U.S. Department
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**Federal Aviation
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# Advisory Circular

**Subject:** CHANGE 2 TO AIRPORT PAVEMENT DESIGN AND EVALUATION

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**Initiated by:** AAS-200

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**Change:** 2

1. **PURPOSE.** This change adds guidance on the economic analysis of various pavement design alternatives to determine the most economical pavement section. In instances where no clear cost advantage can be determined, alternate bids should be taken. If factors other than costs control the design, these considerations must be addressed in the engineer's report.

2. **PRINCIPAL CHANGES.** Paragraph 1b, Selection of Pavement Type, has been deleted and replaced with Economic Analysis and Design Selection, which contains information on economic analyses of airport pavement design. Appendix 4, Related Reading Material, was expanded to include an additional advisory circular and research report. Appendix 5, Economic Analysis, was added.

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for Leonard E. Mudd
Director, Office of Airport Standards

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# CHAPTER 1. AIRPORT PAVEMENTS - THEIR FUNCTION AND PURPOSES.

**1. GENERAL.** Airport pavements are constructed to provide adequate support for the loads imposed by aircraft using an airport and to produce a firm, stable, smooth, all-year, all-weather surface free from dust or other particles that may be blown or picked up by propeller wash or jet blast. In order to satisfactorily fulfill these requirