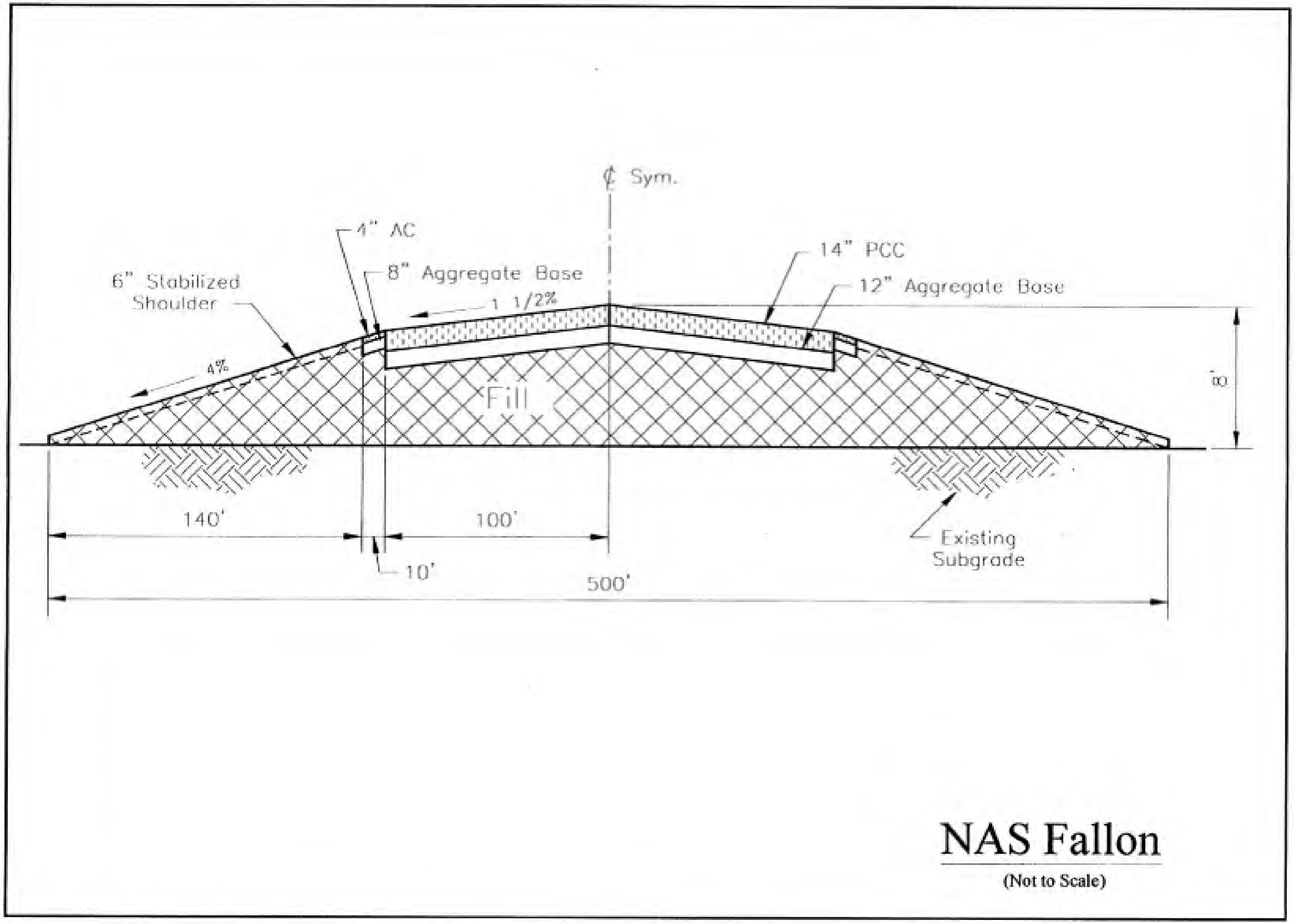

Figure 9. Typical cross section of proposed new Portland cement concrete runway.

Figure 10. Asphalt drainage ditch constructed in 1992 at McCarran International Airport.

Figure 11. Rutting of asphalt pavement taxiway at McCarran International Airport.

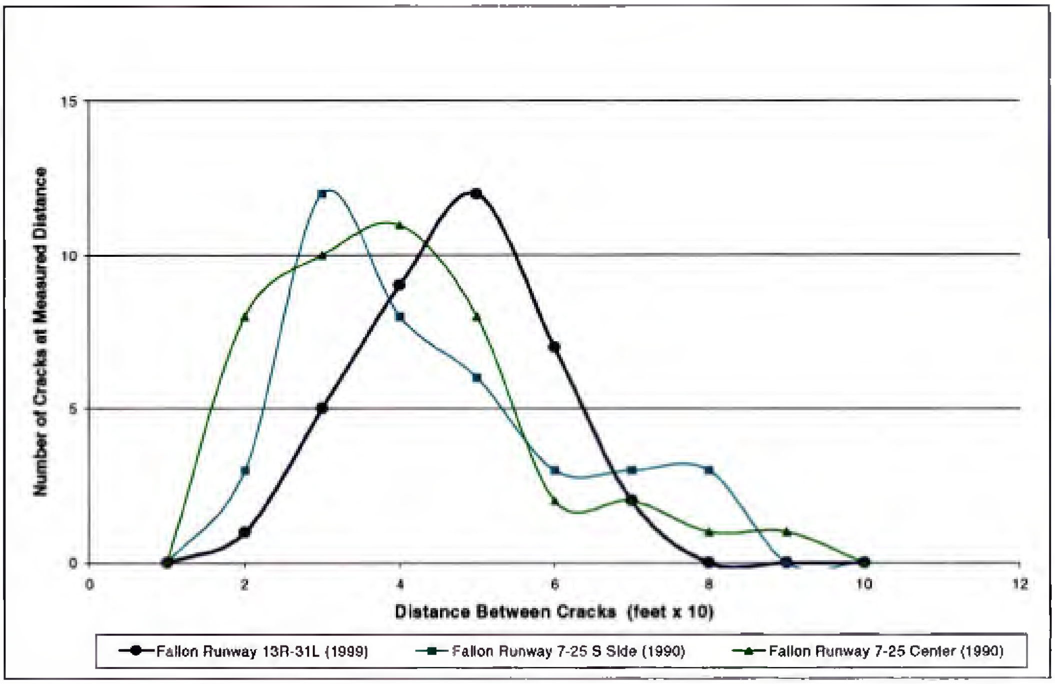

Figure 12. Measured crack frequency at Naval Air station Fallon.

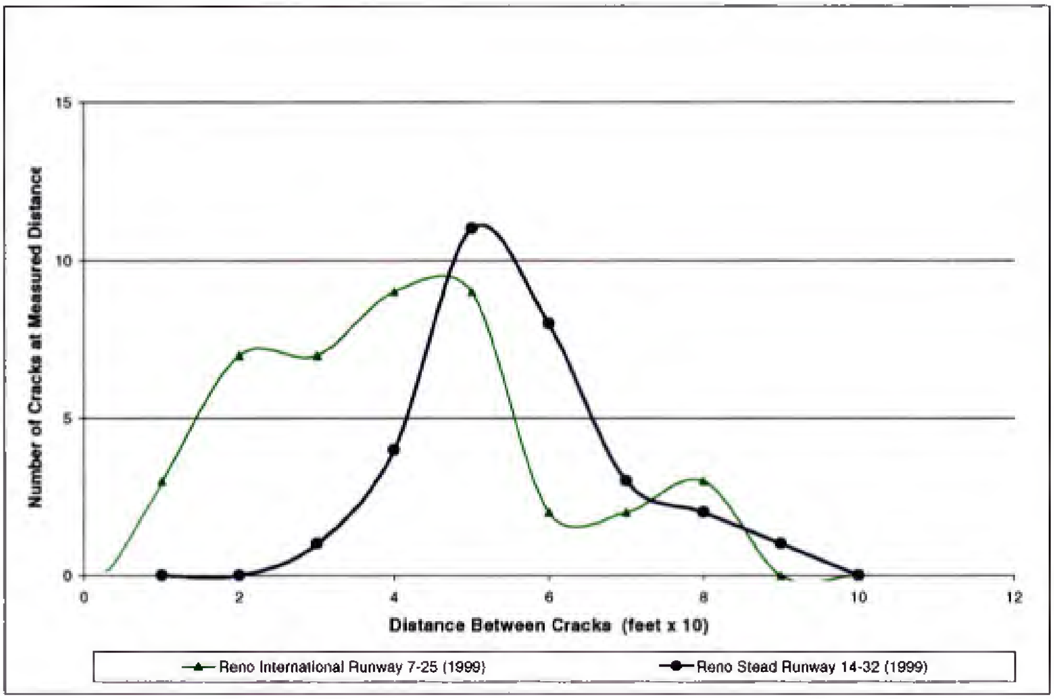

Figure 13. Measured crack frequency at Reno International and Stead Airports.

Figure 14. Low temperature thermal cracked asphalt pavement, Reno International Airport.

Figure 15. Low temperature induced thermal crack in AC, Reno International Airport.

Figure 16. Low temperature thermal cracked AC pavement, Runway 14, Reno-Stead Airport.

Figure 17. Sealed thermal crack in AC pavement, Runway 14-32, Reno-Stead Airport.

Figure 18. Saw-cut and grooved AC pavement, Runway 8-26, Reno-Stead Airport.

Figure 19. Saw-cut joint (sealed) and grooved AC pavement, Runway 8-26, Reno-Stead Airport.

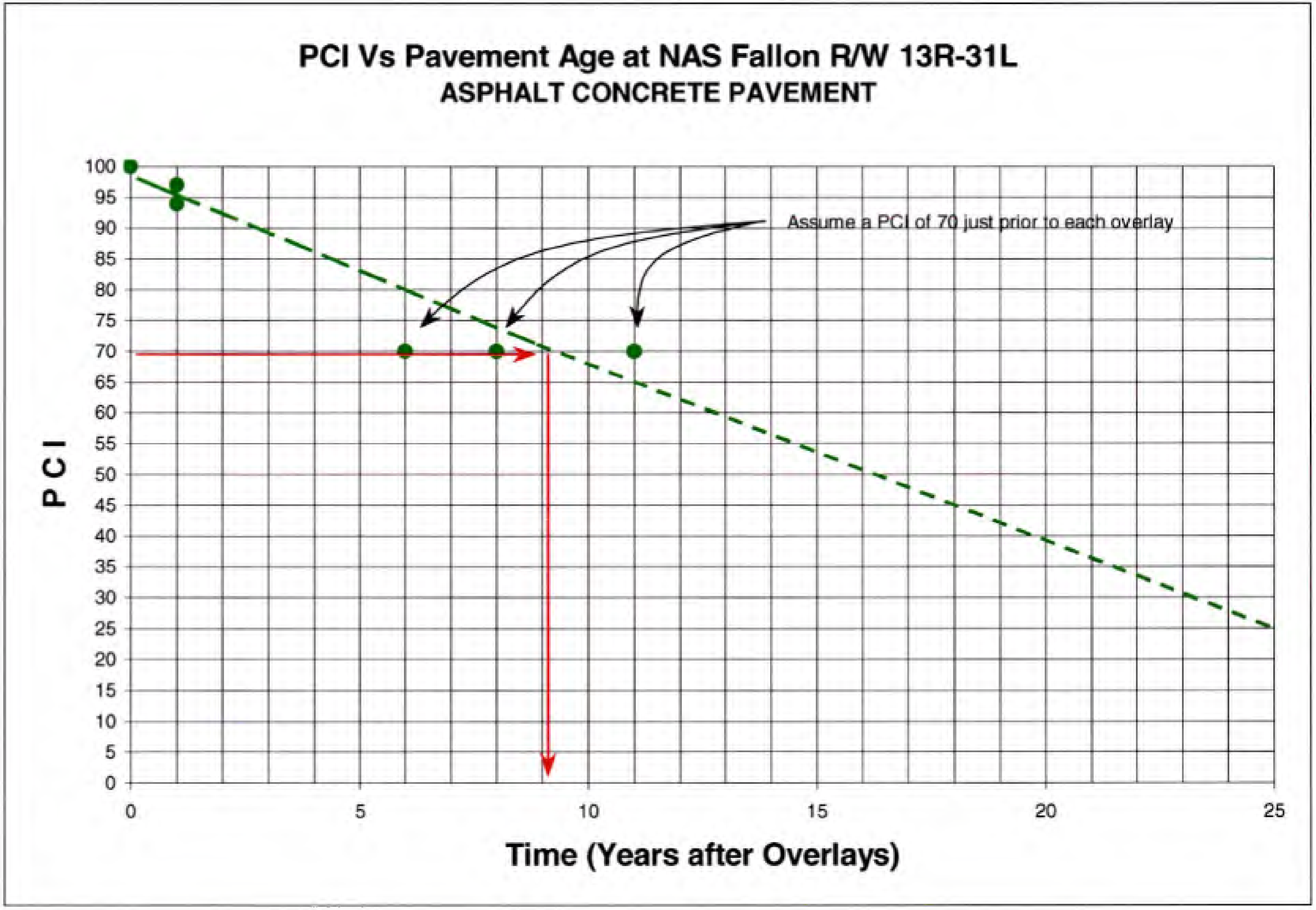

Figure 20. PCI prediction model for asphalt concrete runway pavement, historical data from NAS Fallon.

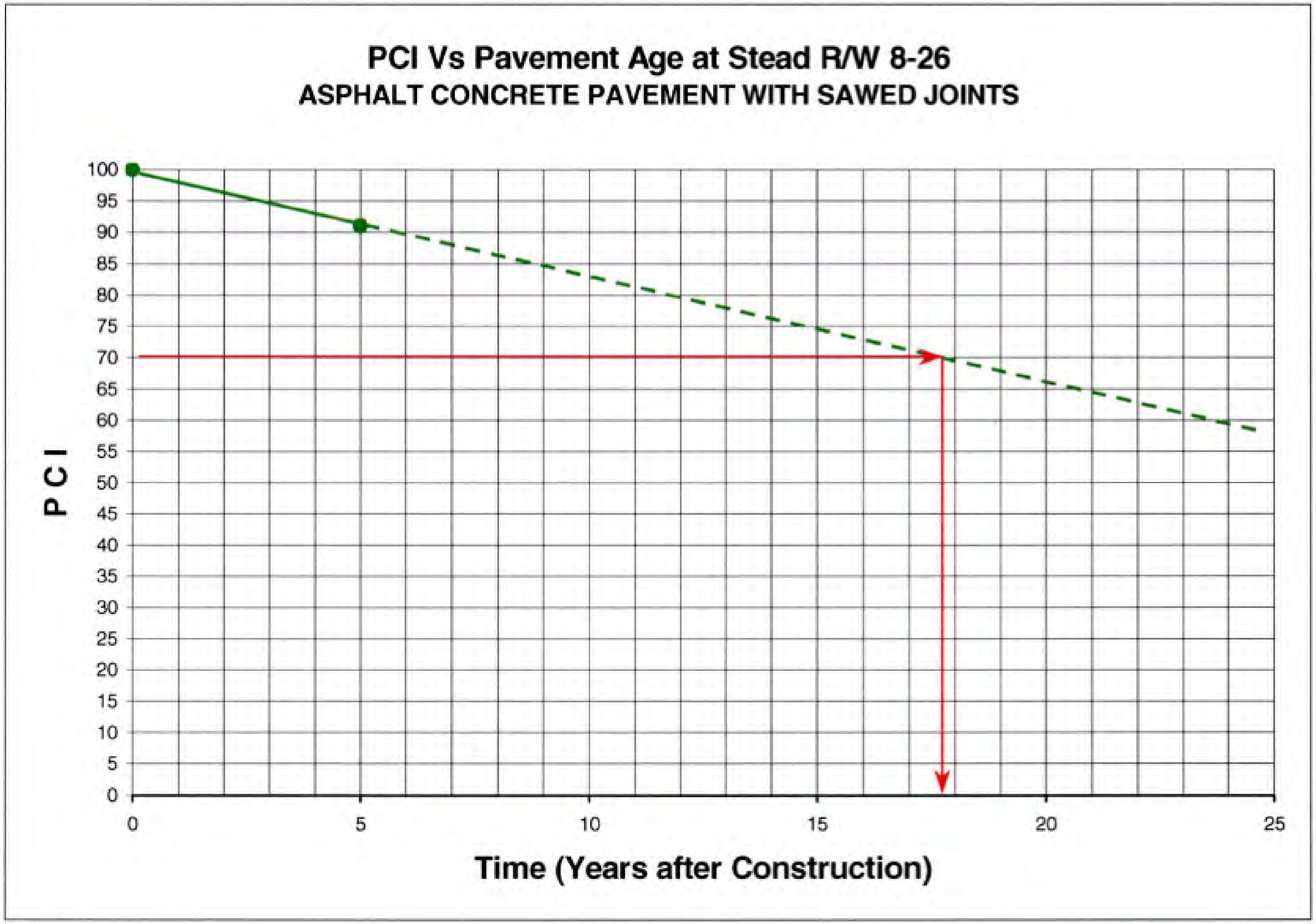

Figure 21. PCI prediction model for asphalt concrete R/W pavement with sawed joints, historical data from Reno Stead Airport.

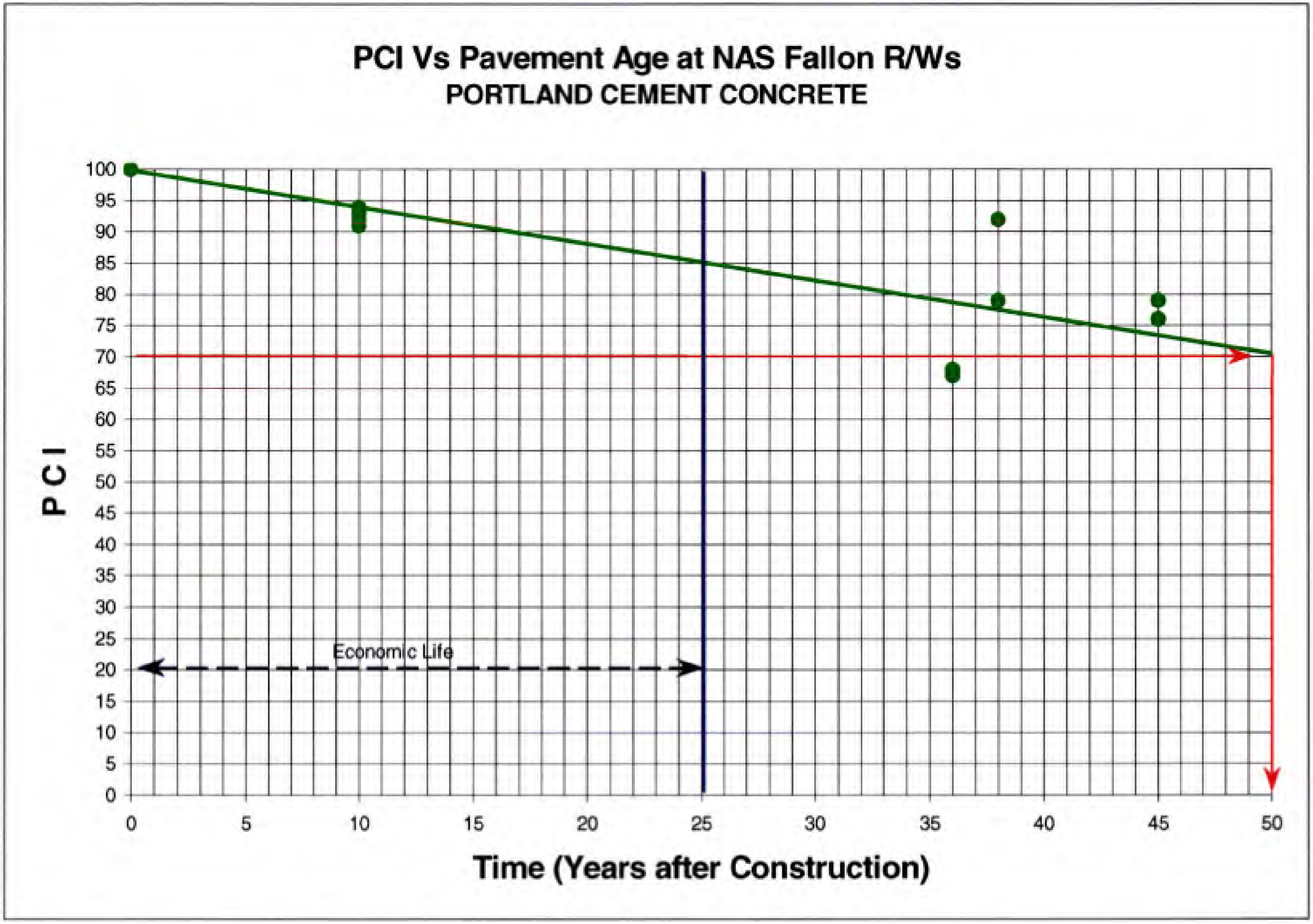

Figure 22. PCI prediction model for Portland cement concrete runway pavement, historical data from NAS Fallon.

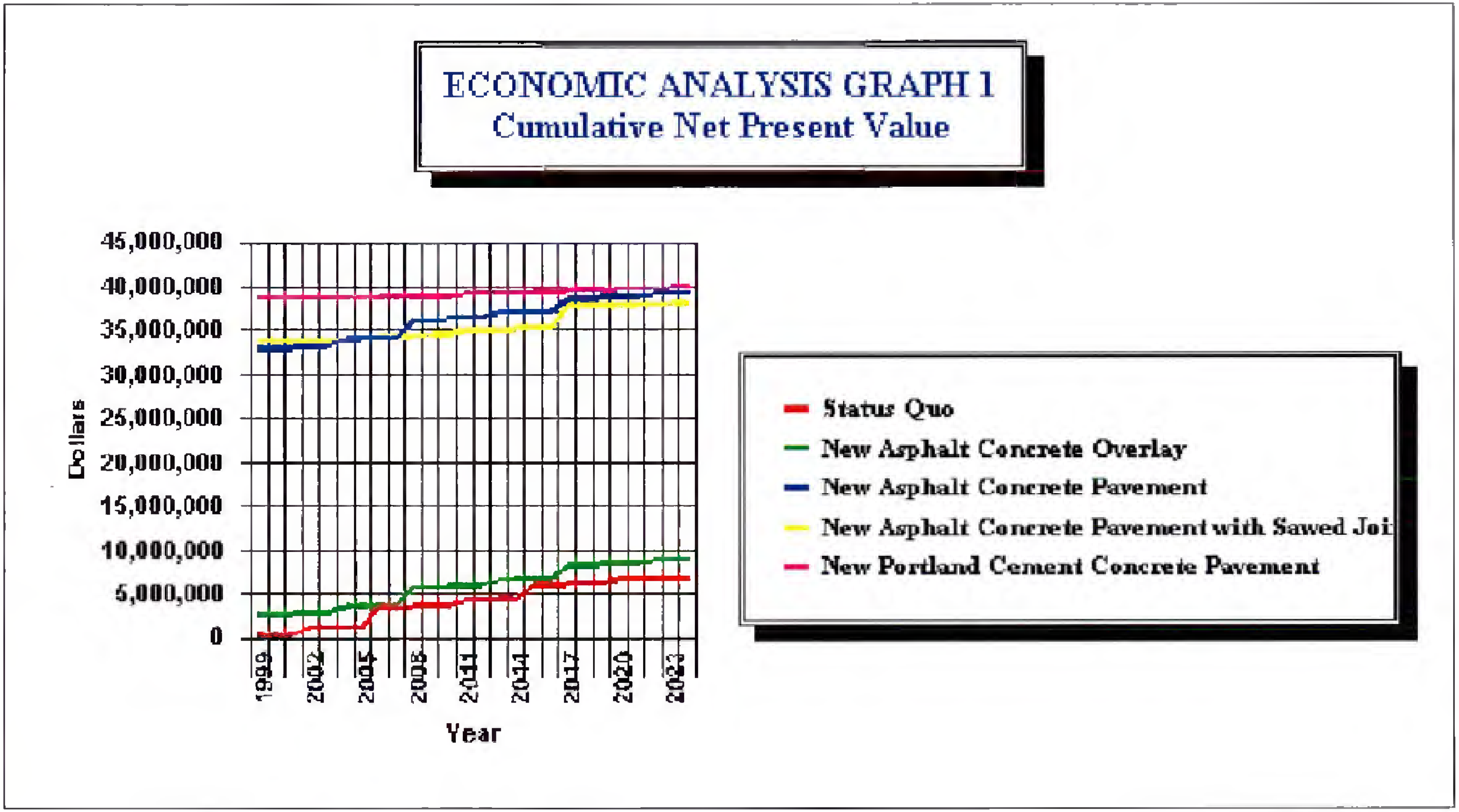

Figure 23. Graphical representation of the economic analysis life cycle cost.

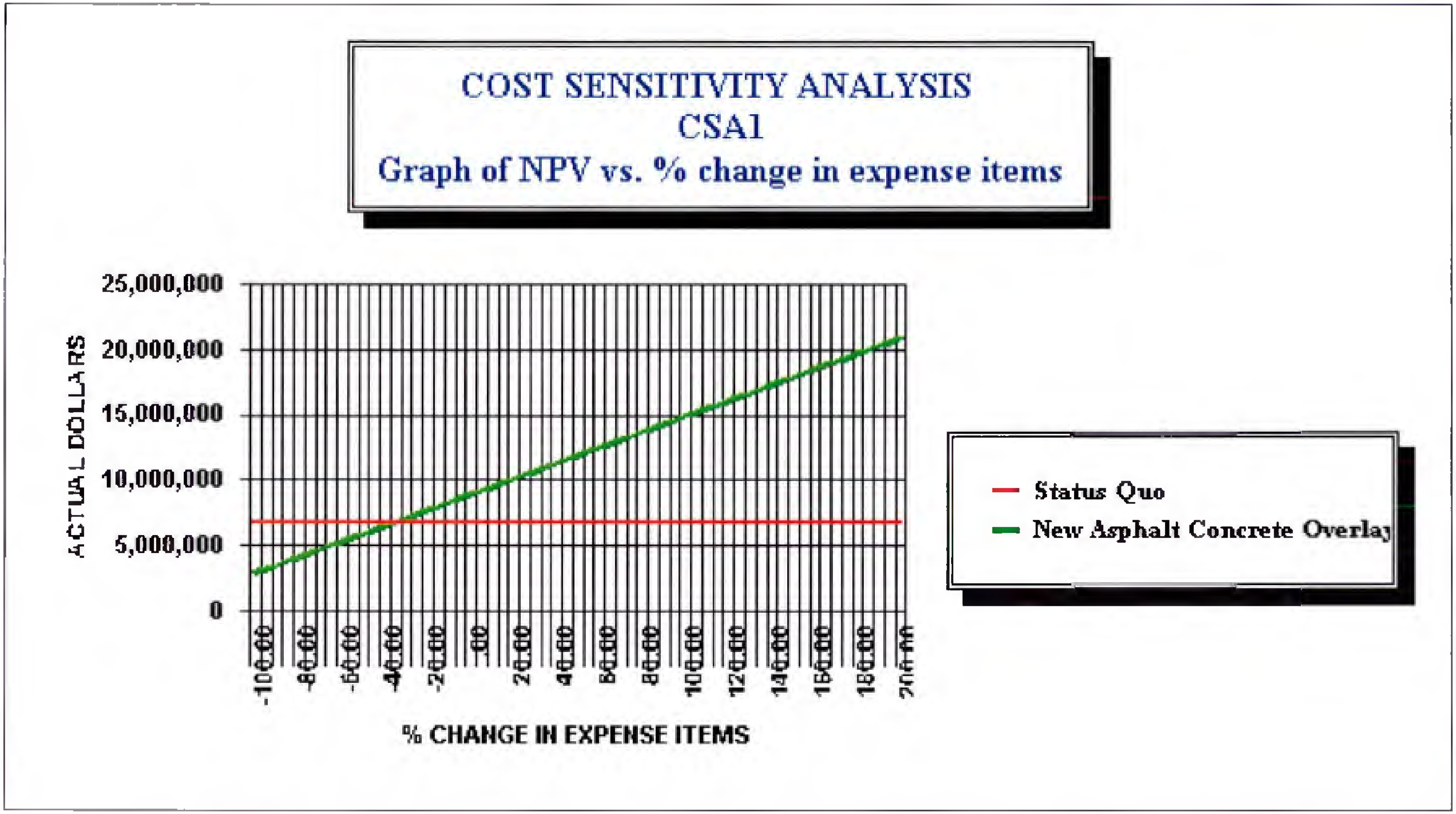

Figure 24. Graphical representation of cost sensitivity analysis from –100% to +100% change in overlay cost.

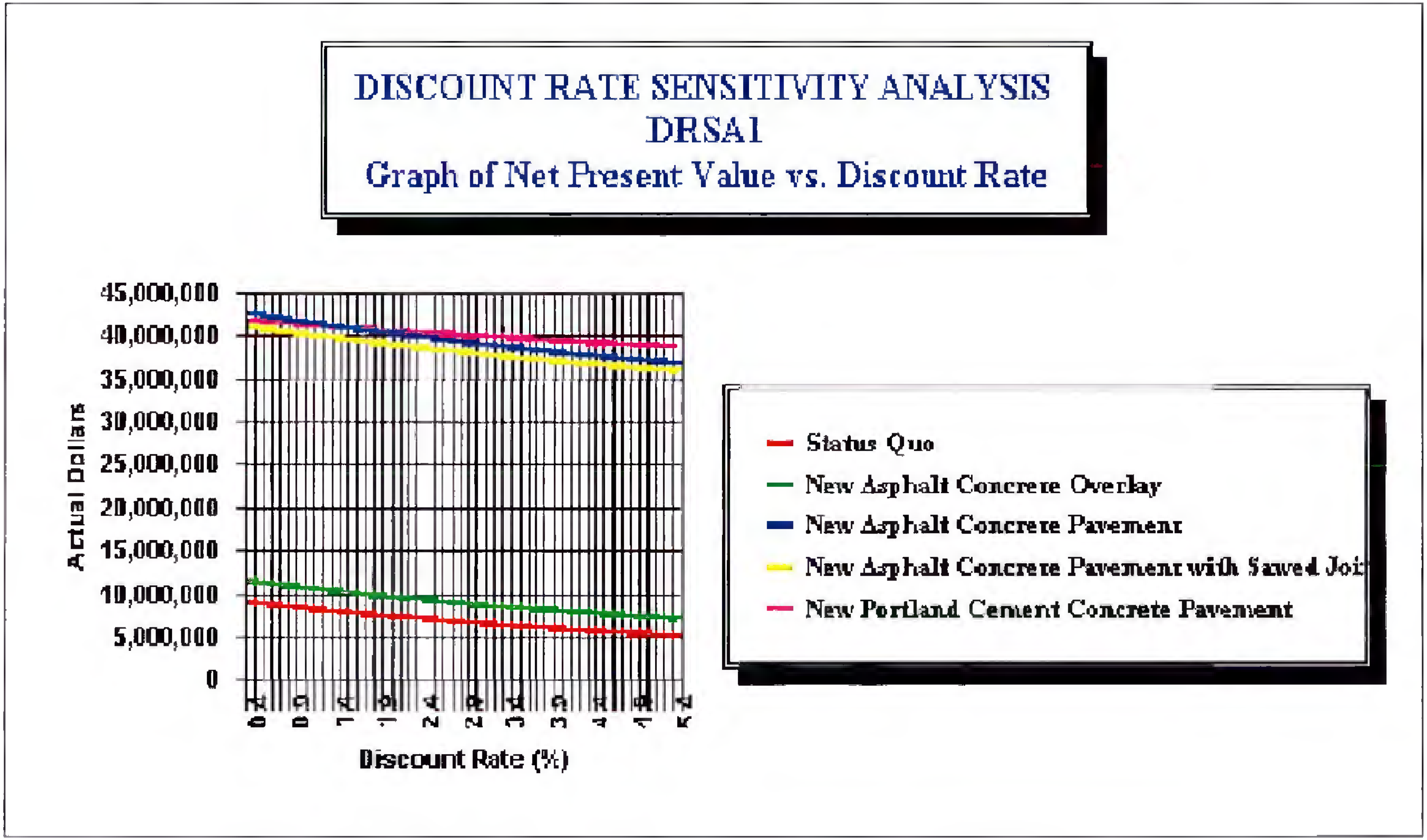

Figure 25. Graphical representation of the economic analysis discount rate sensitivity analysis.

Table 1. Construction History of AC Portion of Runway 13R-31L, NAS Fallon

Year	Type of Construction or Major Maintenance and Repair
1997	Two-inch asphalt concrete overlay
1993	Slurry seal
1986	Two-inch asphalt concrete overlay
1982	Treated with Reclamite rejuvenator
1980	Three-inch asphalt concrete overlay with reinforcing fabric
1979	One-inch pavement removed by cold planing and slurry seal
1971-72	Four-inch asphalt concrete pavement Three-inch asphalt base course Repair existing pavement, seal cracks
1967	Patch cracks and slurry seal
1965	Repair cracks
1959	Three-inch asphalt concrete overlay
1958	Slurry seal
1953	Three-inch asphalt concrete overlay Six-inch graded aggregate base course Four-inch pit run base 24-inch select material

Table 2. Measured or Scaled Distances between Cracks at NAS Fallon and Las Vegas, Reno, and Reno Stead Airports

Fallon NAS			**Reno-Tahoe International Airport**		**Reno-Stead Airport**	
Runway 13R-31L Lane 2, West Side Sta 45+25 to 60+50 Measured Distance (ft)	Runway 7-25 Lane 2, South Side Scaled Distance (ft)	Runway 7-25 Center Scaled Distance (ft)	Runway 7-25 Near Centerline Measured Distance (ft)	Crack Width (in)	Runway 14-32 Near Centerline Measured Distance (ft)	Crack Width (in)
50	32.0	68.0	44	1/8	86	5
36	72.5	17.5	20	1/4	46	1/2
19	42.5	40.0	22	1/16	36	4-1/2
42	22.5	37.5	22	1/4	72	2-1/2
51	47.5	77.5	62	1/4	29	2
48	57.5	50.0	39	1/4	48	3-3/4
68	77.5	25.0	80	1/4	43	1/8
60	37.5	20.0	49	1/8	42	3
69	22.5	32.5	44	1/4	44	2-1/2
26	22.5	12.5	30	1/8	45	2-3/4
41	30.0	30.0	22	1/4	42	1-1/4
41	27.5	37.5	15	.1/16	46	3
54	55.0	17.5	21	1/4	52	1-3/4
23	22.5	55.0	10	1/16	33	2
47	50.0	32.5	20	1/4	58	4-1/4
50	45.0	47.5	30	1/4	60	3-1/2
52	70.0	30.0	33	3/4	56	5
53	75.0	50.0	44	1/4	45	3/8
60	25.0	40.0	31	1/16	38	4-1/4

Table 2. Measured or Scaled Distances between Cracks at NAS Fallon and Las Vegas, Reno, and Stead Airports (Continued)

Fallon NAS			Reno-Tahoe International Airport		Reno-Stead Airport	
Runway 13R-31L Lane 2, West Side Sta 45+25 to 60+50 Measured Distance (ft)	Runway 7-25 Lane 2, South Side Scaled Distance (ft)	Runway 7-25 Center Scaled Distance (ft)	Runway 7-25 Near Centerline Measured Distance (ft)	Crack Width (in)	Runway 14-32 Near Centerline Measured Distance (ft)	Crack Width (in)
28	40.0	25.0	56	1/4	65	4
41	27.5	30.0	50	1/8	69	3
39	35.0	32.5	20	1/16	57	4-1/4
51	37.5	35.0	71	1-1/8	50	3
37	30.0	27.5	38	1/16	48	2
31	30.0	42.5	73	1/4	34	2
28	70.0	47.5	57	1/4	56	3
39	20.0	20.0	9	1/16	58	3-1/2
31	32.5	20.0	32	1/4	67	3-1/2
30	25.0	35.0	16	1/4	58	4-1/4
48	42.5	65.0	8	1/8	79	3-3/4
31	32.5	42.5	15	1/4		
32	62.5	87.5	44	3/4		
48	15.0	30.0	31	1/16		
34	45.0	35.0	44	3/4		
47	30.0	30.0	20	7/8		
45	57.5	30.0	28	1/8		
	20.0	17.5	33	3/4		
	35.0	20.0	36	1		

Table 2. Measured or Scaled Distances between Cracks at NAS Fallon and Las Vegas, Reno, and Stead Airports (Continued)

	Fallon NAS			Reno-Tahoe International Airport		Reno-Stead Airport	
	Runway 13R-31L Lane 2, West Side Sta 45+25 to 60+50 Measured Distance (ft)	Runway 7-25 Lane 2, South Side Scaled Distance (ft)	Runway 7-25 Center Scaled Distance (ft)	Runway 7-25 Near Centerline Measured Distance (ft)	Crack Width (in)	Runway 14-32 Near Centerline Measured Distance (ft)	Crack Width (in)
			37.5	47	7/8		
			57.5	44	3/4		
			27.5	40	1/8		
				63	3/4		
Summary							
Total Number Cracks	36	38	41	42	-	30	-
Average Distance Between Cracks	42.5	40.1	37.0	36.0	-	52.1	-
Average Witdth (in)	(Not measured)				0.4	-	2.9

Table 3. Aggregate Gradation Comparison of Specifications, Submittal and Test Result

Sieve Size	Project Specification % Passing	Submitted Range % Passing	Submitted Mix Design % Passing	Test Result of Sample % Passing
3/4 inch	100	100	100	100
1/2 inch	82 - 96	84 - 98	91	92
3/8 inch	75 - 89	70 - 84	77	84
No. 4	59 - 73	49 - 63	56	63
No. 8	46 - 60	34 - 48	41	49
No. 16	34 - 48	23 - 37	30	38
No. 30	24 - 38	15 - 29	22	30
No. 50	15 - 27	6 - 18	12	21
No. 100	8 - 18	2 - 12	7	13
No. 200	3 - 6	3.6 - 6.6	5.1	10

Table 4. Repair Runway 13R-31L (DD Form 1391)

1. COMPONENT			2. DATE
NAVY	FY 2002 MILITARY CONSTRUCTION PROJECT DATA		6-Apr-99
3. INSTALLATION AND LOCATION NAVAL AIR STATION FALLON, NV		4. PROJECT TITLE REPAIR RUNWAY 13R/31L	
5. PROGRAM ELEMENT	6. CATEGORY CODE 111-10	7. PROJECT NUMBER P-XXX	8. PROJECT COST (COST) ($000) 39,800

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
PRIMARY FACILITY	m2			31,952
PCC PAVEMENT REPLACEMENT	m2	183,000	$134	(24,515)
AC SHOULDER REPLACEMENT	m2	28,500	$30	(842)
SHOULDER STABILIZATION	m2	400,000	$12	(4,888)
AIRFIELD LIGHTING	m	4,300	$397	(1,707)
SUPPORTING FACILITIES	LS			3,793
ELECTRICAL UTILITIES	LS	1	$426,000	(426)
SITE IMPROVEMENTS	m3	55,200	$25	(1,367)
DEMOLITION	m2	183,000	$11	(2,000)
SUBTOTAL				35,745
CONTINGENCY (5%)				1,787
SUBTOTAL				37,533
SIOH (6%)				2,252
TOTAL REQUESTED				39,785
TOTAL REQUESTED (ROUNDED)				39,800
EQUIPMENT PROVIDED FROM OTHER APPROPRIATIONS (NON-ADD)				0

10. DESCRIPTION OF PROPOSED CONSTRUCTION

This project will replace deteriorated AC pavement area of Runway 13R/31L and repair the existing shoulders on each side. The demolition includes removal of the existing AC pavement, base and sub base to the depth of 0.660 m below the top of the existing runway surface. The replacement typical section will consist of subgrade preparation, placing 0.305 m aggregate base and 0.356 m PCC surface. The repairs include replacing the first 3.05 m of shoulder with a 0.102 m of AC surface over 0.203 m aggregate base, and stabilization of the outer 42.67 m shoulders by scarifying the existing material and treat with emulsion asphalt. Options should be included for reprocessing removed AC pavement into aggregate base material for reconstruction activities.

Table 5. Construct New All PCC Parallel Runway (DD Form 1391)

1. COMPONENT		2. DATE
NAVY	FY 2002 MILITARY CONSTRUCTION PROJECT DATA	6-Apr-99

3. INSTALLATION AND LOCATION	4. PROJECT TITLE
NAVAL AIR STATION FALLON, NV	CONSTRUCT NEW RUNWAY

5. PROGRAM ELEMENT	6. CATEGORY CODE	7. PROJECT NUMBER	8. PROJECT COST (COST) ($000)
	111-10	P-XXY	77,700

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
PRIMARY FACILITY	m2			48,487
PCC PAVEMENT REPLACEMENT	m2	296,500	$134	(39,719)
AC SHOULDER REPLACEMENT	m2	53,500	$30	(1,580)
SHOULDER STABILIZATION	m2	315,000	$12	(3,849)
AIRFIELD LIGHTING	m2	4,572	$730	(3,339)
SUPPORTING FACILITIES				21,297
SPECIAL FOUNDATION FEATURES	m3	952,000	$17	(15,765)
ELECTRICAL UTILITIES	LS	1	$1,000,000	(1,000)
DEMOLITION	m3	815,000	$6	(4,531)
SUBTOTAL				69,784
CONTINGENCY (5%)				3,489
SUBTOTAL				73,273
SIOH (6%)				4,396
TOTAL REQUEST				77,669
TOTAL REQUEST (ROUNDED)				77,700
EQUIPMENT PROVIDED FORM OTHER APPROPRIATIONS (NON-ADD)				0

10. DESCRIPTION OF PROPOSED CONSTRUCTION

This project will construct a new PCC Runway with stabilized shoulders, overrun area, blast pads and connecting Taxiways to the east of existing Runway 13L/31R. The project will includes clearing and grubbing of the site and grading the area to improve drainage by raising the runway up to 2.5 m. The new typical PCC section will consist of subgrade preparation, placing 0.305 m aggregate base and 0.356 m PCC surface. The new shoulders will consist of 3.05 m width of shoulder with a 0.102 m of AC surface over 0.203 m aggregate base, and stabilization of the outer 42.67 m shoulders by scarifying the existing material and treat with emulsion asphalt. The project also includes runway approach lighting edge lighting and new drainage improvements.

Table 6. Repair Runway 13R-31L Shoulders (DD Form 1391)

1.				2. DATE
NAVY	FY 2002 MILITARY CONSTRUCTION PROJECT DATA			6-Apr-99
3. INSTALLATION AND LOCATION NAVAL AIR STATION FALLON, NV			4. PROJECT TITLE REPAIR RUNWAY 13R/31L SHOULDERS	
5. PROGRAM ELEMENT	6. CATEGORY CODE 111-10	7. PROJECT NUMBER RXX-00	8. PROJECT COST (COST) ($000) 7,400	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
PRIMARY FACILITY	m2			5,730
Replace AC Shoulder	m2	28,500	$30	(842)
Shoulder Stabilization	m2	400,000	$12	(4,888)
SUPPORTING FACILITIES				215
Special Foundation Features	m3	8,700	$25	(215)
SUBTOTAL				5,945
GENERAL REQUIREMENTS (10%)				595
CONTINGENCY (5%)				327
CONTRACT ADMINISTRATION (8.0%)				549
TOTAL FUNDED COST				7,416
Total Repair Cost				(7,416)
Total Construction Cost				0
TOTAL REQUEST				7,400
Planning and Design Cost (10%)				740

10. DESCRIPTION OF PROPOSED CONSTRUCTION

This project will replace deteriorated shoulders on each side of Runway 13R/31L. The repairs include replacing the first 3.05 m of shoulder with a 0.102 m of AC surface over 0.203 m aggregate base, and stabilization of the outer 42.67 m shoulders by scarifying the existing material and treat with emulsion asphalt.

Table 7. Possible Contributing Factors to Low Temperature Cracking of Asphalt Concrete Pavements (After Ref. 15)

Low-Temperature Cracking of Flexible Pavements

	Surface	Base	Subbase	Subgrade
Component where cracking may initiate	**Surface**	**Base**	**Subbase**	**Subgrade**
Initial possible result	Cracking remains in surface	Cracking through pavement structure	Cracking through pavement structure	Cracking through pavement structure
Possible external factors	1. Low temperature and temperature cycling 2. Action of water (Stripping) 3. Traffic loads 4. Sunlight, air and age 5. Reflection cracking 6. Construction "quality" and uniformity	1. Low temperatures 2. Traffic loads 3. Water intrusion 4. Intrusion of fines 5. Reflection cracking 6. Construction "quality" and uniformity	1. Low temperatures 2. Traffic loads 3. Water intrusion 4. Intrusion of fines 5. Reflection cracking 6. Construction "quality" and uniformity	1. Low temperatures 2. Freezing shrinkage 3. Intrusion of water 4. Construction "quality" and uniformity
Possible component factors	1. Time and age dependent tensile strength and strain 2. Asphalt and aggregate type and composition 3. Density, voids, and asphalt content 4. Aggregate grading 5. Bond between layers 6. Thermal conductivity 7. Long joint construction	1. Aggregate type, composition, and grading 2. Density, voids, and water content	1. Aggregate type, composition, and grading 2. Density, voids, and water content	1. Soil plasticity and mineralogical character 2. Voids, density, and degree of saturation 3. Resiliency

Table 8. Repair Runway 13R-31L with AC Pavement (DD Form 1391)

1. COMPONENT NAVY	FY 2002 MILITARY CONSTRUCTION PROJECT DATA			2. DATE 6-Apr-99
3. INSTALLATION AND LOCATION NAVAL AIR STATION FALLON, NV			4. PROJECT TITLE REPAIR RUNWAY 13R/31L	
5. PROGRAM ELEMENT	6. CATEGORY CODE 111-10	7. PROJECT NUMBER P-XXX	8. PROJECT COST (COST) ($000) 33,900	

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
PRIMARY FACILITY	m2			26,685
AC PAVEMENT REPLACEMENT	m2	183,000	$105	(19,257)
AC SHOULDER REPLACEMENT	m2	28,500	$29	(833)
SHOULDER STABILIZATION	m2	400,000	$12	(4,888)
AIRFIELD LIGHTING	m	4,300	$397	(1,707)
SUPPORTING FACILITIES	LS			3,793
ELECTRICAL UTILITIES	LS	1	$426,000	(426)
SITE IMPROVEMENTS	m3	55,200	$25	(1,367)
DEMOLITION	m2	183,000	$11	(2,000)
SUBTOTAL				30,479
CONTINGENCY (5%)				1,524
SUBTOTAL				32,003
SIOH (6%)				1,920
TOTAL REQUESTED				33,923
TOTAL REQUESTED (ROUNDED)				33,900
EQUIPMENT PROVIDED FROM OTHER APPROPRIATIONS (NON-ADD)				0

10. DESCRIPTION OF PROPOSED CONSTRUCTION

This project will replace deteriorated AC pavement area of Runway 13R/31L and repair the existing shoulders on each side. The demolition includes removal of the existing AC pavement, base and sub base. The replacement typical section will consist of subgrade preparation, placing aggregate base and an AC surface. The repairs include replacing the first 3.05 m of shoulder with a 0.102 m of AC surface over 0.203 m aggregate base, and stabilization of the outer 42.67 m shoulders by scarifying the existing material and treat with emulsion asphalt. Options should be included for reprocessing removed AC pavement into aggregate base material for reconstruction activities.

Table 9. Repair Runway 13R-31L with AC with Sawed Joints (DD Form 1391)

1. COMPONENT		2. DATE
NAVY	FY 2002 MILITARY CONSTRUCTION PROJECT DATA	6-Apr-99

3. INSTALLATION AND LOCATION	4. PROJECT TITLE
NAVAL AIR STATION FALLON, NV	REPAIR RUNWAY 13R/31L

5. PROGRAM ELEMENT	6. CATEGORY CODE	7. PROJECT NUMBER	8. PROJECT COST (COST) ($000)
	111-10	P-XXX	34,800

9. COST ESTIMATES

ITEM	U/M	QUANTITY	UNIT COST	COST ($000)
PRIMARY FACILITY	m2			27,490
AC PAVEMENT REPLACE. W/ SAW JOINTS	m2	183,000	$110	(20,053)
AC SHOULDER REPLACEMENT	m2	28,500	$30	(842)
SHOULDER STABILIZATION	m2	400,000	$12	(4,888)
AIRFIELD LIGHTING	m	4,300	$397	(1,707)
SUPPORTING FACILITIES	LS			3,793
ELECTRICAL UTILITIES	LS	1	$426,000	(426)
SITE IMPROVEMENTS	m3	55,200	$25	(1,367)
DEMOLITION	m2	183,000	$11	(2,000)
SUBTOTAL				31,284
CONTINGENCY (5%)				1,564
SUBTOTAL				32,848
SIOH (6%)				1,971
TOTAL REQUESTED				34,819
TOTAL REQUESTED (ROUNDED)				34,800
EQUIPMENT PROVIDED FROM OTHER APPROPRIATIONS (NON-ADD)				0

10. DESCRIPTION OF PROPOSED CONSTRUCTION

This project will replace deteriorated AC pavement area of Runway 13R/31L and repair the existing shoulders on each side. The demolition includes removal of the existing AC pavement, base and sub base. The replacement typical section will consist of subgrade preparation, placing aggregate base and an AC surface. Surface will be saw cut in 7.5 m by 7.5 m squares and saw cut joints will be sealed. The repairs include replacing the first 3.05 m of shoulder with a 0.102 m of AC surface over 0.203 m aggregate base, and stabilization of the outer 42.67 m shoulders by scarifying the existing material and treat with emulsion asphalt. Options should be included for reprocessing removed AC pavement into aggregate base material for reconstruction activities.

Table 10. 25-Year Life Cycle Cost

ECONOMIC ANALYSES
(ECONPACK for Windows 1.02 and NAVFAC P-442)

Alternative	Economic Life	Costs ($1,000) NPV			Life Cycle Cost NPV ($1,000)
		Initial Construction	Major M & R	O & M	
Status Quo	25 Years	0	6,225	525	6,750
New Asphalt Concrete Overlay	25 Years	2,435	5,990	475	8,900
New Asphalt Concrete Pavement	25 Years	32,995	5,825	480	39,300
New Asphalt Concrete Pavement - Sawed Joints	25 Years	33,820	3,820	460	38,100
New Portland Cement Concrete Pavement	25 Years	38,680	920	500	40,100
Replacement of Runway 13R-31L	25 Years	75,510	1,390	750	77,650
Repair Runway 13R-31L Shoulders	25 Years	7,200	220	30	7,450

Table 11. Number of Occurrences which Interrupt Airfield Operation

Interruptions To Airfield Operations

Alternative	Economic Life	Number Of Occurrences				
		Initial Construction	Overlay	Surface Treatment	Global Crack Seal	Global Joint Repair & Seal
Status Quo	25 Years	0	2	6	9	0
New Asphalt Concrete Overlay	25 Years	0	3	6	9	0
New Asphalt Concrete Pavement	25 Years	1	2	6	8	0
New Asphalt Concrete Pavement with Sawed Joints	25 Years	1	1	6	0	2
New Portland Cement Concrete Pavement	25 Years	1	0	0	0	3
Replacement of Runway 13R-31L	25 Years	*0*	0	0	0	3
Repair Runway 13R-31L Shoulders	25 Years	*0*	*0*	*8*	*8*	*0*

Table 12. Comparison of Pavement Material Performance at NAS Fallon

Factor	AC Pavements	PCC Pavements
Aggregate quality	Absorptive, stripping tendency	Reactive
Cement degradation	Accelerated oxidation	Alkali reactive
Crack development	Low-temperature thermal cracking	Joint spalling
Crack or joint sealing requirements	Rout and seal cracks > ¼ inch or wider	Reseal all joints
Freezing effects	Thermal cracking, reflective cracking	Microcracking, degradation
PCI deterioration rate	3.3 points/year	0.6 points/year

APPENDIX A

NFESC Kick-Off Meeting Visuals

NAS Fallon

5 August 1998

REVIEW OF NAS FALLON PAVEMENT CONSTRUCTION PROGRAM

5 Aug 98

NAS Fallon

NAVAL FACILITIES ENGINEERING SERVICE CENTER
PORT HUENEME, CALIFORNIA

NAVAL FACILITIES ENGINEERING SERVICE CENTER

TASK 1 PROJECT KICKOFF MEETING

- Meeting was held 5 Aug 98
- Topics covered
  - Proposed work plan
  - Scope
  - Data Requirements
  - Project schedule
  - Points of contacts (POCs)
- Summary of pertinent discussions

NAVAL FACILITIES ENGINEERING SERVICE CENTER

TASK 2 RUNWAY 13R-31L ASPHALT CONCRETE

- Problem: AC pavement service life
- Alternatives: Investigate the following:
  - Performance of standard Navy 2" AC overlay M&R procedure
  - Replace AC portion with PCC
  - Construction of a new all PCC parallel runway to the east
- Approach:
  - Investigate AC and PCC performance service lives
  - Design PCC pavement alternatives
  - Calculate life cycle costs
- Products:
  - Life cycle costs of alternatives
  - Determination of superior pavement type (AC or PCC?) for Fallon

NAVAL FACILITIES ENGINEERING SERVICE CENTER

TASK 3 TAXIWAY "A" CONSTRUCTABILITY REVIEW

- Problem: Designed repairs are inadequate? Constructable?
- Approach: Review the following:
  - Design of previous PCC pavement and failure mechanism
  - Geotechnical data (soils reports, subgrade and base materials)
  - Existing design to replace center keel portion & repair remaining areas
- Products:
  - Effectiveness and constructability of designed replacement/repair
  - Recommend other repair alternative - if superior

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TASK 4 AIRFIELD SHOULDER UPGRADE

- Problem: Shoulders do not meet criteria
- Approach:
  - Conduct survey and measure present characteristics
  - Compare measured results with criteria
  - Evaluate the effect of large aircraft on taxiway shoulder
  - Estimate costs to upgrade shoulders to meet criteria
  - Compute life cycle costs
- Products:
  - Identification of deficiencies in meeting criteria
  - Cost estimate to upgrade shoulders
  - Life cycle costs

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MILESTONES AND DELIVERABLES

	Month Number*
Task 1 - Kickoff meeting (Completed 5 Aug. 98)	
Task 2 - Runway 13R-31L alternatives- - - - - - - -	6
Task 3 - Taxiway Aconstructability review - - - -	4**
Task 4 - Airfield shoulder upgrade - - - - - - - - - -	6
Task 5 - Taxiway clearance compliance (Deleted)	
Task 6 - Runway 13R-31L wiring upgrade (*Unfunded*) — 6**)	
Task 7 - Taxiway D upgrade (*Unfunded*)- - - - - - - - -	6
Draft of final report -	7

*Months after receipt of funding
** Interim reports will be provided

NAVAL FACILITIES ENGINEERING SERVICE CENTER

APPENDIX B

LABORATORY EVALUATION OF ASPHALT CONCRETE SAMPLES

FROM NAS FALLON RUNWAY PAVEMENT

Dr. Gary Anderton

Wayne Hodo

June 1999

CEWES-GP-Q (1110-2-1403b)

8 June 1999

MEMORANDUM FOR: Commanding Officer, Naval Facilities Engineering Service Center, 1100 23rd Avenue, Port Hueneme, CA 93043-4370, ATTN: Mr. Mel Hironaka (ESC63)

SUBJECT: Laboratory Evaluation of Asphalt Concrete Samples from Fallon NAS Runway Pavement, located in Fallon, Nevada.

1. Enclosed (encl. 1) are the results of a laboratory evaluation conducted on the subject asphalt concrete samples.

2. If you need any additional information on these test results, please contact Dr. Gary Anderton at (601) 634-2955 or Mr. Wayne Hodo at (601) 634-2752.

FOR THE COMMANDER AND DIRECTOR:

Encl.

W. F. Marcuson III
Chief, Geotechnical Laboratory

Laboratory Evaluation of Asphalt Concrete Samples taken from Fallon NAS Runway Pavement, located in Fallon, NV

1. On 5 May 1999, a 2-ft by 2-ft slab sample of asphalt concrete was received at the U.S. Army Engineer Waterways Experiment Station (WES) from Fallon NAS. When received at WES, the slab was intact and undamaged by the shipping and handling. Figure 1 and Figure 2 show the condition of the slab sample after its arrival at the WES laboratories.

2. WES was tasked by the Navel Facilities Engineering Service Center (NFESC) to conduct a laboratory evaluation of the asphalt concrete slab surface layer according to the test instructions sent from Mel Hironaka to Dr. Gary Anderton (CEWES-GP-Q) on 5 May 1999.

3. The 2-ft by 2-ft slab specimen consisted of three layers: surface layer, intermediate layer, and bottom layer with thickness' of 2 ½ in., 1 ½ in. and 2 in. respectively. Under the direction of Mr. Hironaka, the surface layer was the only material to be tested. Figure 3 and Figure 4 show the surface layer after it was separated from the rest of the slab sample.

4. The following tests and measurements were conducted on the slab specimens.

a. Cut the slab sample into chunks that are easier to handle and then separate the top layer of asphalt concrete from the bottom layers. Measure the thickness of each discernable layer of asphalt of concrete and record these values. Make note of any visual indications, poor coating of aggregates, or anything else unusual.

b. Measure bulk densities of top layer of asphalt concrete. Make these weight measurements before trimming cut edges, to prevent inaccuracies caused by constant loss of loose edge material.

c. Trim cut edges of asphalt concrete (AC) samples, removing at least a ¾-in thickness from all cut edges by the heat and spatula method.

d. Heat and break down all trimmed AC samples in the oven, combining the materials from all samples into one loose AC mixture.

e. Quarter down the combined AC material to produce enough AC mixture for at least two extractions and three recompacted 4-in-dia. Marshall samples.

f. Perform two asphalt extractions to provide two asphalt cement content measurements and two sets of aggregate sieve analyses. Measure specific gravities and absorption percentages of the sieved aggregates.

g. Recompact three Marshall specimens in the gyratory testing machine (GTM) using equivalent 75-blow compactive effort. Measure and record gyratory stability index (GSI) during compaction of each specimen. Measure and record all standard Marshall properties of recompacted specimens.

5. **Discussion of Test Results**:

a. Aggregate Gradations. The results of the sieve analysis conducted on the surface layer of the sample are found on Table 1. The samples had what may be considered significant gradation problems; there was an excessive amount of fines passing the No. 4 sieve. Excessive fines usually cause the asphalt mix to have low percent air voids, pose stability problems, and increase rutting potential. In this case, the percent air voids in the asphalt mixture was high, the AC mixture exhibited adequate stability and there was no reported rutting. The cause for the high percent air voids is likely due to under-compaction of the asphalt during placement. A comparison field sample test results to the tolerances prescribed by the job-mix-formula (JMF), submitted by the paving contractor (Granite Construction Company), is displayed in Table 1 and Figure 5.

b. Recovered Bitumen. The results of the tests conducted on the bitumen recovered from the extraction process versus the bitumen required by the JMF submitted by Granite Construction Company are found in Table 2. The measured asphalt cement content was at the upper limit of the specification requirements, but this property cannot be determined to be a significant material problem.

c. Asphalt concrete mixture recompaction analysis

I. The results of the recompaction analysis, including measurements of density, Marshall, and GSI properties, are found in Table 2. The measured field densities of the slab samples averaged 142.5 pcf. with a reasonable range of 1.5 pcf. The measured laboratory densities of the recompacted field materials were very consistent and averaged 144.8 pcf. WES laboratory density average correlates reasonably well with the mix design (145.1 pcf) prepared by AGRA Earth and Environmental Inc., report dated 2 June 1997. The resulting density percentages reflect a narrow range of values averaging 98.1 percent. These density values and ranges are typical of an airfield asphalt concrete mixture.

II. The test results of the Marshall stability meets the minimum requirement of 1800-lbs. The Marshall flow and percent voids total mix are out of standard specification ranges, however. As discussed earlier, the reason for the high percent air void content is likely due to under-compaction of the asphalt mixture during placement. There is no reported physical evidence of rutting at this time and, furthermore, the recompacted lab specimen densities match the field specimen densities. The Marshall flow exceeds the maximum value allowed by NAVFAC SECTION 02742 asphalt cement mix acceptance criteria. Having a high Marshall flow value usually indicates that the asphalt mix may have stability problems, caused by an excessive amount of fine aggregate in the asphalt mix. The Marshall stability results eliminate the idea of having stability problems, however. In addition, having a high Marshall flow value along with excessive aggregate fines passing the No. 4 sieve, often indicates there may be a high asphalt content present. The following section discusses the asphalt content in more detail.

III. The relative stability of the samples was determined with the gyratory testing machine (GTM). The GTM was used to recompact the asphalt mixtures under high-tire pressure compaction conditions to simulate field behavior and performance under traffic. A gyratory stability index (GSI) was determined for each of the recompacted specimens. A GSI value greater than 1.0 indicates an unstable mixture, usually resulting from excessively high asphalt content, or poor aggregate gradation. All GSI values of Table 3 indicate that none of the recompacted samples were deemed unstable by this test method.

6. **Conclusions**: Based on the results of this laboratory evaluation, the following conclusions are made:

a. The asphalt concrete represented by the slab specimen contained excessively high percent air voids. This Marshall material property indicates the asphalt was under-compacted during placement. Consequently, densification of the asphalt concrete may take place in the future, but the likelihood of this occurring reduces with time as the asphalt concrete material continues to age-harden.

b. The slab specimen gradation has an excessive amount of fines passing the No. 4 sieve. The significance of these excessive fines usually means the asphalt mixture should have low air voids if compacted properly. This is not the case of Fallon NAS runway; there is a high percentage of air voids in the asphalt pavement. The high percentage of.air voids indicates there was under-compaction during placement. It must be noted, however, that experience has shown excessive fines and under-compaction of material has lead to rutting. If high air voids, caused by under-compaction, don't result in rutting during initial trafficking or the first summer, then the other problem can be accelerated oxidation and premature raveling. Accelerated oxidation and premature raveling are believed to be the problems the Fallon NAS runway is experiencing or beginning to experience.

c. The densities of the slab samples were relatively consistent with the densities of the recompacted lab samples, but the high air void contents are evidence of inadequate field compaction. Also, true laboratory (or optimum) densities are usually somewhat higher than recompacted laboratory densities because the recompacted samples are made with stiff, oxidized materials. This means that the percent compaction value reported here (98.1%) is likely skewed too high by nature of the test method, and should not be taken to mean that the field densities are literally 98.1% of optimum.

d. The Marshall flow value was high. This is expected for an asphalt mixture containing an excessive amount of fines. Again, this material property is outside of the specification limits, but does not seem to detrimentally effect other material properties.

e. The stability measurements made by the gyratory testing machine detected no unstable asphalt mixtures. In addition, the gyratory testing machine indicated an excessive amount of asphalt cement was not used.

f. Based on the test results of this laboratory evaluation, the in-place asphalt concrete material appears to be acceptable for an airfield pavement. However, at an undetermined future time, the airfield pavement may experience premature weathering and raveling problems. An increased possibility of moisture damage resulting from the higher than normal percentage of air voids is a concern that could accelerate the weathering and raveling conditions.

7. **Recommendation**: The asphalt pavement runway at Fallon Naval Air Station should be continually monitored to determine if and when significant weathering and raveling conditions begin on the pavement surface. Some form of surface treatment may need to be applied when these conditions first occur to prevent accelerated deterioration. Surface treatments that should be considered include an asphalt emulsion fog seal, a rejuvenator spray application, micro surfacing, and a thin asphalt concrete overlay. These maintenance options are listed in order of increasing effort, cost, and projected effectiveness.

Figure 1. Condition of original sample received.

Figure 2. Condition of original sample received.

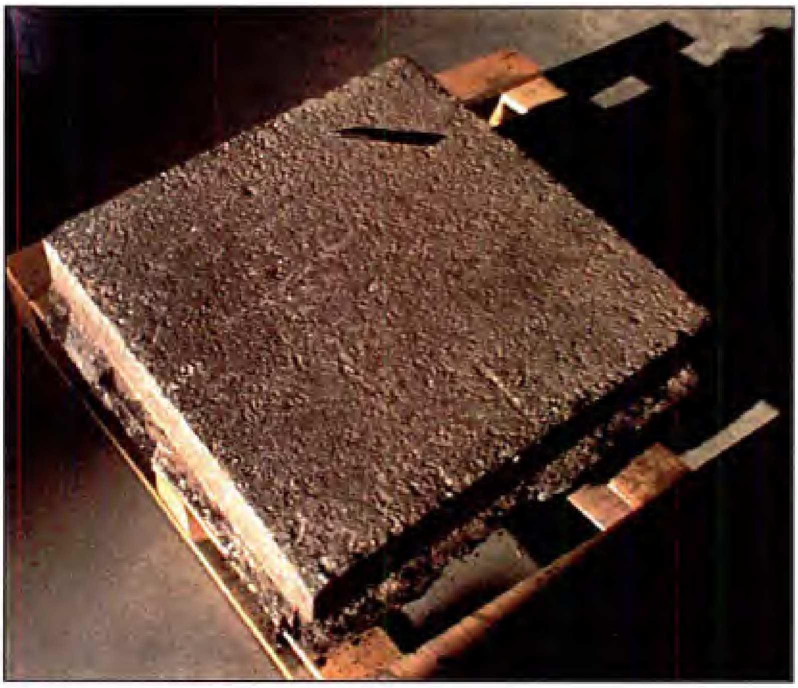


Figure 3. Bottom of surface layer after being removed from intermediate layer 2.

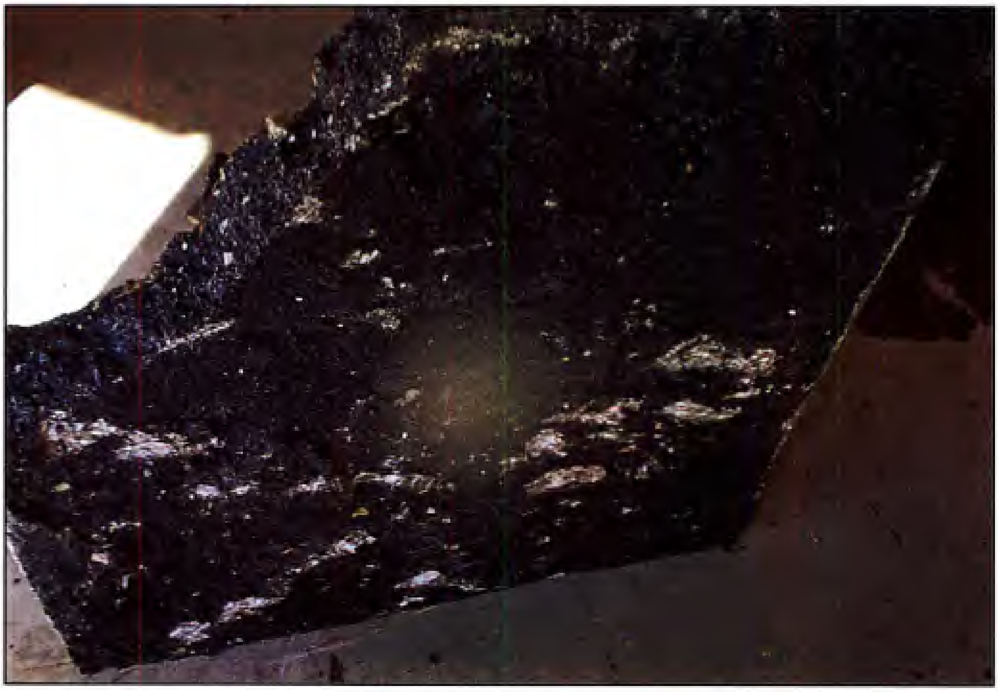


Figure 4. Top of surface layer after being removed from intermediate layer 2.

TABLE 1. AGGREGATE GRADATIONS FROM FIELD SAMPLES

Sieve	JMF Tolerances (percent passing)	Avg. of Field Sample (percent passing)
3/4 in.	100	100
1/2 in.	84 – 98	92
3/8 in.	70 – 84	84
No. 4	49 – 63	63
No. 8	34 – 48	49
No. 16	23 – 37	37.9
No. 30	15 – 29	29.7
No. 50	6 – 18	20.5
No. 100	2 – 12	13
No. 200	3.6 – 6.8	9.9

Note: Underlined data are outside of gradation band.

Figure 5. Comparison field sample test results to the tolerances prescribed by the JMF.

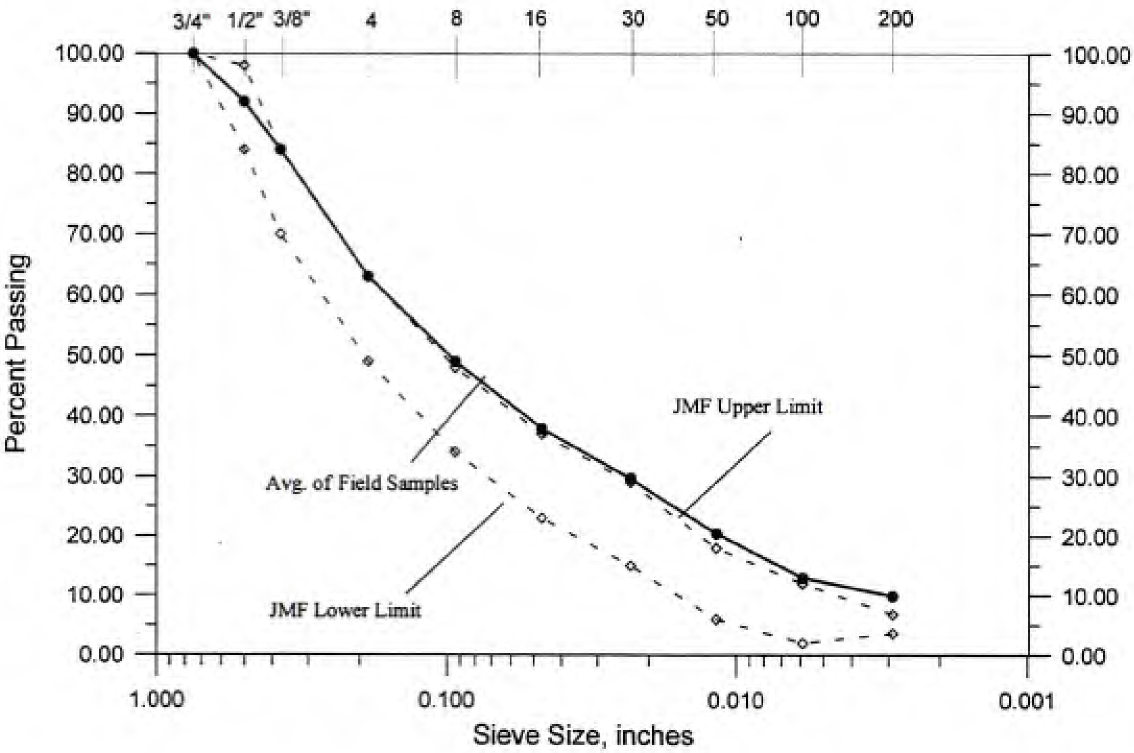


TABLE 2. PHYSICAL PROPERTIES OF FIELD MATERIALS

Property	Specification Requirement	Sample
Field Sample		
Recovered Bitumen:		
(Percent by Wt.)	4.0 – 5.0	5.0
Voids Total Mix (%)	3.0 – 5.0	10.1
Avg. Field Density (pcf)	---	142.5
Specific Gravity	---	1.046
Recovered Aggregates:		
% Water Absorption		
+ No. 4	---	2.1
- No. 4	---	3.2
Apparent Sp. Gr.		
+ No. 4	---	2.79
- No. 4	---	2.73
Lab Sample		
Gyratory Recompaction Study (200 psi, 30 rev, 1°, 250°F)		
Marshall Stability (lbs.)	1800 min.	3360
Marshall Flow (0.01")	8 - 16	17
Voids Total Mix (%)	3.0 – 5.0	8.6
Voids Mineral Aggregate (%)	15 min.	19.7
Avg. Lab Density (pcf)	---	144.8
Avg. Field Density (pcf)	---	142.5
% Compaction	95.0 % min.	98.1

TABLE 3. GYRATORY STABILITY DATA

Property	Standard Requirement	Sample #1	Sample #2	Sample #3
Gyratory Stability Index	1.0 max	0.97	0.99	0.98
Gyratory Flushing	---	No	No	No

APPENDIX C

TAXIWAY "B"

DESIGN COORDINATION AND REVIEW COMMENTS

By

Kerry Nothnagel

DESIGN COORDINATION AND REVIEW COMMENTS 5ND LANTDIV 3-11012/30 (NEW2/76)			JOB ORDER NO.
COMMENTS BY KERRY NOTHNAGEL	BRANCH: 411/ GEOTECHNICAL AND PAVING	PHONE: 757-322-4411 FAX: 757-322-4280 EMAIL: nothnage@efdlant.navfac.navy.mil	DATE 9/10/98

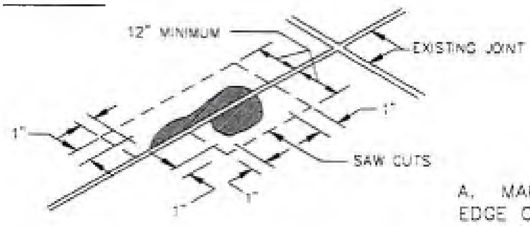
TITLE		
REPAIR TAXIWAY ALPHA/BRAVO NAVAL AIR STATION, FALLON, NEVADA R22-96		**TYPE OF REVIEW**
		35%
	X	100%
		FINAL

DWG. NO. OR PAR NO.	**COMMENTS** (MAKE GENERAL COMMENTS AFTER SPECIFIC COMMENTS)	**ACTION TAKEN** (& REASONS WHERE SIGNIFICANT)
GENERAL COMMENT	THE SELECTION OF THE REPAIR METHOD APPEARS CORRECT. THE AGE OF THE PAVEMENT WOULD INDICATE THAT LOAD AND WEATHERING HAS TAKEN ITS TOLL. THIS IS INDICATIVE OF TYPICAL NAVY PAVEMENTS. WE ARE CURRENTLY REPLACING KEEL SECTIONS IN ROTA AND OCEANA. IN AREAS THAT CAN TOLERATE IT WE HAVE USED ASPHALT OVERLAYS AS STOP GAPS. ROTA'S PARALLEL TAXIWAY HAS HAD AN ASPHALT OVERLAY FOR 10 YEARS. THE ARE SOME CAUTIONS THAT I HAVE THAT DID NOT APPEAR EXPICITLY IN THE SPECIFICATION OR DRAWINGS.	
DEMOLITION 02220 PG 3	THIS PARAGRAPH ELUDES TO SAW CUTTING. WE HAVE FOUND THAT THE REMAINING PAVEMENT CAN AND IS SERIOUSLY DAMAGED BY THE REMOVAL OF THE ADJACENT SLABS. I REQUIRE THAT THE PAVEMENT TO BE REMOVED BE SAW CUT COMPLETELY THROUGH BETWEEN 3" TO 6" FROM THE EDGE OF THE SLAB TO REMAIN. THIS MAY ALSO REQUIRE ANOTHER SAW CUT IN THE JOINT IF THERE IS STEEL PRESENT. AT ROOSEVELT ROADS, THE SLAB TO REMAIN WAS FRACTURED FROM UNDERNEATH WHEN THIS SAW CUTTING WAS NOT DONE. THE FRACTURES DID NOT APPEAR IN THE SURFACE FOR OVER 12 MONTHS. THIS HAPPENED AGAIN AT OCEANA. THEN WE STARTED SAW CUTTING.	
PAVEMENT SECTION	I RAN THE SECTION ON TWO DIFFERENT PROGRAMS. THE THICKNESS APPEARS CORRECT FOR THE SILTY SAND SUBGRADE, FROST, AND 150,000 F-14'S AND 150,000 FA-18'S.	
BASE COURSE	SINCE THERE IS AMPLE CONCRETE TO BE REMOVED, I WOULD ALLOW THE CONTRACTOR TO CRUSH AND RE-USE THE EXISTING CONCRETE AS BASE COURSE IN THE NEW PAVEMENT SECTION. WE HAVE FOUND THAT THE CBR VALUES OF CRUSHED CONCRETE EXCEED 100. ALL THAT IS REQUIRED IS TO MODIFY SECTION 02721.2.1 AND ALLOW THE SOURCE TO BE THE EXISTING CONCRETE AND MUST MEET ALL OF THE ABOVE STATED REQUIREMENTS IN THE SPECIFICATION.	
SPEC 02711.2.1.3.b	NEED TO SUPPLY GRADATION FOR THE BITUMINOUS BASE COURSE.	

C1.0	THE USE OF THE TERM "SHOULDER" CONFUSES ME BECAUSE IT IS ON THE TAXIWAY AND IS NOT THE SHOULDER. JUST SAY "PCC SLABS ALONG EDGE TO REMAIN"	
C4.0	STA 10+251, REMOVE THIS SLAB RATHER THAN SPALL REPAIR. SPALL REPAIR COST ALMOST EXCEEDS THE SLAB REPLACEMENT COST AND YOU STILL HAVE A PATCHED SLAB.	
C5.0	WE DO NOT USE TRIANGULAR OR ANY SHAPE OTHER THAN SQ OR RECTANGULAR AND THE SMALLEST DIMENSION IS NEVER LESS THAN 304MM (12").	
C9.0	I PREFER TO USE AN EPOXY RESIN TO BOND THE FRESH CONCRETE TO THE EXISTING CONCRETE. SEE ENCLOSED DETAIL SHEET. I ALSO PREFER AS STATED ABOVE TO PATCH NEVER LESS THAN 12" IN ANY HORIZONTAL DIRECTION. THE PATCHES BOND BETTER THAN THE SMALL PATCHES. GOOD DETAILS.	
SPEC 2762	I SEE THAT YOU STILL SPECIFY SS-S-1614. LANTDIV AND SOUTHDIV HAVE GONE TO SLICONE SEALANTS ALMOST EXCLUSIVELY. WE FOUND THAT OUR PCC PAVEMENTS ARE DOING MUCH BETTER AFTER 10 YEARS IN SOME CASES SINCE THE JOINT SEAL DOES WHAT IT IS SUPPOSE TO DO. IT EVEN BONDS TO DIRTY JOINTS. BUT AFTER 10 YEARS AT SOME FIELDS TO STILL CONTINUES TO PERFORM EXCELLENTLY. THERE IS A GUIDE SPEC ON CCB. IF NOT CALL ME IF YOU WOULD PREFER TO USE. IT.	
BASIS OF DESIGN, PG 5	SUBRADE SOIL CONDITIONS: SUBGRADE MODULUS IS NOT EXPRESSED IN KPA OR PSI IT IS PSI/I OR LB/IN3 OR KG/CM2/CM OR KPA/M	
JOINT CLEANING AND RESEAL	I SEE IN THE ESTIMATE A LINE ITEM FOR CLEANING AND RESEALING OF JOINTS. I DO NOT SEE ANYTHING ON THE DRAWINGS THAT WOULD INDICATE TO THE CONTRACTOR TO CLEAN AND RESEAL THE JOINTS.	

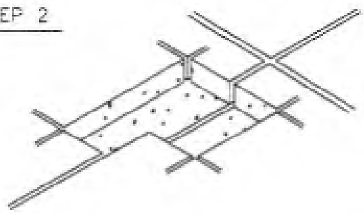
RECOMMENDED METHOD FOR SPALL REPAIRS

STEP 1



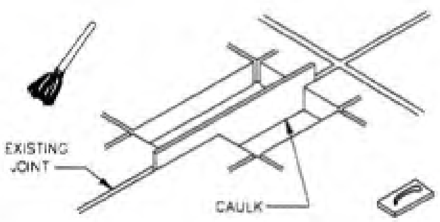
A. MAKE SAW CUT AT LEAST 1 INCH BEYOND THE OUTER EDGE OF THE AREA OF DAMAGED CONCRETE, SAWING NOT LESS THAN 3 INCHES DEEP.

STEP 2



A. REMOVE ALL SPALLED PCC DOWN TO FIRM SOUND CONCRETE (INDICATED BY A RINGING TONE WHEN TAPPED WITH A STEEL BAR), PROVIDING A MINIMUM OF 2.5 INCHES DEPTH OF CONCRETE REMOVAL. REMOVE ALL LOOSE MATERIAL AND DUST FROM THE AREA BY AIR BLASTING.

STEP 3



A. MAINTAIN THE WORKING JOINT BY USE OF A FIBERBOARD OR OTHER SUITABLE INSERT MATERIAL. CAULK THE BASE OF THE INSERT TO PREVENT MATERIAL FROM ENTERING THE VOID AREA BETWEEN THE INSERT AND THE CONCRETE TO REMAIN. OILS, WAXES, GREASE, OR SILICONES SHOULD NOT BE USED ON THE INSERT SINCE BONDING OF THE JOINT SEALING MARETIALS WOULD BE PREVENTED.

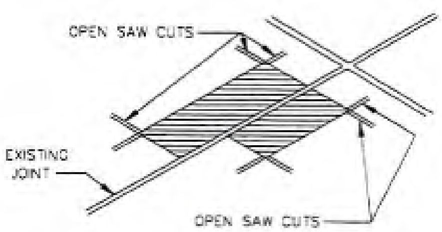
B. THOROUGHLY CLEAN THE AREA BY AIR JET TO REMOVE ALL RESIDUAL FINES. CAREFULLY CHECK THAT NO TRACE OF OIL, GREASE, OR MATERIALS THAT WOULD PREVENT CONCRETE FROM BONDING ARE PRESENT.

C. IMMEDIATELY PRIOR TO PLACEMENT OF NEW CONCRETE, THE SURFACE OF THE CAVITY (EXCEPT THE FACE OF THE WORKING JOINT) SHALL BE COATED WITH EPOXY BINDER. APPLY THE BINDER IN A RELATIVELY THIN COAT SCRUBBED INTO THE CONCRETE SURFACE WITH A STIFF BRISTLE BRUSH.

D. PLACEMENT OF THE CONCRETE SHALL BE STARTED IMMEDIATELY UPON THE APPLIED BINDER BECOMING "TACKY".

E. CAREFULLY REMOVE THE INSERT BEFORE THE CONCRETE HARDENS TO A HIGH BOND. SLIGHTLY TOOL THE EDGES.

STEP 4



A. FINISH CONCRETE TO GRADE. EXCESS MORTAR OR BINDER CARRIED OVER THE PAVEMENT SHALL BE REMOVED. FINALLY, OPEN SAW CUTS ARE TO BE FILLED WITH A SAND AND EPOXY RESIN BINDER.

APPENDIX D

SAWCUT JOINT SPECIFICATIONS

(FAA ITEM P-605)

ITEM P-605
SAWCUT JOINTS
JOINT SEALING FILLER

DESCRIPTION

605-1.1 This item shall consist of providing and installing a resilient joint filler capable of effectively sealing joints and cracks in pavements. This item shall also include sawcutting longitudinal and transverse joints the full width and length of the reconstructed apron and Taxiway B area.

MATERIALS

605-2.1 JOINT SEALERS. Joint sealing material shall be Craft Co. No. 221 crackseal. Joint sealing materials shall meet the requirements of ASTM D 3405 Modified.

CONSTRUCTION METHODS

605-3.1 SAWCUT JOINT. Continuous sawcut joints shall be provided for in the longitudinal and transverse direction full length and width of the apron and Taxiway surface. Longitudinal and transverse joints shall be spaced at 25 feet on center.

The depth of the cut joint shall be a minimum of 2-inches with a minimum width of one-half inch (½") for a depth of 5/8". The width below 5/8" shall be one-quarter inch (¼"). Backing tape shall be placed at the change in joint width as shown on the plans. The new asphaltic concrete surface shall have adequate curing time prior to commencing with making the sawcut joint. Sawing shall not occur while the pavement is hot. Pavement temperature should be maintained under 65°F (18°C) during all sawing.

Prior to placing any joint filler, the sawcut joint shall be blown clean of all loose material and residue from the sawcut operation as specified within this section.

605-3.2 PREPARATION OF JOINTS. Immediately before sealing, the joints shall be thoroughly cleaned of all laitance, curing compound, and other foreign material. Cleaning shall be accomplished by high pressure water blast. Upon completion of cleaning, the joints shall be blown out with compressed air. The joint faces shall be surface dry when the seal is applied.

605-3.3 TIME OF APPLICATION. Joints shall be sealed as soon after completion of the curing period as feasible and before the pavement is opened to traffic, including construction equipment. The pavement temperature shall be above 50°F (10°C) at the time of installation of the poured joint sealing material.

605-3.4 INSTALLATION OF SEALANTS. Joints shall be inspected for proper width, depth, alignment, and preparation, and shall be approved by the Engineer before sealing is allowed. Sealants shall be installed in accordance with the following requirements:

Hot Poured Sealants. The joint sealing compound shall be applied by means of pressure equipment that will force the sealing material to the bottom of the joint and leave the sealing material depressed as shown on the contract plans.

The heating kettle shall be an indirect heating type, constructed as a double boiler. A positive temperature control and mechanical agitation shall be provided. The sealant shall not be heated to more than 20°F (11°C) below the safe heating temperature. The safe heating temperature can be obtained from the manufacturer's shipping container. A direct connecting pressure type extruding device with nozzles shaped for insertion into the joint shall be provided. Any sealant spilled on the surface of the pavement shall be removed immediately.

Sealant which does not bond to the asphaltic concrete surface of the joint walls, contains voids, or fails to set to a tack-free condition will be rejected and replaced by the Contractor at no additional cost. Before sealing the joints, the Contractor shall demonstrate that the equipment and procedures for preparing, mixing, and placing the sealant will produce a satisfactory joint seal. This shall include the preparation of two small batches and the application of the resulting material.

METHOD OF MEASUREMENT

605-4.1 Joint cutting and sealing material shall be measured by the linear foot of sealed joint in place, complete, and accepted.

BASIS OF PAYMENT

605-5.1 Payment for joint cutting sealant material shall be made at the contract unit price per linear foot. The price shall be full compensation for furnishing all materials, for all preparation, delivering, and placing of these materials, and for all labor, equipment, tools, and incidentals necessary to complete the item.

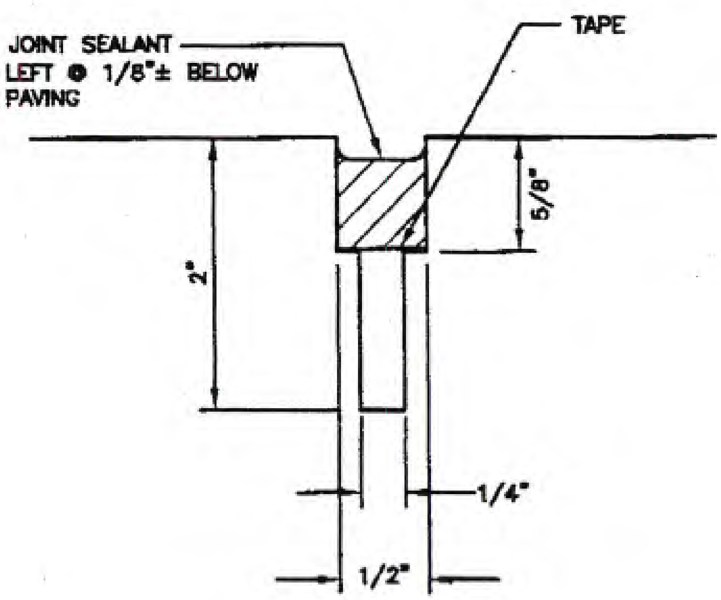
Payment will be made under:

Item P-605-5.1	Joint Cutting and Sealant - per linear foot

MATERIAL REQUIREMENTS

ASTM D 3405 Modified	Joint Sealants, Hot-Poured, for Concrete and Asphalt Pavements

END OF ITEM P-605



WEAKENED PLANE CONTROL JOINT 11/9

N.T.S.

ASBUILTS 11-22-96

APPENDIX E

ECONOMIC ANALYSIS OF ALTERNATIVES

FOR

AC PORTION OF RUNWAY 13R-31L

DATE GENERATED: 06 Jul 1999
TIME GENERATED: 11:07:37
VERSION: ECONPACK for Windows 1.02

PAVEMENT ALTERNATIVES
ECONOMIC ANALYSIS

EXECUTIVE SUMMARY REPORT

PROJECT TITLE : NAVAL AIR STATION, FALLON, NEVADA
DISCOUNT RATE : 2.9%
PERIOD OF ANALYSIS : 26 Years
START YEAR : 1999
BASE YEAR : 1999
REPORT OUTPUT : Constant Dollars

PROJECT OBJECTIVE : To evaluate various M&R and new pavement alternatives to the asphalt portion of Runway 13R-31L.

ALTERNATIVES CONSIDERED FOR THIS ANALYSIS:

A. Background

The asphalt concrete portion of Runway 13R-31L had major repair performed during the summer of 1997 which included repair of existing cracks and provided a two-inch overlay. Thermal cracking became noticeable in January 1998. NAVFAC (EFD Southwest) 1998 strength evaluation and the 1999 surface condition evaluation found this pavement to be in very good condition. This situation has resulted in an NFESC study, funded by CINCPACFLT, to determine performance characteristics of asphalt concrete in this high desert region.

B. Objective

To evaluate various maintenance and repair (M&R) and new pavement alternatives to the asphalt portion of Runway 13R-31L and a completely new all Portland Cement concrete runway parallel and outboard to the existing runway.

C. Description of Alternatives

1. Status Quo. Seal the cracks and maintain the pavement until such time in the future when the Pavement Condition Index (PCI) falls below the critical PCI of 70. At that time, select one of the alternatives below based on re-evaluated economic conditions at that time and operational concerns for implementation.

2. New Asphalt Concrete Overlay. Install a two-inch asphalt concrete overlay using the proper SHRP performance grade of asphalt cement for the temperature conditions at NAS Fallon. Expect this asphalt cement to retard reflection cracking but expect the existing cracks to reflect through eventually. Seal the cracks and maintain the pavement as in alternative 1.

3. New Asphalt Concrete Pavement. Remove the entire pavement concrete structure including the base and install a new base and AC surface course using proper SHRP performance grade of asphalt cement for the temperature conditions at NAS Fallon and expect cracks to appear eventually. Seal cracks and maintain the pavement as in alternative 1.

4. New Asphalt Concrete Pavement with Sawed Joints. Remove the entire pavement concrete structure including the base and install a new base and AC surface course using proper SHRP performance grade of asphalt cement for the temperature conditions at NAS Fallon. Saw cut joints in both longitudinal and transverse directions to obtain 25 foot square slabs. Seal the joints and maintain the pavement as deemed necessary.

5. New Portland Cement Concrete Pavement. Remove the entire pavement structure including the base and install a new base and Portland cement concrete pavement. Seal the joints and maintain the pavement as deemed necessary.

ASSUMPTIONS OF THE ANALYSIS:

A. Time-Value of Money

1. The discount rate used in this analysis is 2.9%. This rate was obtained from Appendix C of the OMB Circular A-94 (Revised January 1999).

2. The base year will be Fiscal Year 1999.

3. Project life of 26 years will be used. This is calculated as a 25-year economic life for airfield pavements, and a 12 month "construction" period.

4. An End-of-Year cost convention will be used.

B. Construction / Design Criteria

1. Status Quo: No initial construction cost is associated with this alternative. Major maintenance and repair consist of crack sealing and surface treatment to eliminate the threat of foreign object damage (FOD) resulting from the pavement itself. The current asphalt concrete surface will be crack sealed in 1999 and maintained on an as-needed basis. For this analysis it is assumed the cracks will be sealed properly thereby reducing the frequency of global crack sealing to every 3 years. Surface treatment consisting of a single bituminous spray (fog seal) to be applied on the existing surface in 1999. An additional surface treatment to be applied three years after the completion of the fog seal.

2. New Asphalt Concrete Overlay: The current asphalt concrete surface will be crack sealed as-needed and a two-inch asphalt concrete overlay will be installed. Major maintenance and repair is the same as the status quo alternative beginning the second year after the new asphalt concrete overlay is placed.

3. New Asphalt Concrete Pavement: Replace the existing asphalt concrete section with a new asphalt concrete section. Major maintenance and repair consist of crack sealing, surface treatments and overlays. Frequency of maintenance is based on the 44 year actual maintenance history of the existing asphalt concrete pavement. Global crack sealing to be completed every 3 years. Surface treatment consisting of a single bituminous spray (fog seal) to be applied on the new overlay (and every additional overlay) two years after overlay is completed. An additional surface treatment to be applied three years after the completion of each fog seal. A two-inch asphalt concrete overlay will be installed every nine years.

4. New Asphalt Concrete Pavement With Sawed Joints: Replace the existing asphalt concrete section with a new asphalt concrete section and saw cut joints to obtain 25 foot square slabs. Major maintenance and repair consist of global joint sealing and spall & joint repair. Frequency of maintenance is based on the 34 and 45 year actual maintenance histories of the existing Portland cement concrete pavement at the ends of Runway 13R-31L and the recent history of the asphalt concrete pavement with sawed joints on Runway 8-26 at Stead Airport. A two-inch asphalt concrete

overlay with saw cut joints will be installed every 18 years. A surface treatment (fog seal) to be applied at three year intervals. Global joint sealing and spall & joint repair to be completed twelve years after initial construction and at 18 years (prior to the new overlay).

5. New Portland Cement Concrete Pavement: Replace the existing asphalt concrete section with a new Portland cement concrete section. Major maintenance and repair consist of global joint sealing and spall & joint repair. Frequency of maintenance is based on the 34 and 45 year actual maintenance histories of the existing Portland cement concrete pavement at the ends of Runway 13R-31L. Global joint sealing and spall & joint repair to be completed at 12, 18 and 24 years after initial construction.

C. Cost Related:

1. In all alternatives operations and maintenance costs go up as the PCI of the pavement goes down. Pavement age multipliers (cost per square yard of pavement surface) for predicted PCI of each pavement surface type were used. Actual costs used are from the PCI vs Cost Table in PAVER (pavement management program used on all Naval Air Stations). Predicted PCI is based on straight line prediction models using actual data from NAS Fallon (asphalt concrete and Portland cement concrete pavements) and Stead Airport (asphalt concrete pavement with sawed joints).

2. Land value on the installation will not be considered.

3. Terminal value will be equal in all alternatives therefore terminal value will not be considered.

D. Economic Life:

The economic life of airfield pavements is 25 years which was obtained from Appendix A, Reference Code A1 of the NAVFAC Economic Life Analysis Consolidated Report (dated 24 February 1999).

E. Sustainable Materials:

Estimates of material costs used in this analysis do not include sustainable or "green" materials. Initially, "green" or recycled materials and processes may cost more than the materials historically used. However, the durability of these new materials may provide an overall lower life-cycle cost of the facility. The repair alternative or the status quo, would have limited opportunity to use new "green" technology. Further study and economic analysis should be completed to determine if sustainable materials are more beneficial if alternatives 3,4 or 5 are considered. For the purpose of this analysis it is assumed that the use of "green" materials will not substantially alter the cost analysis of any of the alternatives.

ECONOMIC INDICATORS:

ALTERNATIVE NAME	NPV	SIR	DPP	BIR
1 Status Quo	$6,750,164	N/A	N/A	N/A
2 New Asphalt Concrete Overlay	$8,898,349	0.74	N/A	N/A
3 New Asphalt Concrete Pavement	$39,284,692	0.16	N/A	N/A
4 New Asphalt Concrete Pavement with	$38,067,351	0.17	N/A	N/A
5 New Portland Cement Concrete Paveme	$40,067,488	0.16	N/A	N/A

NON-MONETARY COSTS AND BENEFITS:

A. Foreign Object Damage (FOD)

Analysis of results from previous studies and published information (NFESC. Memorandum: Causes of Foreign Object Damage (FOD) to Aircraft engines. ESC63/MCH/D14-11, 13 March 1998) indicate that material originating from the pavement matrix account for only a small percentage of foreign object debris (FO). The percentage would be a small percent of all types of rock and sand products attributable to FO. Rock, sand and ice type FO cause about five percent of FOD. Pavement fragments, if any, represents only a fraction of the five percent. FO removal would be considered part of the O&M costs which, in this analysis, O&M costs escalate as the pavement surface ages.

B. Disruption and Interruption to the Mission (25 years)

Status Quo. Mission will be interrupted by two overlays, six surface treatments and global crack sealing every three years.

New Asphalt Concrete Overlay. Mission will be interrupted by three overlays, six surface treatments and global crack sealing every three years.

New Asphalt Concrete Pavement. Mission will be disrupted by initial construction and interrupted by two overlays, six surface treatments and global crack sealing every three years.

New Asphalt Concrete Pavement With Sawed joints. Mission will be disrupted by initial construction and interrupted by one overlay, six surface treatments and global joint sealing (and spall & joint repair) two times.

New Portland Cement Concrete Pavement. Mission will be disrupted by initial construction and interrupted by global joint sealing (and joint & spall repair) three times.

RESULTS AND RECOMMENDATIONS:

A. Discussion of Alternatives

The status quo alternative is the least cost alternative to the government with a 25 year life cycle cost of $6.75M (NPV), followed by a new asphalt concrete overlay at $8.90M (NPV). All remove and replace alternatives are between $38.1M and $40.1M (NPV). Life cycle cost reports, which tabulates each expense item, total annual outlays, end-of-year discount factors, present values and cumulative net present values for each economic year and for each alternative, are on Pages 9 - 25 in this economic analysis report.

B. Discussion of Cost Sensitivity Analysis

In determining which expense items should be used for a cost sensitivity analysis, a preview report of the Life Cycle cost for each alternative was screened to find the expense items with the greatest potential for variance. These are expense items that make up the largest percentage of the Net Present value or can fluctuate based on local conditions or uncertainty.

The only significant expense item is the initial construction costs. Performing a sensitivity analysis on this expense item and others, the status quo is insensitive to all alternatives except the alternative for a new asphalt concrete overlay. If the expense of the initial overlay is reduced by more than 35.8%, the least cost alternative would be to overlay instead of the status quo. However, if a removal and replacement alternative will be considered in the future, the three alternatives change rankings as the least cost alternative and should be re-evaluated at the time these alternatives are considered.

C. Discussion of Discount Rate Sensitivity Analysis

The Discount Rate was allowed to vary according to the default ECONPACK settings. This resulted in an analysis range from a low of 0.4% to a high of 5.4%. An analysis discount rate of 2.9% was prescribed by OMB Circular A-94. The results show that should the discount rate decrease to 1.6% NPV rankings will change between the remove and replace alternatives. However, the status quo alternative is insensitive to the discount rate with all other alternatives.

D. Non Monetary Benefits for Various Alternatives

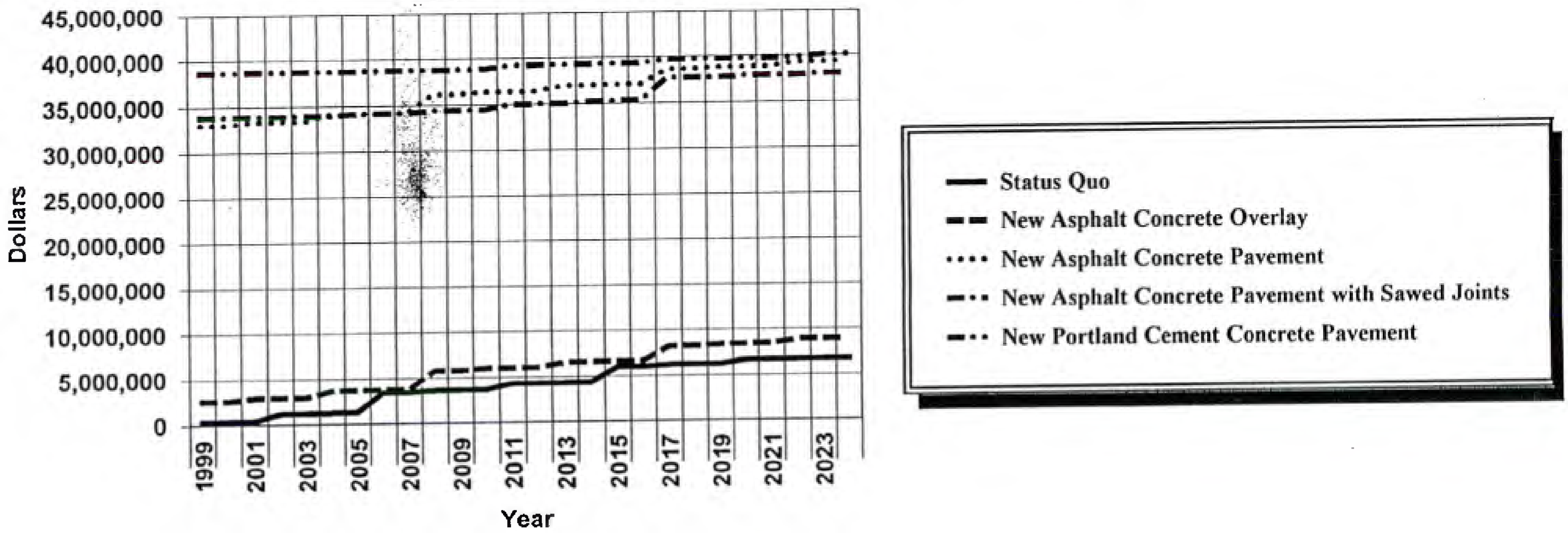
In this analysis, the non-quantifiable benefits (or costs) were not used to determine quantifiable impact on any of the alternatives.

E. Recommendation

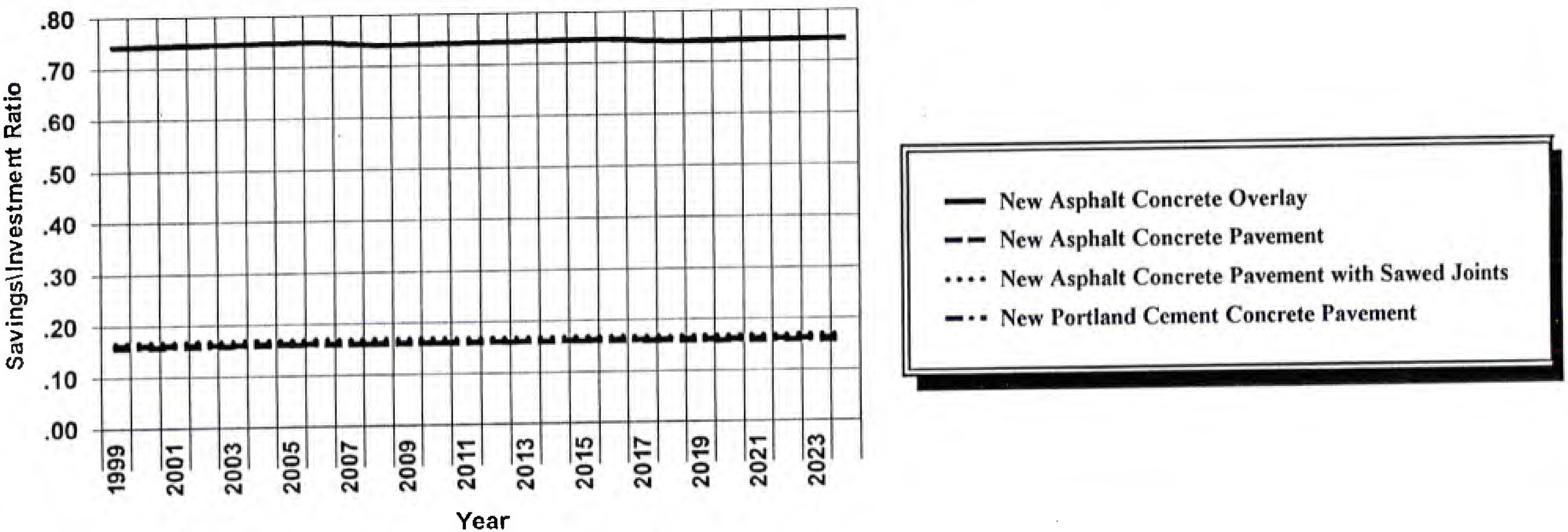
The results of this analysis indicate that the status quo is the least costly. At the time this pavement falls below a PCI of 70 (anticipate around FY2006) a new alternative should be selected based on re-evaluated economic conditions at the time and operational concerns for implementation.

ACTION OFFICER: Gregory D. Cline
ORGANIZATION : NFESC

ECONOMIC ANALYSIS GRAPH 1
Cumulative Net Present Value



SIR ECONOMIC ANALYSIS GRAPH 1
SIR Vs. Years



LIFE CYCLE COST REPORT

1 Status Quo

YEAR	Overlay (1)	Surface Treatment (2)	Crack Seal - Global (3)	O & M (4)	TOTAL ANNUAL OUTLAYS
1999	$0	$270,000	$34,776	$16,000	$320,776
2000	$0	$0	$0	$22,000	$22,000
2001	$0	$0	$0	$26,000	$26,000
2002	$0	$810,000	$34,776	$32,000	$876,776
2003	$0	$0	$0	$38,000	$38,000
2004	$0	$0	$0	$42,000	$42,000
2005	$0	$0	$34,776	$48,000	$82,776
2006	$2,600,000	$0	$0	$52,000	$2,652,000
2007	$0	$0	$0	$6,000	$6,000
2008	$0	$270,000	$34,776	$10,000	$314,776
2009	$0	$0	$0	$16,000	$16,000
2010	$0	$0	$0	$22,000	$22,000
2011	$0	$810,000	$34,776	$26,000	$870,776
2012	$0	$0	$0	$32,000	$32,000
2013	$0	$0	$0	$38,000	$38,000
2014	$0	$0	$34,776	$42,000	$76,776
2015	$2,600,000	$0	$0	$48,000	$2,648,000
2016	$0	$0	$0	$52,000	$52,000
2017	$0	$270,000	$34,776	$6,000	$310,776
2018	$0	$0	$0	$10,000	$10,000
2019	$0	$0	$0	$16,000	$16,000
2020	$0	$810,000	$34,776	$22,000	$866,776
2021	$0	$0	$0	$26,000	$26,000
2022	$0	$0	$0	$32,000	$32,000
2023	$0	$0	$34,776	$38,000	$72,776
2024	$0	$0	$0	$42,000	$42,000
%NPV	54.34	34.59	3.28	7.80	
	$3,667,709	$2,335,022	$221,165	$526,267	
DISCOUNTING CONVENTION	E-O-Y	E-O-Y	E-O-Y	E-O-Y	
INFLATION INDEX	No Inflation	No Inflation	No Inflation	No Inflation	

LIFE CYCLE COST REPORT

1 Status Quo

YEAR	END OF YEAR DISCOUNT FACTORS	PRESENT VALUE	CUMULATIVE NET PRESENT VALUE
1999	0.972	$311,736	$311,736
2000	0.944	$20,777	$332,513
2001	0.918	$23,863	$356,376
2002	0.892	$782,037	$1,138,413
2003	0.867	$32,939	$1,171,352
2004	0.842	$35,380	$1,206,732
2005	0.819	$67,764	$1,274,495
2006	0.796	$2,109,845	$3,384,340
2007	0.773	$4,639	$3,388,979
2008	0.751	$236,509	$3,625,488
2009	0.730	$11,683	$3,637,171
2010	0.710	$15,611	$3,652,782
2011	0.690	$600,491	$4,253,273
2012	0.670	$21,445	$4,274,719
2013	0.651	$24,749	$4,299,468
2014	0.633	$48,594	$4,348,061
2015	0.615	$1,628,758	$5,976,819
2016	0.598	$31,083	$6,007,903
2017	0.581	$180,532	$6,188,435
2018	0.565	$5,645	$6,194,080
2019	0.549	$8,778	$6,202,859
2020	0.533	$462,135	$6,664,993
2021	0.518	$13,472	$6,678,465
2022	0.504	$16,113	$6,694,578
2023	0.489	$35,613	$6,730,191
2024	0.476	$19,973	$6,750,164

2.9% DISCOUNT RATE, 26 YEARS

LIFE CYCLE COST REPORT

2 New Asphalt Concrete Overlay

YEAR	Overlay (1)	Surface Treatment (2)	Crack Seal - Global (3)	O & M (4)	TOTAL ANNUAL OUTLAYS
1999	$2,600,000	$0	$34,776	$6,000	$2,640,776
2000	$0	$0	$0	$10,000	$10,000
2001	$0	$270,000	$34,776	$16,000	$320,776
2002	$0	$0	$0	$22,000	$22,000
2003	$0	$0	$0	$26,000	$26,000
2004	$0	$810,000	$34,776	$32,000	$876,776
2005	$0	$0	$0	$38,000	$38,000
2006	$0	$0	$0	$42,000	$42,000
2007	$0	$0	$34,776	$48,000	$82,776
2008	$2,600,000	$0	$0	$52,000	$2,652,000
2009	$0	$0	$0	$6,000	$6,000
2010	$0	$270,000	$34,776	$10,000	$314,776
2011	$0	$0	$0	$16,000	$16,000
2012	$0	$0	$0	$22,000	$22,000
2013	$0	$810,000	$34,776	$26,000	$870,776
2014	$0	$0	$0	$32,000	$32,000
2015	$0	$0	$0	$38,000	$38,000
2016	$0	$0	$34,776	$42,000	$76,776
2017	$2,600,000	$0	$0	$48,000	$2,648,000
2018	$0	$0	$0	$52,000	$52,000
2019	$0	$270,000	$34,776	$6,000	$310,776
2020	$0	$0	$0	$10,000	$10,000
2021	$0	$0	$0	$16,000	$16,000
2022	$0	$810,000	$34,776	$22,000	$866,776
2023	$0	$0	$0	$26,000	$26,000
2024	$0	$0	$0	$32,000	$32,000
%NPV	67.32 $5,990,615	24.78 $2,205,262	2.55 $226,599	5.35 $475,872	
DISCOUNTING CONVENTION	E-O-Y	E-O-Y	E-O-Y	E-O-Y	
INFLATION INDEX	No Inflation	No Inflation	No Inflation	No Inflation	

LIFE CYCLE COST REPORT

2 New Asphalt Concrete Overlay

YEAR	END OF YEAR DISCOUNT FACTORS	PRESENT VALUE	CUMULATIVE NET PRESENT VALUE
1999	0.972	$2,566,352	$2,566,352
2000	0.944	$9,444	$2,575,796
2001	0.918	$294,412	$2,870,208
2002	0.892	$19,623	$2,889,831
2003	0.867	$22,537	$2,912,368
2004	0.842	$738,578	$3,650,946
2005	0.819	$31,108	$3,682,054
2006	0.796	$33,414	$3,715,468
2007	0.773	$63,998	$3,779,466
2008	0.751	$1,992,598	$5,772,065
2009	0.730	$4,381	$5,776,446
2010	0.710	$223,366	$5,999,812
2011	0.690	$11,034	$6,010,845
2012	0.670	$14,744	$6,025,589
2013	0.651	$567,121	$6,592,710
2014	0.633	$20,254	$6,612,964
2015	0.615	$23,373	$6,636,337
2016	0.598	$45,893	$6,682,231
2017	0.581	$1,538,246	$8,220,477
2018	0.565	$29,356	$8,249,833
2019	0.549	$170,500	$8,420,333
2020	0.533	$5,332	$8,425,664
2021	0.518	$8,290	$8,433,955
2022	0.504	$436,453	$8,870,408
2023	0.489	$12,723	$8,883,131
2024	0.476	$15,218	$8,898,349

2.9% DISCOUNT RATE, 26 YEARS

PRIMARY ECONOMIC ANALYSIS

Status Quo Alternative: Status Quo
Proposed Alternative : New Asphalt Concrete Overlay

Project Year(s)	Recurring Annual Operating Costs Status Quo Alternative	Proposed Alternative	Differential Costs	Present Value Factor	Present Value of Differential Costs
1999	$16,000	$6,000	$10,000	0.972	$9,718
2000	$22,000	$10,000	$12,000	0.944	$11,333
2001	$26,000	$16,000	$10,000	0.918	$9,178
2002	$32,000	$22,000	$10,000	0.892	$8,919
2003	$38,000	$26,000	$12,000	0.867	$10,402
2004	$42,000	$32,000	$10,000	0.842	$8,424
2005	$48,000	$38,000	$10,000	0.819	$8,186
2006	$52,000	$42,000	$10,000	0.796	$7,956
2007	$6,000	$48,000	-$42,000	0.773	-$32,472
2008	$10,000	$52,000	-$42,000	0.751	-$31,557
2009	$16,000	$6,000	$10,000	0.730	$7,302
2010	$22,000	$10,000	$12,000	0.710	$8,515
2011	$26,000	$16,000	$10,000	0.690	$6,896
2012	$32,000	$22,000	$10,000	0.670	$6,702
2013	$38,000	$26,000	$12,000	0.651	$7,815
2014	$42,000	$32,000	$10,000	0.633	$6,329
2015	$48,000	$38,000	$10,000	0.615	$6,151
2016	$52,000	$42,000	$10,000	0.598	$5,978
2017	$6,000	$48,000	-$42,000	0.581	-$24,398
2018	$10,000	$52,000	-$42,000	0.565	-$23,711
2019	$16,000	$6,000	$10,000	0.549	$5,486
2020	$22,000	$10,000	$12,000	0.533	$6,398
2021	$26,000	$16,000	$10,000	0.518	$5,181
2022	$32,000	$22,000	$10,000	0.504	$5,035
2023	$38,000	$26,000	$12,000	0.489	$5,872
2024	$42,000	$32,000	$10,000	0.476	$4,756
Totals	$760,000	$696,000	$64,000		$50,395

PRIMARY ECONOMIC ANALYSIS

Total present value of investment	$8,422,477
Plus: present value of existing assets to be used	$0
Less: present value of existing assets replaced	$0
Less: present value of proposed alternative salvage value	$0
Total present value of net investment	$8,422,477
Total present value of differential costs	$50,395
Plus: present value of status quo investment costs eliminated	$6,223,897
Less: present value of status quo salvage value	$0
Total present value of savings	$6,274,292
Savings/Investment Ratio	0.74

SIR is less than one at end of period of analysis

For Status Quo:

Recurring Costs - Expense Item(s)	4		
Investment Costs - Expense Item(s)	1	2	3

For Proposed Alternative:

Recurring Costs - Expense Item(s)	4		
Investment Costs - Expense Item(s)	1	2	3

LIFE CYCLE COST REPORT

3 New Asphalt Concrete Pavement

YEAR	Initial Construction (1)	Overlay (2)	Surface Treatment (3)	Crack Seal - Global (4)	O & M (5)
1999	$33,900,000	$0	$0	$0	$6,000
2000	$0	$0	$0	$0	$10,000
2001	$0	$0	$270,000	$34,776	$16,000
2002	$0	$0	$0	$0	$22,000
2003	$0	$0	$0	$0	$26,000
2004	$0	$0	$810,000	$34,776	$32,000
2005	$0	$0	$0	$0	$38,000
2006	$0	$0	$0	$0	$42,000
2007	$0	$0	$0	$34,776	$48,000
2008	$0	$2,600,000	$0	$0	$52,000
2009	$0	$0	$0	$0	$6,000
2010	$0	$0	$270,000	$34,776	$10,000
2011	$0	$0	$0	$0	$16,000
2012	$0	$0	$0	$0	$22,000
2013	$0	$0	$810,000	$34,776	$26,000
2014	$0	$0	$0	$0	$32,000
2015	$0	$0	$0	$0	$38,000
2016	$0	$0	$0	$34,776	$42,000
2017	$0	$2,600,000	$0	$0	$48,000
2018	$0	$0	$0	$0	$56,000
2019	$0	$0	$270,000	$34,776	$6,000
2020	$0	$0	$0	$0	$10,000
2021	$0	$0	$0	$0	$16,000
2022	$0	$0	$810,000	$34,776	$22,000
2023	$0	$0	$0	$0	$26,000
2024	$0	$0	$0	$0	$32,000
%NPV	83.86	8.82	5.61	0.49	1.22
	$32,944,606	$3,463,890	$2,205,262	$192,803	$478,130
DISCOUNTING CONVENTION	E-O-Y	E-O-Y	E-O-Y	E-O-Y	E-O-Y
INFLATION INDEX	No Inflation	No Inflation	No Inflation	No Inflation	No Inflation

LIFE CYCLE COST REPORT

3 New Asphalt Concrete Pavement

YEAR	TOTAL ANNUAL OUTLAYS	END OF YEAR DISCOUNT FACTORS	PRESENT VALUE	CUMULATIVE NET PRESENT VALUE
1999	$33,906,000	0.972	$32,950,437	$32,950,437
2000	$10,000	0.944	$9,444	$32,959,882
2001	$320,776	0.918	$294,412	$33,254,294
2002	$22,000	0.892	$19,623	$33,273,917
2003	$26,000	0.867	$22,537	$33,296,454
2004	$876,776	0.842	$738,578	$34,035,032
2005	$38,000	0.819	$31,108	$34,066,140
2006	$42,000	0.796	$33,414	$34,099,554
2007	$82,776	0.773	$63,998	$34,163,552
2008	$2,652,000	0.751	$1,992,598	$36,156,150
2009	$6,000	0.730	$4,381	$36,160,531
2010	$314,776	0.710	$223,366	$36,383,897
2011	$16,000	0.690	$11,034	$36,394,931
2012	$22,000	0.670	$14,744	$36,409,675
2013	$870,776	0.651	$567,121	$36,976,796
2014	$32,000	0.633	$20,254	$36,997,049
2015	$38,000	0.615	$23,373	$37,020,423
2016	$76,776	0.598	$45,893	$37,066,316
2017	$2,648,000	0.581	$1,538,246	$38,604,562
2018	$56,000	0.565	$31,614	$38,636,176
2019	$310,776	0.549	$170,500	$38,806,676
2020	$10,000	0.533	$5,332	$38,812,008
2021	$16,000	0.518	$8,290	$38,820,298
2022	$866,776	0.504	$436,453	$39,256,752
2023	$26,000	0.489	$12,723	$39,269,475
2024	$32,000	0.476	$15,218	$39,284,692

2.9% DISCOUNT RATE, 26 YEARS

PRIMARY ECONOMIC ANALYSIS

Status Quo Alternative: Status Quo
Proposed Alternative : New Asphalt Concrete Pavement

Project Year(s)	Recurring Annual Operating Costs Status Quo Alternative	Recurring Annual Operating Costs Proposed Alternative	Differential Costs	Present Value Factor	Present Value of Differential Costs
1999	$16,000	$6,000	$10,000	0.972	$9,718
2000	$22,000	$10,000	$12,000	0.944	$11,333
2001	$26,000	$16,000	$10,000	0.918	$9,178
2002	$32,000	$22,000	$10,000	0.892	$8,919
2003	$38,000	$26,000	$12,000	0.867	$10,402
2004	$42,000	$32,000	$10,000	0.842	$8,424
2005	$48,000	$38,000	$10,000	0.819	$8,186
2006	$52,000	$42,000	$10,000	0.796	$7,956
2007	$6,000	$48,000	-$42,000	0.773	-$32,472
2008	$10,000	$52,000	-$42,000	0.751	-$31,557
2009	$16,000	$6,000	$10,000	0.730	$7,302
2010	$22,000	$10,000	$12,000	0.710	$8,515
2011	$26,000	$16,000	$10,000	0.690	$6,896
2012	$32,000	$22,000	$10,000	0.670	$6,702
2013	$38,000	$26,000	$12,000	0.651	$7,815
2014	$42,000	$32,000	$10,000	0.633	$6,329
2015	$48,000	$38,000	$10,000	0.615	$6,151
2016	$52,000	$42,000	$10,000	0.598	$5,978
2017	$6,000	$48,000	-$42,000	0.581	-$24,398
2018	$10,000	$56,000	-$46,000	0.565	-$25,969
2019	$16,000	$6,000	$10,000	0.549	$5,486
2020	$22,000	$10,000	$12,000	0.533	$6,398
2021	$26,000	$16,000	$10,000	0.518	$5,181
2022	$32,000	$22,000	$10,000	0.504	$5,035
2023	$38,000	$26,000	$12,000	0.489	$5,872
2024	$42,000	$32,000	$10,000	0.476	$4,756
Totals	$760,000	$700,000	$60,000		$48,137

PRIMARY ECONOMIC ANALYSIS

Total present value of investment	$38,806,562
Plus: present value of existing assets to be used	$0
Less: present value of existing assets replaced	$0
Less: present value of proposed alternative salvage value	$0
Total present value of net investment	$38,806,562
Total present value of differential costs	$48,137
Plus: present value of status quo investment costs eliminated	$6,223,897
Less: present value of status quo salvage value	$0
Total present value of savings	$6,272,034
Savings/Investment Ratio	0.16

SIR is less than one at end of period of analysis

For Status Quo:

Recurring Costs - Expense Item(s) 4
Investment Costs - Expense Item(s) 1 2 3

For Proposed Alternative:

Recurring Costs - Expense Item(s) 5
Investment Costs - Expense Item(s) 1 2 3 4

LIFE CYCLE COST REPORT

4 New Asphalt Concrete Pavement with Sawed Joints

YEAR	Initial Construction (1)	Surface Treatment (2)	Overlay (3)	Spall & Joint Repair (4)	Joint Seal - Global (5)
1999	$34,800,000	$0	$0	$0	$0
2000	$0	$0	$0	$0	$0
2001	$0	$0	$0	$0	$0
2002	$0	$0	$0	$0	$0
2003	$0	$0	$0	$0	$0
2004	$0	$0	$0	$0	$0
2005	$0	$270,000	$0	$0	$0
2006	$0	$0	$0	$0	$0
2007	$0	$0	$0	$0	$0
2008	$0	$270,000	$0	$0	$0
2009	$0	$0	$0	$0	$0
2010	$0	$0	$0	$0	$0
2011	$0	$270,000	$0	$334,800	$168,750
2012	$0	$0	$0	$0	$0
2013	$0	$0	$0	$0	$0
2014	$0	$270,000	$0	$0	$0
2015	$0	$0	$0	$0	$0
2016	$0	$0	$0	$0	$0
2017	$0	$0	$3,600,000	$334,800	$168,750
2018	$0	$0	$0	$0	$0
2019	$0	$0	$0	$0	$0
2020	$0	$270,000	$0	$0	$0
2021	$0	$0	$0	$0	$0
2022	$0	$0	$0	$0	$0
2023	$0	$270,000	$0	$0	$0
2024	$0	$0	$0	$0	$0
%NPV	88.84 $33,819,242	2.78 $1,057,060	5.49 $2,091,271	1.12 $425,368	0.56 $214,399
DISCOUNTING CONVENTION	E-O-Y	E-O-Y	E-O-Y	E-O-Y	E-O-Y
INFLATION INDEX	No Inflation	No Inflation	No Inflation	No Inflation	No Inflation

LIFE CYCLE COST REPORT

4 New Asphalt Concrete Pavement with Sawed Joints

YEAR	O & M (6)	TOTAL ANNUAL OUTLAYS	END OF YEAR DISCOUNT FACTORS	PRESENT VALUE	CUMULATIVE NET PRESENT VALUE
1999	$6,000	$34,806,000	0.972	$33,825,073	$33,825,073
2000	$8,000	$8,000	0.944	$7,555	$33,832,628
2001	$10,000	$10,000	0.918	$9,178	$33,841,806
2002	$14,000	$14,000	0.892	$12,487	$33,854,294
2003	$16,000	$16,000	0.867	$13,869	$33,868,163
2004	$20,000	$20,000	0.842	$16,848	$33,885,010
2005	$22,000	$292,000	0.819	$239,043	$34,124,053
2006	$24,000	$24,000	0.796	$19,094	$34,143,146
2007	$26,000	$26,000	0.773	$20,102	$34,163,248
2008	$30,000	$300,000	0.751	$225,407	$34,388,655
2009	$32,000	$32,000	0.730	$23,366	$34,412,021
2010	$36,000	$36,000	0.710	$25,546	$34,437,567
2011	$38,000	$811,550	0.690	$559,649	$34,997,215
2012	$40,000	$40,000	0.670	$26,807	$35,024,022
2013	$42,000	$42,000	0.651	$27,354	$35,051,376
2014	$46,000	$316,000	0.633	$200,005	$35,251,381
2015	$48,000	$48,000	0.615	$29,524	$35,280,905
2016	$50,000	$50,000	0.598	$29,888	$35,310,793
2017	$52,000	$4,155,550	0.581	$2,413,995	$37,724,788
2018	$52,000	$52,000	0.565	$29,356	$37,754,144
2019	$6,000	$6,000	0.549	$3,292	$37,757,436
2020	$8,000	$278,000	0.533	$148,220	$37,905,656
2021	$10,000	$10,000	0.518	$5,181	$37,910,837
2022	$14,000	$14,000	0.504	$7,050	$37,917,887
2023	$16,000	$286,000	0.489	$139,953	$38,057,840
2024	$20,000	$20,000	0.476	$9,511	$38,067,351

%NPV 1.21
$460,010

DISCOUNTING CONVENTION E-O-Y

INFLATION INDEX No Inflation

2.9% DISCOUNT RATE, 26 YEARS

PRIMARY ECONOMIC ANALYSIS

Status Quo Alternative: Status Quo
Proposed Alternative : New Asphalt Concrete Pavement with Sawed Joints

Project Year(s)	Recurring Annual Operating Costs Status Quo Alternative	Proposed Alternative	Differential Costs	Present Value Factor	Present Value of Differential Costs
1999	$16,000	$6,000	$10,000	0.972	$9,718
2000	$22,000	$8,000	$14,000	0.944	$13,222
2001	$26,000	$10,000	$16,000	0.918	$14,685
2002	$32,000	$14,000	$18,000	0.892	$16,055
2003	$38,000	$16,000	$22,000	0.867	$19,070
2004	$42,000	$20,000	$22,000	0.842	$18,532
2005	$48,000	$22,000	$26,000	0.819	$21,285
2006	$52,000	$24,000	$28,000	0.796	$22,276
2007	$6,000	$26,000	-$20,000	0.773	-$15,463
2008	$10,000	$30,000	-$20,000	0.751	-$15,027
2009	$16,000	$32,000	-$16,000	0.730	-$11,683
2010	$22,000	$36,000	-$14,000	0.710	-$9,934
2011	$26,000	$38,000	-$12,000	0.690	-$8,275
2012	$32,000	$40,000	-$8,000	0.670	-$5,361
2013	$38,000	$42,000	-$4,000	0.651	-$2,605
2014	$42,000	$46,000	-$4,000	0.633	-$2,532
2015	$48,000	$48,000	$0	0.615	$0
2016	$52,000	$50,000	$2,000	0.598	$1,196
2017	$6,000	$52,000	-$46,000	0.581	-$26,722
2018	$10,000	$52,000	-$42,000	0.565	-$23,711
2019	$16,000	$6,000	$10,000	0.549	$5,486
2020	$22,000	$8,000	$14,000	0.533	$7,464
2021	$26,000	$10,000	$16,000	0.518	$8,290
2022	$32,000	$14,000	$18,000	0.504	$9,064
2023	$38,000	$16,000	$22,000	0.489	$10,766
2024	$42,000	$20,000	$22,000	0.476	$10,462
Totals	$760,000	$686,000	$74,000		$66,257

PRIMARY ECONOMIC ANALYSIS

Total present value of investment	$37,607,341
Plus: present value of existing assets to be used	$0
Less: present value of existing assets replaced	$0
Less: present value of proposed alternative salvage value	$0
Total present value of net investment	$37,607,341
Total present value of differential costs	$66,257
Plus: present value of status quo investment costs eliminated	$6,223,897
Less: present value of status quo salvage value	$0
Total present value of savings	$6,290,154
Savings/Investment Ratio	0.17
SIR is less than one at end of period of analysis	

For Status Quo:

Recurring Costs - Expense Item(s)	4				
Investment Costs - Expense Item(s)	1	2	3		

For Proposed Alternative:

Recurring Costs - Expense Item(s)	6				
Investment Costs - Expense Item(s)	1	2	3	4	5

LIFE CYCLE COST REPORT

5 New Portland Cement Concrete Pavement

YEAR	Initial Construction (1)	Spall & Joint Repair (2)	Joint Seal (3)	O & M (4)	TOTAL ANNUAL OUTLAYS
1999	$39,800,000	$0	$0	$6,000	$39,806,000
2000	$0	$0	$0	$8,000	$8,000
2001	$0	$0	$0	$10,000	$10,000
2002	$0	$0	$0	$12,000	$12,000
2003	$0	$0	$0	$14,000	$14,000
2004	$0	$0	$0	$16,000	$16,000
2005	$0	$0	$0	$18,000	$18,000
2006	$0	$0	$0	$20,000	$20,000
2007	$0	$0	$0	$22,000	$22,000
2008	$0	$0	$0	$24,000	$24,000
2009	$0	$0	$0	$26,000	$26,000
2010	$0	$0	$0	$28,000	$28,000
2011	$0	$334,800	$168,750	$30,000	$533,550
2012	$0	$0	$0	$32,000	$32,000
2013	$0	$0	$0	$34,000	$34,000
2014	$0	$0	$0	$36,000	$36,000
2015	$0	$0	$0	$38,000	$38,000
2016	$0	$0	$0	$40,000	$40,000
2017	$0	$334,800	$168,750	$42,000	$545,550
2018	$0	$0	$0	$44,000	$44,000
2019	$0	$0	$0	$46,000	$46,000
2020	$0	$0	$0	$48,000	$48,000
2021	$0	$0	$0	$50,000	$50,000
2022	$0	$0	$0	$52,000	$52,000
2023	$0	$334,800	$168,750	$54,000	$557,550
2024	$0	$0	$0	$56,000	$56,000
%NPV	96.53	1.47	0.74	1.26	
	$38,678,328	$589,201	$296,976	$502,983	
DISCOUNTING CONVENTION	E-O-Y	E-O-Y	E-O-Y	E-O-Y	
INFLATION INDEX	No Inflation	No Inflation	No Inflation	No Inflation	

LIFE CYCLE COST REPORT

5 New Portland Cement Concrete Pavement

YEAR	END OF YEAR DISCOUNT FACTORS	PRESENT VALUE	CUMULATIVE NET PRESENT VALUE
1999	0.972	$38,684,159	$38,684,159
2000	0.944	$7,555	$38,691,715
2001	0.918	$9,178	$38,700,893
2002	0.892	$10,703	$38,711,596
2003	0.867	$12,135	$38,723,732
2004	0.842	$13,478	$38,737,210
2005	0.819	$14,736	$38,751,945
2006	0.796	$15,911	$38,767,857
2007	0.773	$17,009	$38,784,866
2008	0.751	$18,033	$38,802,898
2009	0.730	$18,985	$38,821,883
2010	0.710	$19,869	$38,841,752
2011	0.690	$367,939	$39,209,690
2012	0.670	$21,445	$39,231,136
2013	0.651	$22,144	$39,253,279
2014	0.633	$22,785	$39,276,065
2015	0.615	$23,373	$39,299,438
2016	0.598	$23,910	$39,323,348
2017	0.581	$316,915	$39,640,263
2018	0.565	$24,840	$39,665,103
2019	0.549	$25,237	$39,690,340
2020	0.533	$25,592	$39,715,932
2021	0.518	$25,907	$39,741,839
2022	0.504	$26,184	$39,768,022
2023	0.489	$272,835	$40,040,857
2024	0.476	$26,631	$40,067,488

2.9% DISCOUNT RATE, 26 YEARS

PRIMARY ECONOMIC ANALYSIS

Status Quo Alternative: Status Quo
Proposed Alternative : New Portland Cement Concrete Pavement

Project Year(s)	Recurring Annual Operating Costs Status Quo Alternative	Proposed Alternative	Differential Costs	Present Value Factor	Present Value of Differential Costs
1999	$16,000	$6,000	$10,000	0.972	$9,718
2000	$22,000	$8,000	$14,000	0.944	$13,222
2001	$26,000	$10,000	$16,000	0.918	$14,685
2002	$32,000	$12,000	$20,000	0.892	$17,839
2003	$38,000	$14,000	$24,000	0.867	$20,803
2004	$42,000	$16,000	$26,000	0.842	$21,902
2005	$48,000	$18,000	$30,000	0.819	$24,559
2006	$52,000	$20,000	$32,000	0.796	$25,458
2007	$6,000	$22,000	-$16,000	0.773	-$12,370
2008	$10,000	$24,000	-$14,000	0.751	-$10,519
2009	$16,000	$26,000	-$10,000	0.730	-$7,302
2010	$22,000	$28,000	-$6,000	0.710	-$4,258
2011	$26,000	$30,000	-$4,000	0.690	-$2,758
2012	$32,000	$32,000	$0	0.670	$0
2013	$38,000	$34,000	$4,000	0.651	$2,605
2014	$42,000	$36,000	$6,000	0.633	$3,798
2015	$48,000	$38,000	$10,000	0.615	$6,151
2016	$52,000	$40,000	$12,000	0.598	$7,173
2017	$6,000	$42,000	-$36,000	0.581	-$20,913
2018	$10,000	$44,000	-$34,000	0.565	-$19,194
2019	$16,000	$46,000	-$30,000	0.549	-$16,459
2020	$22,000	$48,000	-$26,000	0.533	-$13,862
2021	$26,000	$50,000	-$24,000	0.518	-$12,435
2022	$32,000	$52,000	-$20,000	0.504	-$10,071
2023	$38,000	$54,000	-$16,000	0.489	-$7,830
2024	$42,000	$56,000	-$14,000	0.476	-$6,658
Totals	$760,000	$806,000	-$46,000		$23,285

PRIMARY ECONOMIC ANALYSIS

Total present value of investment	$39,564,505
Plus: present value of existing assets to be used	$0
Less: present value of existing assets replaced	$0
Less: present value of proposed alternative salvage value	$0
Total present value of net investment	$39,564,505
Total present value of differential costs	$23,285
Plus: present value of status quo investment costs eliminated	$6,223,897
Less: present value of status quo salvage value	$0
Total present value of savings	$6,247,181
Savings/Investment Ratio	0.16

SIR is less than one at end of period of analysis

For Status Quo:

Recurring Costs - Expense Item(s)	4		
Investment Costs - Expense Item(s)	1	2	3

For Proposed Alternative:

Recurring Costs - Expense Item(s)	4		
Investment Costs - Expense Item(s)	1	2	3

LIFE CYCLE COST REPORT

SOURCE AND DERIVATION OF COSTS AND BENEFITS:

A. Status Quo

There is no estimated construction cost associated with this alternative.

MAINTENANCE AND REPAIR COSTS

		QUANTITY		COSTS	
ITEM DESCRIPTION	Year	NUMBER	UNIT	UNIT	TOTAL
Crack Seal and Routing	1999	15120	LF	2.30	34776
Surface Treatment	1999	1800000	SF	0.15	270000
Crack Seal and Routing	2002	15120	LF	2.30	34776
Surface Treatment	2002	1800000	LF	0.45	810000
Crack Seal and Routing	2005	15120	SF	2.30	34776

The increase cost for the second surface treatment takes into account the possibility that a sealcoat product may be used for a typical asphalt concrete pavement surface.

B. New Asphalt Concrete Overlay

The estimated construction cost was obtained from unit cost used in a previous economic analysis (Referenced below) and provided in the Means Construction Cost Data escalated to 1999 base year constant dollars. The higher increase for Hot Mix Asphalt is the result of an increased cost of $10.00 per Ton (placed) for performance grade asphalt cements.

Reference: NAS Fallon ltr 11010 Ser 183/0577 of 10 Apr 1997.
Subj: PROJECT R3-95, RUNWAY 13R/31L REPAIRS ECONOMIC ANALYSIS

	QUANTITY		MATERIAL COSTS		LABOR COSTS		
ITEM DESCRIPTION	NUMBER	UNIT	UNIT	TOTAL	UNIT	TOTAL	TOTAL
Cold Mill Excess Disp.	1260	CY	17.50	22050	11.70	14742	36792
HMA (2") PG Asphalt	21680	TON	30.50	661240	35.25	764220	1425460
Bit. Tack Coat	130	TON	154.00	20020	30.25	3933	23953
Pavement Markings	254420	SF	0.23	58517	0.25	63605	122122
Joints in PCC Pavement	400	LF	1.60	640	9.00	3600	4240
Cold Mill AC Pavement	22500	SY	0.00	0	2.15	48375	48375
Crack Seal and Routing	15120	LF	0.65	9828	1.65	24948	34776
General Requirements	1	LS		0		0	270100
							1,965,817

General Contractor Overhead and Profit 12%	235,898
Project Cost	2,201,715
SIOH 6%	132,103
Cost	2,333,818
Planning Costs 10%	233,382
TOTAL COST	**$2,567,200**
TOTAL REQUESTED (ROUNDED)	**$2,600,000**

MAINTENANCE AND REPAIR COSTS

		QUANTITY		COSTS	
ITEM DESCRIPTION	Year	NUMBER	UNIT	UNIT	TOTAL
Crack Seal and Routing	2002	15120	LF	2.30	34776
Surface Treatment	2002	1800000	SF	0.15	270000
Crack Seal and Routing	2005	15120	LF	2.30	34776
Surface Treatment	2005	1800000	SF	0.45	810000
Crack Seal and Routing	2008	15120	LF	2.30	34776

The increase cost for the second surface treatment takes into account the possibility that a sealcoat product may be used for a typical asphalt concrete pavement surface.

C. New Asphalt Concrete Pavement

The estimated construction cost (pavement replacement cost) was obtained from unit cost used in a previous economic analysis (Referenced below) and provided in the Means Construction Cost Data escalated to 1999 base year constant dollars. The higher increase for Asphaltic Pavement is the result of an increased cost of $10.00 per Ton (placed) for performance grade asphalt cements. This cost was inserted as the pavement replacement cost in the Form 1391 used in the new Portland cement concrete pavement alternative.

Reference: NAS Fallon ltr 11010 Ser 183/0577 of 10 Apr 1997.
Subj: PROJECT R3-95, RUNWAY 13R/31L REPAIRS ECONOMIC ANALYSIS

	QUANTITY		MATERIAL COSTS		LABOR COSTS		
ITEM DESCRIPTION	NUMBER	UNIT	UNIT	TOTAL	UNIT	TOTAL	TOTAL
Sawcut AC pavement	400	LF	0.30	120	1.10	440	560
Demo and Remove AC	268000	SY		0	5.05	1353400	1353400
Dispose AC	89333	CY		0	15.95	1424861	1424861
Excavate Excess Soil	89000	CY		0	1.90	169100	169100
Compact Subbase 95%	89000	CY		0	2.75	244750	244750
Install Aggregate Base	144180	TON	19.00	2739420	21.20	3056616	5796036
Install AC Pavement	144180	TON	54.40	7843392	11.35	1636443	9479835
Paint Center and Edge	216972	SF	1.85	401398	1.00	216972	618370
Paint threshold mark.	43394	SF	1.85	80279	1.00	43394	123673
Paint & letters	16544	SF	1.85	30606	4.25	70312	100918
							$19,311,504

	U/M	Quantity	Unit Cost	
AC Pavement Replacement	m2	183,000	$105.53	**$19,311,504**

MAINTENANCE AND REPAIR COSTS

		QUANTITY		COSTS	
ITEM DESCRIPTION	Year	NUMBER	UNIT	UNIT	TOTAL
Crack Seal and Routing	2001	15120	LF	2.30	34776
Surface Treatment	2001	1800000	SF	0.15	270000
Crack Seal and Routing	2004	15120	LF	2.30	34776
Surface Treatment	2004	1800000	SF	0.45	810000
Crack Seal and Routing	2007	15120	LF	2.30	34776
Two-inch Overlay	2008	1800000	SF	1.45	2600000
Crack Seal and Routing	2010	15120	LF	2.30	34776
Surface Treatment	2010	1800000	SF	0.15	270000
Crack Seal and Routing	2013	15120	LF	2.30	34776
Surface Treatment	2013	1800000	SF	0.45	810000
Crack Seal and Routing	2016	15120	LF	2.30	34776
Two-inch Overlay	2017	1800000	SF	1.45	2600000
Crack Seal and Routing	2019	15120	LF	2.30	34776
Surface Treatment	2009	1800000	SF	0.15	270000
Crack Seal and Routing	2022	15120	LF	2.30	34776
Surface Treatment	2022	1800000	SF	0.45	810000

The increase cost for the second surface treatment takes into account the possibility that a sealcoat product may be used for a typical asphalt concrete pavement surface.

D. New Asphalt Concrete Pavement With Sawed joints

The estimated construction cost was obtained from unit cost used in a previous economic analysis (Referenced below) and provided in the Means Construction Cost Data escalated to 1999 base year constant dollars. The higher increase for Asphaltic Pavement is the result of an increased cost of $10.00 per Ton (placed) for performance grade asphalt cements. This cost was inserted as the pavement replacement cost in the Form 1391 used in the new Portland cement concrete pavement alternative.

Reference: NAS Fallon ltr 11010 Ser 183/0577 of 10 Apr 1997.
Subj: PROJECT R3-95, RUNWAY 13R/31L REPAIRS ECONOMIC ANALYSIS

	QUANTITY		MATERIAL COSTS		LABOR COSTS		
ITEM DESCRIPTION	NUMBER	UNIT	UNIT	TOTAL	UNIT	TOTAL	TOTAL
Sawcut AC pavement	400	LF	0.30	120	1.10	440	560
Demo and Remove AC	268000	SY		0	5.05	1353400	1353400
Dispose AC	89333	CY		0	15.95	1424861	1424861
Excavate Excess Soil	89000	CY		0	1.90	169100	169100
Compact Subbase 95%	89000	CY		0	2.75	244750	244750
Install Aggregate Base	144180	TON	19.00	2739420	21.20	3056616	5796036
Install AC Pavement	144180	TON	54.40	7843392	11.35	1636443	9479835
Sawcut Joints and Seal	135000	LF	1.50	202500	4.00	540000	742500
Paint Center and Edge	216972	SF	1.85	401398	1.00	216972	618370
Paint threshold mark.	43394	SF	1.85	80279	1.00	43394	123673
Paint & letters	16544	SF	1.85	30606	4.25	70312	100918
							$20,054,004

	U/M	Quantity	Unit Cost	
AC Pavement Replacement	m2	183,000	$109.58	**$20,054,004**

MAINTENANCE AND REPAIR COSTS

		QUANTITY		COSTS	
ITEM DESCRIPTION	Year	NUMBER	UNIT	UNIT	TOTAL
Surface Treatment	2005,8	1800000	SF	0.15	270000
Spall and Joint Repair	2011	90000	SF	3.72	334800
Global Joint Sealing	2011	135000	LF	1.25	168750
Surface Treatment	2011,14	1800000	SF	0.15	270000
Spall and Joint Repair	2017	90000	SF	3.72	334800
Global Joint Sealing	2017	135000	LF	1.25	168750
Two-inch Overlay w Saw Cuts	2017	1800000	SF	2.00	3600000
Surface Treatment	2020,23	1800000	SF	0.15	270000

E. New Portland Cement Concrete Pavement

This cost was estimated by EFA West and is presented in the Form 1391.

MAINTENANCE AND REPAIR COSTS

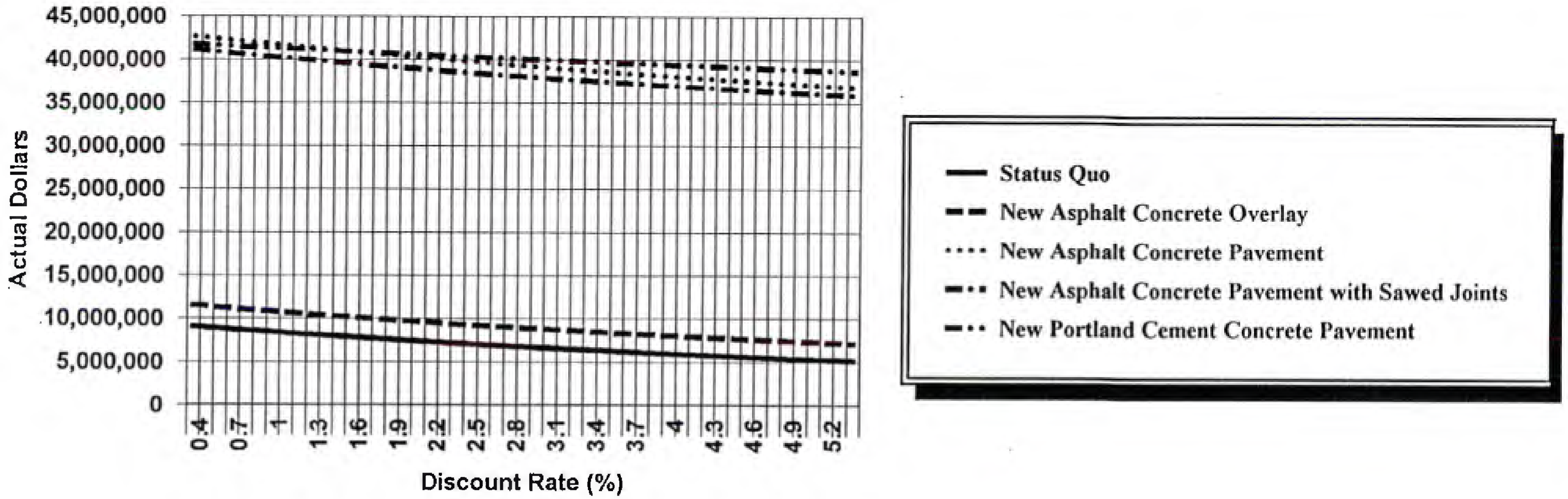
		QUANTITY		COSTS	
ITEM DESCRIPTION	Year	NUMBER	UNIT	UNIT	TOTAL
Spall and Joint Repair	2011	90000	SF	3.72	334800
Global Joint Sealing	2011	135000	LF	1.25	168750
Spall and Joint Repair	2017	90000	SF	3.72	334800
Global Joint Sealing	2017	135000	LF	1.25	168750
Spall and Joint Repair	2023	90000	SF	3.72	334800
Global Joint Sealing	2023	135000	LF	1.25	168750

F. Operations and Maintenance

O & M Costs (PCI Vs Cost for Pavements); Pavement Age Multiplyers

	Status Quo (AC)		A/C Overlay		A/C		A/C w/ Joints		PCC	
YEAR	PCI	$/SY	PCI	$/SY	PCI	$/SY	PCI	$/SY	PCI	$/SY
1999	91	0.08	100/97	0.03	100/97	0.03	100/97	0.03	100/99	0.03
2000	88	0.11	94	0.05	94	0.05		0.04	98	0.04
2001	85	0.13	91	0.08	91	0.08	94	0.05	98	0.05
2002	82	0.16	88	0.11	88	0.11		0.07	97	0.06
2003	79	0.19	85	0.13	85	0.13	91	0.08	97	0.07
2004	76	0.21	82	0.16	82	0.16		0.10	96	0.08
2005	73	0.24	79	0.19	79	0.19	88	0.11	96	0.09
2006	70	0.26	76	0.21	76	0.21		0.12	95	0.10
2007	100/97	0.03	73	0.24	73	0.24	85	0.13	95	0.11
2008	94	0.05	70	0.26	70	0.26		0.15	94	0.12
2009	91	0.08	100/97	0.03	100/97	0.03	82	0.16	94	0.13
2010	88	0.11	94	0.05	94	0.05		0.18	93	0.14
2011	85	0.13	91	0.08	91	0.08	79	0.19	93	0.15
2012	82	0.16	88	0.11	88	0.11		0.20	92	0.16
2013	79	0.19	85	0.13	85	0.13	76	0.21	92	0.17
2014	76	0.21	82	0.16	82	0.16		0.23	91	0.18
2015	73	0.24	79	0.19	79	0.19	73	0.24	91	0.19
2016	70	0.26	76	0.21	76	0.21		0.25	90	0.20
2017	100/97	0.03	73	0.24	73	0.24	70	0.26	90	0.21
2018	94	0.05	70/100	0.26	70/100	0.26	70/100	0.26	89	0.22
2019	91	0.08	100/97	0.03	100/97	0.03	100/97	0.03	89	0.23
2020	88	0.11	94	0.05	94	0.05		0.04	88	0.24
2021	85	0.13	91	0.08	91	0.08	94	0.05	88	0.25
2022	82	0.16	88	0.11	88	0.11		0.07	87	0.26
2023	79	0.19	85	0.13	85	0.13	91	0.08	87	0.27
2024	76	0.21	82	0.16	82	0.16		0.10	86	0.28

DISCOUNT RATE SENSITIVITY ANALYSIS 1
DRSA1
Graph of Net Present Value vs. Discount Rate



DISCOUNT RATE SENSITIVITY ANALYSIS 1

TITLE: DRSA1

Summary of Alternative Rankings by Discount Rate

Discount Rate: 2.9 Lower Limit: 00.40 Upper Limit: 05.40

Discount Rate (%)	Alternative Ranking	Discount Rate (%)	Alternative Ranking
0.40	1 2 4 5 3	3.00	1 2 4 3 5
0.50	1 2 4 5 3	3.10	1 2 4 3 5
0.60	1 2 4 5 3	3.20	1 2 4 3 5
0.70	1 2 4 5 3	3.30	1 2 4 3 5
0.80	1 2 4 5 3	3.40	1 2 4 3 5
0.90	1 2 4 5 3	3.50	1 2 4 3 5
1.00	1 2 4 5 3	3.60	1 2 4 3 5
1.10	1 2 4 5 3	3.70	1 2 4 3 5
1.20	1 2 4 5 3	3.80	1 2 4 3 5
1.30	1 2 4 5 3	3.90	1 2 4 3 5
1.40	1 2 4 5 3	4.00	1 2 4 3 5
1.50	1 2 4 5 3	4.10	1 2 4 3 5
* 1.60	1 2 4 3 5	4.20	1 2 4 3 5
1.70	1 2 4 3 5	4.30	1 2 4 3 5
1.80	1 2 4 3 5	4.40	1 2 4 3 5
1.90	1 2 4 3 5	4.50	1 2 4 3 5
2.00	1 2 4 3 5	4.60	1 2 4 3 5
2.10	1 2 4 3 5	4.70	1 2 4 3 5
2.20	1 2 4 3 5	4.80	1 2 4 3 5
2.30	1 2 4 3 5	4.90	1 2 4 3 5
2.40	1 2 4 3 5	5.00	1 2 4 3 5
2.50	1 2 4 3 5	5.10	1 2 4 3 5
2.60	1 2 4 3 5	5.20	1 2 4 3 5
2.70	1 2 4 3 5	5.30	1 2 4 3 5
2.80	1 2 4 3 5	5.40	1 2 4 3 5
2.90	1 2 4 3 5		

RESULTS:

* indicates a change in the alternative ranking occurred.

DISCOUNT RATE SENSITIVITY ANALYSIS 1

TITLE: DRSA1

Table of Net Present Value for each Discount Rate

Disc Rate = 00.40% Alt - NPV	Disc Rate = 00.50% Alt - NPV	Disc Rate = 00.60% Alt - NPV	Disc Rate = 00.70% Alt - NPV
1 - $9,051,730	1 - $8,941,044	1 - $8,832,139	1 - $8,724,983
2 - $11,517,026	2 - $11,389,705	2 - $11,264,562	2 - $11,141,553
4 - $41,114,218	4 - $40,970,090	4 - $40,828,108	4 - $40,688,232
5 - $41,794,997	5 - $41,716,870	5 - $41,639,619	5 - $41,563,225
3 - $42,661,380	3 - $42,503,001	3 - $42,346,863	3 - $42,192,921

Disc Rate = 00.80% Alt - NPV	Disc Rate = 00.90% Alt - NPV	Disc Rate = 01.00% Alt - NPV	Disc Rate = 01.10% Alt - NPV
1 - $8,619,542	1 - $8,515,784	1 - $8,413,678	1 - $8,313,193
2 - $11,020,636	2 - $10,901,768	2 - $10,784,910	2 - $10,670,022
4 - $40,550,418	4 - $40,414,625	4 - $40,280,814	4 - $40,148,945
5 - $41,487,672	5 - $41,412,941	5 - $41,339,015	5 - $41,265,877
3 - $42,041,134	3 - $41,891,459	3 - $41,743,856	3 - $41,598,284

Disc Rate = 01.20% Alt - NPV	Disc Rate = 01.30% Alt - NPV	Disc Rate = 01.40% Alt - NPV	Disc Rate = 01.50% Alt - NPV
1 - $8,214,299	1 - $8,116,966	1 - $8,021,167	1 - $7,926,871
2 - $10,557,064	2 - $10,445,999	2 - $10,336,789	2 - $10,229,399
4 - $40,018,980	4 - $39,890,881	4 - $39,764,611	4 - $39,640,134
5 - $41,193,512	5 - $41,121,904	5 - $41,051,036	5 - $40,980,895
3 - $41,454,705	3 - $41,313,080	3 - $41,173,372	3 - $41,035,545

Disc Rate = 01.60% Alt - NPV	Disc Rate = 01.70% Alt - NPV	Disc Rate = 01.80% Alt - NPV	Disc Rate = 01.90% Alt - NPV
1 - $7,834,053	1 - $7,742,683	1 - $7,652,737	1 - $7,564,188
2 - $10,123,792	2 - $10,019,934	2 - $9,917,791	2 - $9,817,329
4 - $39,517,416	4 - $39,396,421	4 - $39,277,116	4 - $39,159,468
3 - $40,899,562	3 - $40,765,389	3 - $40,632,991	3 - $40,502,335
5 - $40,911,465	5 - $40,842,731	5 - $40,774,681	5 - $40,707,299

Disc Rate = 02.00% Alt - NPV	Disc Rate = 02.10% Alt - NPV	Disc Rate = 02.20% Alt - NPV	Disc Rate = 02.30% Alt - NPV
1 - $7,477,010	1 - $7,391,179	1 - $7,306,669	1 - $7,223,458
2 - $9,718,516	2 - $9,621,320	2 - $9,525,709	2 - $9,431,654
4 - $39,043,444	4 - $38,929,014	4 - $38,816,146	4 - $38,704,810
3 - $40,373,388	3 - $40,246,118	3 - $40,120,494	3 - $39,996,484
5 - $40,640,573	5 - $40,574,490	5 - $40,509,037	5 - $40,444,201

DISCOUNT RATE SENSITIVITY ANALYSIS 1

TITLE: DRSA1

Table of Net Present Value for each Discount Rate

Disc Rate = 02.40% Alt - NPV	Disc Rate = 02.50% Alt - NPV	Disc Rate = 02.60% Alt - NPV	Disc Rate = 02.70% Alt - NPV
1 - $7,141,521	1 - $7,060,835	1 - $6,981,379	1 - $6,903,129
2 - $9,339,124	2 - $9,248,090	2 - $9,158,523	2 - $9,070,395
4 - $38,594,976	4 - $38,486,616	4 - $38,379,701	4 - $38,274,203
3 - $39,874,058	3 - $39,753,188	3 - $39,633,845	3 - $39,515,999
5 - $40,379,970	5 - $40,316,333	5 - $40,253,277	5 - $40,190,792

Disc Rate = 02.80% Alt - NPV	Disc Rate = 02.90% Alt - NPV	Disc Rate = 03.00% Alt - NPV	Disc Rate = 03.10% Alt - NPV
1 - $6,826,065	1 - $6,750,164	1 - $6,675,407	1 - $6,601,772
2 - $8,983,680	2 - $8,898,349	2 - $8,814,377	2 - $8,731,738
4 - $38,170,095	4 - $38,067,351	4 - $37,965,944	4 - $37,865,850
3 - $39,399,624	3 - $39,284,692	3 - $39,171,178	3 - $39,059,055
5 - $40,128,866	5 - $40,067,488	5 - $40,006,649	5 - $39,946,337

Disc Rate = 03.20% Alt - NPV	Disc Rate = 03.30% Alt - NPV	Disc Rate = 03.40% Alt - NPV	Disc Rate = 03.50% Alt - NPV
1 - $6,529,240	1 - $6,457,791	1 - $6,387,407	1 - $6,318,067
2 - $8,650,407	2 - $8,570,359	2 - $8,491,570	2 - $8,414,016
4 - $37,767,042	4 - $37,669,498	4 - $37,573,192	4 - $37,478,102
3 - $38,948,297	3 - $38,838,880	3 - $38,730,780	3 - $38,623,972
5 - $39,886,542	5 - $39,827,256	5 - $39,768,467	5 - $39,710,167

Disc Rate = 03.60% Alt - NPV	Disc Rate = 03.70% Alt - NPV	Disc Rate = 03.80% Alt - NPV	Disc Rate = 03.90% Alt - NPV
1 - $6,249,755	1 - $6,182,451	1 - $6,116,139	1 - $6,050,800
2 - $8,337,675	2 - $8,262,523	2 - $8,188,539	2 - $8,115,701
4 - $37,384,204	4 - $37,291,477	4 - $37,199,898	4 - $37,109,446
3 - $38,518,434	3 - $38,414,143	3 - $38,311,076	3 - $38,209,211
5 - $39,652,347	5 - $39,594,997	5 - $39,538,110	5 - $39,481,675

Disc Rate = 04.00% Alt - NPV	Disc Rate = 04.10% Alt - NPV	Disc Rate = 04.20% Alt - NPV	Disc Rate = 04.30% Alt - NPV
1 - $5,986,417	1 - $5,922,975	1 - $5,860,456	1 - $5,798,845
2 - $8,043,987	2 - $7,973,376	2 - $7,903,849	2 - $7,835,385
4 - $37,020,099	4 - $36,931,838	4 - $36,844,641	4 - $36,758,490
3 - $38,108,528	3 - $38,009,004	3 - $37,910,619	3 - $37,813,354
5 - $39,425,685	5 - $39,370,132	5 - $39,315,008	5 - $39,260,304

DISCOUNT RATE SENSITIVITY ANALYSIS 1

TITLE: DRSA1

Table of Net Present Value for each Discount Rate

Disc Rate = 04.40% Alt - NPV	Disc Rate = 04.50% Alt - NPV	Disc Rate = 04.60% Alt - NPV	Disc Rate = 04.70% Alt - NPV
1 - $5,738,126	1 - $5,678,284	1 - $5,619,302	1 - $5,561,167
2 - $7,767,965	2 - $7,701,570	2 - $7,636,180	2 - $7,571,778
4 - $36,673,365	4 - $36,589,246	4 - $36,506,117	4 - $36,423,957
3 - $37,717,188	3 - $37,622,103	3 - $37,528,079	3 - $37,435,097
5 - $39,206,014	5 - $39,152,130	5 - $39,098,644	5 - $39,045,549

Disc Rate = 04.80% Alt - NPV	Disc Rate = 04.90% Alt - NPV	Disc Rate = 05.00% Alt - NPV	Disc Rate = 05.10% Alt - NPV
1 - $5,503,865	1 - $5,447,379	1 - $5,391,698	1 - $5,336,807
2 - $7,508,345	2 - $7,445,864	2 - $7,384,317	2 - $7,323,689
4 - $36,342,750	4 - $36,262,477	4 - $36,183,123	4 - $36,104,670
3 - $37,343,140	3 - $37,252,190	3 - $37,162,229	3 - $37,073,240
5 - $38,992,839	5 - $38,940,507	5 - $38,888,545	5 - $38,836,948

Disc Rate = 05.20% Alt - NPV	Disc Rate = 05.30% Alt - NPV	Disc Rate = 05.40% Alt - NPV
1 - $5,282,692	1 - $5,229,341	1 - $5,176,740
2 - $7,263,961	2 - $7,205,118	2 - $7,147,143
4 - $36,027,102	4 - $35,950,403	4 - $35,874,557
3 - $36,985,207	3 - $36,898,112	3 - $36,811,941
5 - $38,785,709	5 - $38,734,821	5 - $38,684,280

APPENDIX F

ECONOMIC ANALYSIS

FOR

REPLACEMENT OF RUNWAY 13R-31L

DATE GENERATED: 06 Jul 1999
TIME GENERATED: 11:10:26
VERSION: ECONPACK for Windows 1.02

REPLACEMENT OF 13R 31L
ECONOMIC ANALYSIS

EXECUTIVE SUMMARY REPORT

PROJECT TITLE	:	NAVAL AIR STATION, FALLON, NEVADA
DISCOUNT RATE	:	2.9%
PERIOD OF ANALYSIS	:	26 Years
START YEAR	:	1999
BASE YEAR	:	1999
REPORT OUTPUT	:	Constant Dollars

PROJECT OBJECTIVE : To evaluate various M&R and new pavement alternatives to the asphalt portion of Runway 13R-31L.

ALTERNATIVES CONSIDERED FOR THIS ANALYSIS:

A. Background

The asphalt concrete portion of Runway 13R-31L had major repair performed during the summer of 1997 which included repair of existing cracks and provided a two-inch overlay. Thermal cracking became noticeable in January 1998. NAVFAC (EFD Southwest) 1998 strength evaluation and the 1999 surface condition evaluation found this pavement to be in very good condition. This situation has resulted in an NFESC study, funded by CINCPACFLT, to determine performance characteristics of asphalt concrete in this high desert region.

B. Objective

To evaluate various maintenance and repair (M&R) and new pavement alternatives to the asphalt portion of Runway 13R-31L and a completely new all Portland Cement concrete runway parallel and outboard to the existing runway.

C. Description of Alternatives

1. Replacement of Runway 13R-31L. Construct a new all Portland cement concrete parallel runway to the east of Runway 13L-31R and abandon the existing Runway 13R-31L when complete. Seal the joints and maintain the pavement as deemed necessary.

ASSUMPTIONS OF THE ANALYSIS:

A. Time-Value of Money

1. The discount rate used in this analysis is 2.9%. This rate was obtained from Appendix C of the OMB Circular A-94 (Revised January 1999).

2. The base year will be Fiscal Year 1999.

3. Project life of 26 years will be used. This is calculated as a 25-year economic life for airfield pavements, and a 12 month "construction" period.

4. An End-of-Year cost convention will be used.

B. Construction / Design Criteria

1. Replacement of Runway 13R-31L. Construct a new Portland cement concrete parallel runway to the east of Runway 13L-31R and abandon the existing Runway 13R-31L when complete. Major maintenance and repairs consist of global joint sealing and spall & joint repair. Frequency of maintenance is based on the 34 and 45 year maintenance histories of the existing Portland cement concrete pavement at the ends of Runway 13R-31L. Global joint sealing and spall & joint repair to be completed at 12, 18 and 24 years after initial construction

C. Cost Related:

1. Operations and maintenance costs go up as the PCI of the pavement goes down. Pavement age multipliers (cost per square yard of pavement surface) for predicted PCI will be used. Actual costs used are from the PCI vs Cost Table in PAVER (pavement management program used on all Naval Air Stations). Predicted PCI is based on straight line prediction models using actual data from NAS Fallon.

2. Land value on the installation will not be considered.

3. Terminal value will not be considered.

D. Economic Life:

The economic life of airfield pavements is 25 years which was obtained from Appendix A, Reference Code A1 of the NAVFAC Economic Life Analysis Consolidated Report (dated 24 February 1999).

ECONOMIC INDICATORS:

ALTERNATIVE NAME	NPV
1 New Portland Cement Concrete Paveme	$77,638,798

NON-MONETARY COSTS AND BENEFITS:

A. Foreign Object Damage (FOD)

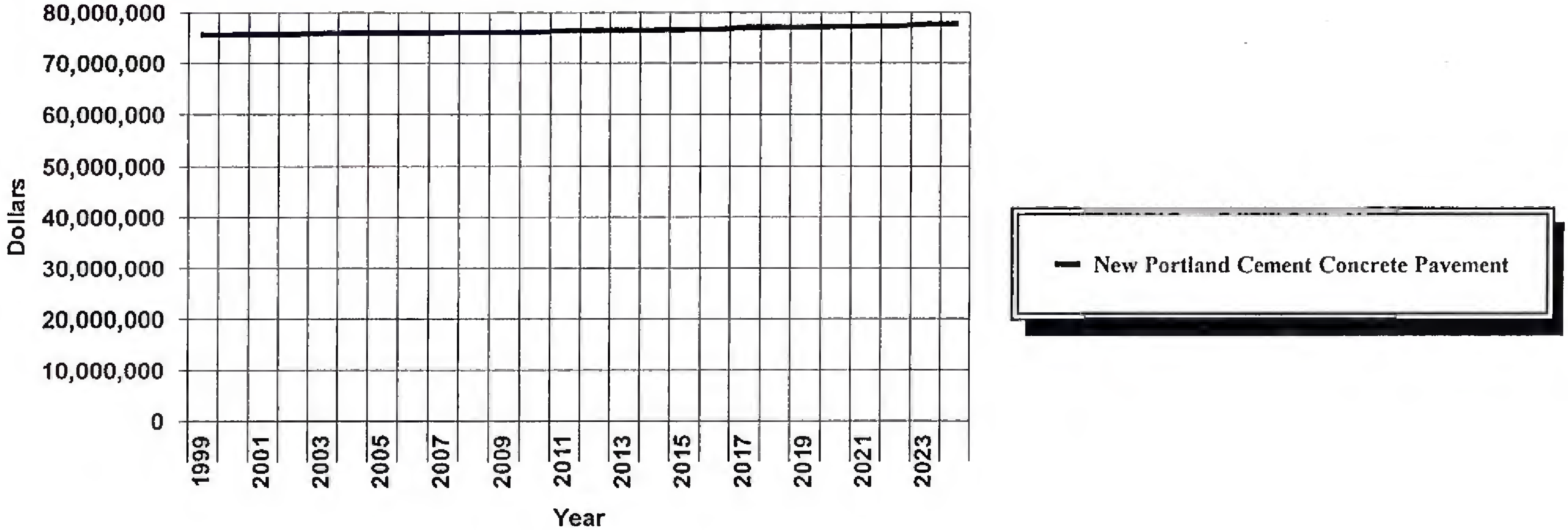
Analysis of results from previous studies and published information (NFESC. Memorandum: Causes of Foreign Object Damage (FOD) to Aircraft engines. ESC63/MCH/D14-11, 13 March 1998) indicate that material originating from the pavement matrix account for only a small percentage of foreign object debris (FO). The percentage would be a small percent of all types of rock and sand products attributable to FO. Rock, sand and ice type FO cause about five percent of FOD. Pavement fragments, if any, represents only a fraction of the five percent. FO removal would be considered part of the O&M costs which, in this analysis, O&M costs escalate as the pavement surface ages.

B. Disruption and Interruption to the Mission (25 years)

Replacement of Runway 13R-31L. Mission will be interrupted by global joint sealing (and joint & spall repair) three times.

ACTION OFFICER: Gregory D. Cline
ORGANIZATION : NFESC

ECONOMIC ANALYSIS GRAPH 1
Cumulative Net Present Value



LIFE CYCLE COST REPORT

1 New Portland Cement Concrete Pavement

YEAR	Initial Construction (1)	Spall & Joint Repair (2)	Joint Seal (3)	O & M (4)	TOTAL ANNUAL OUTLAYS
1999	$77,700,000	$0	$0	$9,000	$77,709,000
2000	$0	$0	$0	$12,000	$12,000
2001	$0	$0	$0	$15,000	$15,000
2002	$0	$0	$0	$18,000	$18,000
2003	$0	$0	$253,125	$21,000	$274,125
2004	$0	$0	$0	$24,000	$24,000
2005	$0	$0	$0	$27,000	$27,000
2006	$0	$0	$0	$30,000	$30,000
2007	$0	$0	$0	$33,000	$33,000
2008	$0	$0	$0	$36,000	$36,000
2009	$0	$0	$0	$39,000	$39,000
2010	$0	$0	$0	$42,000	$42,000
2011	$0	$502,200	$0	$45,000	$547,200
2012	$0	$0	$0	$48,000	$48,000
2013	$0	$0	$0	$51,000	$51,000
2014	$0	$0	$0	$54,000	$54,000
2015	$0	$0	$0	$57,000	$57,000
2016	$0	$0	$0	$60,000	$60,000
2017	$0	$502,200	$253,125	$63,000	$818,325
2018	$0	$0	$0	$66,000	$66,000
2019	$0	$0	$0	$69,000	$69,000
2020	$0	$0	$0	$72,000	$72,000
2021	$0	$0	$0	$75,000	$75,000
2022	$0	$0	$0	$78,000	$78,000
2023	$0	$502,200	$253,125	$81,000	$836,325
2024	$0	$0	$0	$84,000	$84,000
%NPV	97.26	1.14	0.63	0.97	
	$75,510,204	$883,801	$490,319	$754,474	
DISCOUNTING CONVENTION	E-O-Y	E-O-Y	E-O-Y	E-O-Y	
INFLATION INDEX	No Inflation	No Inflation	No Inflation	No Inflation	

LIFE CYCLE COST REPORT

1 New Portland Cement Concrete Pavement

YEAR	END OF YEAR DISCOUNT FACTORS	PRESENT VALUE	CUMULATIVE NET PRESENT VALUE
1999	0.972	$75,518,950	$75,518,950
2000	0.944	$11,333	$75,530,284
2001	0.918	$13,767	$75,544,051
2002	0.892	$16,055	$75,560,106
2003	0.867	$237,614	$75,797,720
2004	0.842	$20,217	$75,817,937
2005	0.819	$22,103	$75,840,040
2006	0.796	$23,867	$75,863,907
2007	0.773	$25,514	$75,889,421
2008	0.751	$27,049	$75,916,470
2009	0.730	$28,477	$75,944,947
2010	0.710	$29,803	$75,974,750
2011	0.690	$377,352	$76,352,102
2012	0.670	$32,168	$76,384,270
2013	0.651	$33,215	$76,417,485
2014	0.633	$34,178	$76,451,663
2015	0.615	$35,060	$76,486,723
2016	0.598	$35,865	$76,522,589
2017	0.581	$475,372	$76,997,961
2018	0.565	$37,259	$77,035,220
2019	0.549	$37,855	$77,073,076
2020	0.533	$38,388	$77,111,464
2021	0.518	$38,860	$77,150,324
2022	0.504	$39,276	$77,189,600
2023	0.489	$409,252	$77,598,852
2024	0.476	$39,947	$77,638,798

2.9% DISCOUNT RATE, 26 YEARS

LIFE CYCLE COST REPORT

SOURCE AND DERIVATION OF COSTS AND BENEFITS:

A. New Portland Cement Concrete Pavement

This cost was estimated by EFA West and is presented in the Form 1391.

MAINTENANCE AND REPAIR COSTS

ITEM DESCRIPTION	Year	QUANTITY NUMBER	QUANTITY UNIT	COSTS UNIT	COSTS TOTAL
Spall and Joint Repair	2011	135000	SF	3.72	502200
Global Joint Sealing	2011	202500	LF	1.25	253125
Spall and Joint Repair	2017	135000	SF	3.72	502200
Global Joint Sealing	2017	202500	LF	1.25	253125
Spall and Joint Repair	2023	135000	SF	3.72	502200
Global Joint Sealing	2023	202500	LF	1.25	253125

B. Operations and Maintenance

O & M Costs (PCI Vs Cost for Pavements); Pavement Age Multiplyers

	Status Quo (AC)		A/C Overlay		A/C		A/C w/ Joints		PCC	
YEAR	PCI	$/SY	PCI	$/SY	PCI	$/SY	PCI	$/SY	PCI	$/SY
1999	91	0.08	100/97	0.03	100/97	0.03	100/97	0.03	100/99	0.03
2000	88	0.11	94	0.05	94	0.05		0.04	98	0.04
2001	85	0.13	91	0.08	91	0.08	94	0.05	98	0.05
2002	82	0.16	88	0.11	88	0.11		0.07	97	0.06
2003	79	0.19	85	0.13	85	0.13	91	0.08	97	0.07
2004	76	0.21	82	0.16	82	0.16		0.10	96	0.08
2005	73	0.24	79	0.19	79	0.19	88	0.11	96	0.09
2006	70	0.26	76	0.21	76	0.21		0.12	95	0.10
2007	100/97	0.03	73	0.24	73	0.24	85	0.13	95	0.11
2008	94	0.05	70	0.26	70	0.26		0.15	94	0.12
2009	91	0.08	100/97	0.03	100/97	0.03	82	0.16	94	0.13
2010	88	0.11	94	0.05	94	0.05		0.18	93	0.14
2011	85	0.13	91	0.08	91	0.08	79	0.19	93	0.15
2012	82	0.16	88	0.11	88	0.11		0.20	92	0.16
2013	79	0.19	85	0.13	85	0.13	76	0.21	92	0.17
2014	76	0.21	82	0.16	82	0.16		0.23	91	0.18
2015	73	0.24	79	0.19	79	0.19	73	0.24	91	0.19
2016	70	0.26	76	0.21	76	0.21		0.25	90	0.20
2017	100/97	0.03	73	0.24	73	0.24	70	0.26	90	0.21
2018	94	0.05	70/100	0.26	70/100	0.26	70/100	0.26	89	0.22
2019	91	0.08	100/97	0.03	100/97	0.03	100/97	0.03	89	0.23
2020	88	0.11	94	0.05	94	0.05		0.04	88	0.24
2021	85	0.13	91	0.08	91	0.08	94	0.05	88	0.25
2022	82	0.16	88	0.11	88	0.11		0.07	87	0.26
2023	79	0.19	85	0.13	85	0.13	91	0.08	87	0.27
2024	76	0.21	82	0.16	82	0.16		0.10	86	0.28

APPENDIX G

ECONOMIC ANALYSIS

FOR

REPAIR OF RUNWAY 13R-31L SHOULDERS

AIRFIELD SHOULDER UPGRADE
ECONOMIC ANALYSIS

EXECUTIVE SUMMARY REPORT

PROJECT TITLE : NAVAL AIR STATION, FALLON, NEVADA
DISCOUNT RATE : 2.9%
PERIOD OF ANALYSIS: 26 Years
START YEAR : 1999
BASE YEAR : 1999
REPORT OUTPUT : Constant Dollars

PROJECT OBJECTIVE : Life Cycle Cost for airfield shoulder upgrade.

ALTERNATIVES CONSIDERED FOR THIS ANALYSIS:

A. Background

Airfield shoulders do not meet criteria.

B. Objective

The task is to identify deficiencies in meeting the criteria, develop a cost estimate to upgrade shoulders and to perform life cycle cost on the upgrade.

C. Description of Alternatives

1. Replace AC shoulders. Maintain the pavement as deemed necessary.

ASSUMPTIONS OF THE ANALYSIS:

A. Time-Value of Money

1. The discount rate used in this analysis is 2.9%. This rate was obtained from Appendix C of the OMB Circular A-94 (Revised January 1999).

2. The base year will be Fiscal Year 1999.

3. Project life of 26 years will be used. This is calculated as a 25-year economic life for airfield pavements, and a 12 month "construction" period.

4. An End-of-Year cost convention will be used.

B. Construction / Design Criteria

1. Replace AC Shoulders: Replace the existing asphalt concrete section with a new asphalt concrete section. Major maintenance and repair consist of crack sealing and surface treatments. Global crack sealing to be completed every 3 years. Surface treatment consisting of a single bituminous spray (fog seal) to be applied every three years.

C. Cost Related:

1. Operations and maintenance costs are relatively insignificant; therefore, a

constant cost for yearly maintenance will be used.

2. Land value on the installation will not be considered.

3. Terminal value will not be considered.

D. Economic Life:

The economic life of airfield pavements is 25 years which was obtained from Appendix A, Reference Code A1 of the NAVFAC Economic Life Analysis Consolidated Report (dated 24 February 1999).

E. Sustainable Materials:

Estimates of material costs used in this analysis do not include sustainable or "green" materials. Initially, "green" or recycled materials and processes may cost more than the materials historically used. However, the durability of these new materials may well provide an overall lower life-cycle cost of the facility.

ECONOMIC INDICATORS:

ALTERNATIVE NAME	NPV
1 New Asphalt Concrete Pavement	$7,454,533

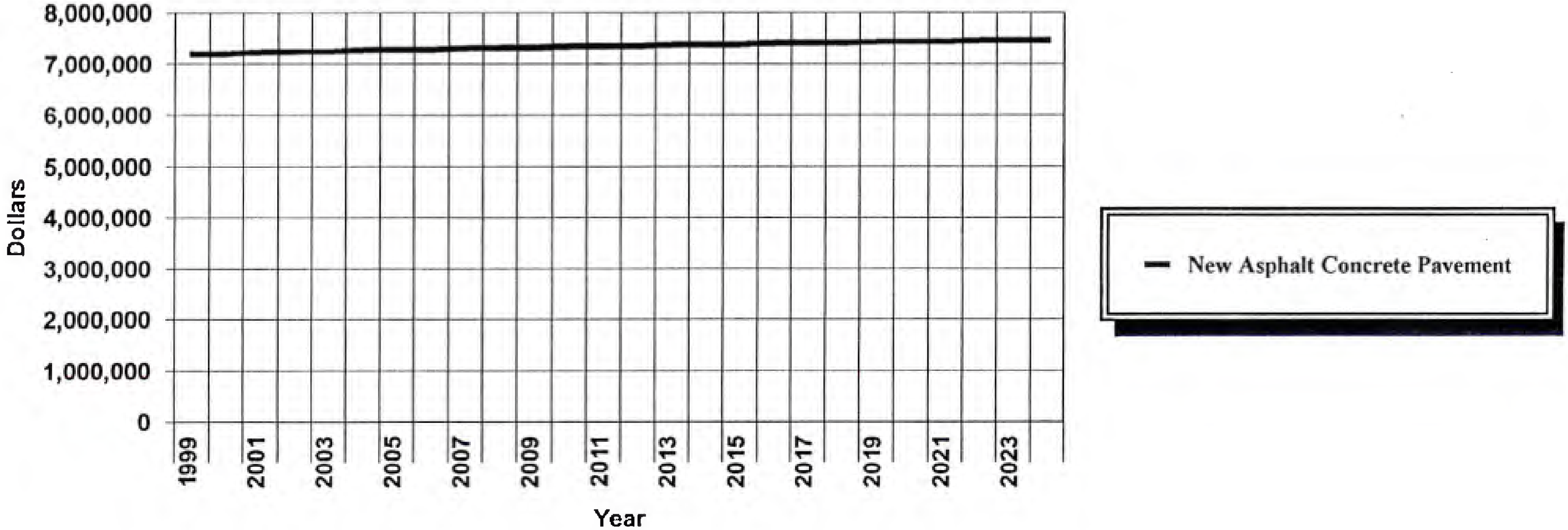
NON-MONETARY COSTS AND BENEFITS:

A. Foreign Object Damage (FOD)

Analysis of results from previous studies and published information (NFESC. Memorandum: Causes of Foreign Object Damage (FOD) to Aircraft Engines. ESC63/MCH/D14-11, 13 March 1998) indicate that material originating from the pavement matrix account for only a small percentage of foreign object debris (FO). The percentage would be a small percent of all types of rock and sand products attributable to FO. Rock, sand and ice type FO cause about five percent of FOD. Pavement fragments, if any, represents only a fraction of the five percent. FO removal would be considered part of the O&M costs.

ACTION OFFICER: Gregory D. Cline
ORGANIZATION : NFESC

ECONOMIC ANALYSIS GRAPH 1
Cumulative Net Present Value



LIFE CYCLE COST REPORT

1 New Asphalt Concrete Pavement

YEAR	Initial Construction (1)	Surface Treatment (2)	Crack Seal - Global (3)	O & M (4)	TOTAL ANNUAL OUTLAYS
----	------------	------------	------------	------------	------------
1999	$7,400,000	$0	$0	$1,500	$7,401,500
2000	$0	$0	$0	$1,500	$1,500
2001	$0	$37,500	$5,060	$1,500	$44,060
2002	$0	$0	$0	$1,500	$1,500
2003	$0	$0	$0	$1,500	$1,500
2004	$0	$37,500	$5,060	$1,500	$44,060
2005	$0	$0	$0	$1,500	$1,500
2006	$0	$0	$0	$1,500	$1,500
2007	$0	$37,500	$5,060	$1,500	$44,060
2008	$0	$0	$0	$1,500	$1,500
2009	$0	$0	$0	$1,500	$1,500
2010	$0	$37,500	$5,060	$1,500	$44,060
2011	$0	$0	$0	$1,500	$1,500
2012	$0	$0	$0	$1,500	$1,500
2013	$0	$37,500	$5,060	$1,500	$44,060
2014	$0	$0	$0	$1,500	$1,500
2015	$0	$0	$0	$1,500	$1,500
2016	$0	$37,500	$5,060	$1,500	$44,060
2017	$0	$0	$0	$1,500	$1,500
2018	$0	$0	$0	$1,500	$1,500
2019	$0	$37,500	$5,060	$1,500	$44,060
2020	$0	$0	$0	$1,500	$1,500
2021	$0	$0	$0	$1,500	$1,500
2022	$0	$37,500	$5,060	$1,500	$44,060
2023	$0	$0	$0	$1,500	$1,500
2024	$0	$0	$0	$1,500	$1,500
	------------	------------	------------	------------	
%NPV	96.47	2.79	0.38	0.36	
	$7,191,448	$207,905	$28,053	$27,126	
DISCOUNTING CONVENTION	E-O-Y	E-O-Y	E-O-Y	E-O-Y	
INFLATION INDEX	No Inflation	No Inflation	No Inflation	No Inflation	

LIFE CYCLE COST REPORT

1 New Asphalt Concrete Pavement

YEAR	END OF YEAR DISCOUNT FACTORS	PRESENT VALUE	CUMULATIVE NET PRESENT VALUE
1999	0.972	$7,192,906	$7,192,906
2000	0.944	$1,417	$7,194,322
2001	0.918	$40,439	$7,234,761
2002	0.892	$1,338	$7,236,099
2003	0.867	$1,300	$7,237,399
2004	0.842	$37,115	$7,274,515
2005	0.819	$1,228	$7,275,743
2006	0.796	$1,193	$7,276,936
2007	0.773	$34,065	$7,311,001
2008	0.751	$1,127	$7,312,128
2009	0.730	$1,095	$7,313,223
2010	0.710	$31,265	$7,344,488
2011	0.690	$1,034	$7,345,523
2012	0.670	$1,005	$7,346,528
2013	0.651	$28,696	$7,375,223
2014	0.633	$949	$7,376,173
2015	0.615	$923	$7,377,095
2016	0.598	$26,337	$7,403,432
2017	0.581	$871	$7,404,304
2018	0.565	$847	$7,405,151
2019	0.549	$24,173	$7,429,323
2020	0.533	$800	$7,430,123
2021	0.518	$777	$7,430,900
2022	0.504	$22,186	$7,453,086
2023	0.489	$734	$7,453,820
2024	0.476	$713	$7,454,533

2.9% DISCOUNT RATE, 26 YEARS

LIFE CYCLE COST REPORT

SOURCE AND DERIVATION OF COSTS AND BENEFITS:

A. New Asphalt Concrete Pavement

This cost was estimated by EFA West and is presented in the Form 1391.

MAINTENANCE AND REPAIR COSTS

		QUANTITY		COSTS	
ITEM DESCRIPTION	Year	NUMBER	UNIT	UNIT	TOTAL
Crack Seal and Routing	2001	2200	LF	2.30	5060
Surface Treatment	2001	250000	SF	0.15	37500
Crack Seal and Routing	2004	2200	LF	2.30	5060
Surface Treatment	2004	250000	SF	0.15	37500
Crack Seal and Routing	2007	2200	LF	2.30	5060
Surface Treatment	2007	250000	SF	0.15	37500
Crack Seal and Routing	2010	2200	LF	2.30	5060
Surface Treatment	2010	250000	SF	0.15	37500
Crack Seal and Routing	2013	2200	LF	2.30	5060
Surface Treatment	2013	250000	SF	0.45	37500
Crack Seal and Routing	2016	2200	LF	2.30	5060
Surface Treatment	2016	250000	SF	0.45	37500
Crack Seal and Routing	2019	2200	LF	2.30	5060
Surface Treatment	2009	250000	SF	0.15	37500
Crack Seal and Routing	2022	2200	LF	2.30	5060
Surface Treatment	2022	250000	SF	0.45	37500

APPENDIX H

LISTING OF TASKS AND ESTIMATED TIME TO COMPLETE

FOR

PAVEMENT MAINTENANCE AND REPAIR ALTERNATIVES

Asphalt Concrete Pavements
Fog Seal
Crack Seal
2" Overlay

Portland Cement Concrete Pavements
Joint Resealing
Spall and Joint Repair

Asphalt Concrete Pavement
FOG SEAL

ASPHALT CONCRETE PAVEMENTS			
TASKS	OUTPUT RATE	QUANTITY	CALCULATED TIME
A. FOG SEAL			
	Note: Detailed estimate not available.		
Clean pavement surface	**Estimated Completion time: 1 to 2 months**		
loose materials	Assumed Area: 1,800,000sq.ft.		
dirt	Actual completion time depends on many site specific		
vegetation	factors, including the following:		
paints/landing stripes	a. Amount of cleanup.		
rubber deposit	b. The amount & severity of cracks and its repairs.		
oil/grease	c. The availability/capability of equipment.		
any objectionable material	d. Size of crew & rate of sealing.		
	e. The cure time of the sealing material.		
Clean cracks	f. Weather conditions.		
Clean/vacuum cracks	g. Repaint of safety lanes /markings		
Sterilize cracks of vegetation	h. Other contingencies		
Apply fog spray of water			
Apply fog seal			
manually seal areas where needed			
manually finish surface with burlap bags			
machine roll-smooth surface			
Allow fog seal to cure			
Repaint landing/safety stripes			
Allow paint to dry			

Asphalt Concrete Pavement
CRACK SEAL

ASPHALT CONCRETE PAVEMENTS			
TASKS	OUTPUT RATE	QUANTITY	CALCULATED TIME
B. CRACK SEAL			
	Note: Detailed estimate not available.		
Hairline Cracks (Less than 1/4" & Less than 80%)	**Estimated Completion time: 0 to 6 months**		
Normally not sealed	Assumed Linear Length: 20,000ft.		
	Actual completion time depends on many site specific		
Hairline Cracks (Less than 1/4" & More than 80%)	factors, including the following:		
Requires no preparation of cracks	a. Amount of cleanup.		
Clean surface	b. The amount & severity of cracks and its repairs.		
Apply slurry seal, asphalt overlay, or pavement	c. The availability/capability of equipment.		
recycling method	d. Size of crew & rate of repairing cracks		
Allow time for curing	e. The cure time of the crack repair material.		
	f. Weather conditions.		
Small Cracks (1/4 to 3/4")	g. Repaint of safety lanes /markings		
Sawcut cracks 1/4" wider	h. Other contingencies		
Remove old sealant if present			
Sandblast, waterblast, and airblast			
Insert backer rod if needed			
Fill with sealant			
Allow time for curing			
Medium Cracks (3/4" to 2")			
Initial clean cracks using sanblaster, HCA heat			
lance, or wire brushes			
Clean with high pressure water or airblaster			
Fill with asphalt sand or fine graded asphalt mix			
Compact asphalt fill			
Allow time for curing			
Large Cracks (2" or larger)			
Sawcut perimeter around crack			
Remove pavement inside sawcut perimeter			
Sandblast inside sawcut area			
Clean with water pressure and air blast			
Fill with asphalt sand or fine graded asphalt mix			
Compact asphalt fill			
Allow time for curing			
Small & Medium Cracks to be Overlayed			
Clean surface using sandblaster,			
HCA heat lancer, or wire brushes			
Clean surface with compressed air			
Seal cracks with sand emulsion mix, or sealant			
for pavements to be overlayed			
Apply asphalt overlay			
Compact overlay			
Allow time for curing			

Asphalt Concrete Pavement
2" AC OVERLAY

ASPHALT CONCRETE PAVEMENTS			
TASKS	OUTPUT RATE	QUANTITY	CALCULATED TIME
C. 2" ASPHALT OVERLAY			
	Note: Detailed estimate not available.		
Clean pavement surface	**Estimated Completion time: 2 to 6 months**		
loose materials	Assumed Area: 1,800,000sq.ft..		
dirt	Actual completion time depends on many site specific		
vegetation	factors, including the following:		
paints/landing stripes	a. Amount of cleanup.		
rubber deposit	b. The amount & severity of cracks and its repairs.		
oil/grease	c. The availability/capability of equipment.		
any objectionable material	d. Size of crew & rate of overlaying		
	e. The cure time of the overlay material.		
Clean cracks	f. Weather conditions.		
Clean/vacuum cracks	g. Repaint of safety lanes /markings		
Sterilize cracks of vegetation	h. Other contingencies		
Prepare Equipment & Overlay Material			
Sandblast, Waterblast, and Airblast Pavement			
Patch Major Cracks & Damages			
Fill & Compact Depressions			
Apply Asphalt Tack Coat or Fog Seal			
Apply Asphalt Slurry Seal if Required			
Apply 2" Asphalt Overlay			
Compact Asphalt Overlay			
Allow time for Curing			
Repaint Safety Lanes or Markings			

Portland Cement Concrete Pavement
JOINT RESEALING

PORTLAND CEMENT CONCRETE PAVEMENTS			
TASKS	**OUTPUT RATE**	**QUANTITY**	**CALCULATED TIME**
A. Joint Resealing			
	Note: Detailed estimate not available.		
Develop construction drawings	**Estimated Completion time: 1 to 2 months**		
Location of joints to repaired/resealed	Assumed Linear Length: 140,000 ft.		
Show typical details	Actual completion time depends on many site specific		
Include joint seal specification	factors, including the following:		
Etc...	a. Amount of cleanup.		
	b. The amount & severity of joints and its repairs.		
Joint Preparation	c. The availability/capability of equipment.		
Removal of existing material	d. Size of crew & sealing rate.		
Remove existing sealant with routing tool	e. Sealant tests.		
Clean joint with vacuum sweeper	f. Weather conditions.		
Air-blow joint with compressed air	g. Other contingencies		
Refacing of joints			
Re-saw joint grooves			
Flush saw cuts with water under pressure			
Blow out water/debris with compressed air			
Final cleaning			
Sandblast joint grooves			
Blow out with compressed air			
Apply bond breaker material			
Install blocking media (backer rod)			
Insert separating tape			
Preparation of Sealant			
Hot-poured type			
Cold-applied, two component type			
Installation of Sealant			
Conduct sealant test for approval			
Verify joint cleaned with bond breaker in place			
Pour sealent (remove over-poured sealant)			
Protect poured sealant from rain			
Cure sealant 3 to 5 hours			
Check sealant frequently for proper curing/bonding			

Portland Cement Concrete Pavement
SPALL AND JOINT REPAIR

PORTLAND CEMENT CONCRETE PAVEMENTS			
TASKS	OUTPUT RATE	QUANTITY	CALCULATED TIME
B. Spall and Joint Repair			
	Note: Detailed estimate not available.		
Develop construction drawings	**Estimated Completion time: 4 to 6 months**		
Show location and size of all spalls to be repaired	Assumed Spall Repair Area: 100,000sq.ft..		
Show typical spall and joint repair details	Actual completion time depends on many site specific		
Include spall and joint material specification	factors, including the following:		
Etc...	a. Amount of cleanup.		
	b. The severity of spall and joint and their repairs.		
Spall Repair Preparation	c. The availability/capability of equipment.		
Mark repair perimeter for the spalled area	d. Size of crew & rate of repairing spall repair		
Remove joint sealant to outside of marked perimeter	e. Weather conditions.		
Saw cut the marked perimeter of repair area	f. Repaint of safety lanes /markings		
Jack-hammer concrete inside repair perimeter	g. Other contingencies		
Remove unsound base concrete			
Sandblast inside repair perimeter			
Clean by waterblasting and airblasting			
Clean area outside/around the repair perimeter			
Patch Material Installation			
Reclean repair area if needed			
Insert joint filler to expansion joints or cracks			
Apply bonding agent			
Pour PCC, rapid-setting, or polymer concrete			
Vibrate or tamp concrete			
Finish concrete patch to match existing surface			
Cure concrete patch before repair joint			
Repair Joint			
Sawcut joint over repaired spall to match existing			
Remove joint filler previously inserted			
Sandblast, waterblast, and airblast sawcuts			
Clean area adjacent to sawcuts			
Insert backer rod to joint			
Insert separating tape			
Pour sealant			
Allow sealant to cure			

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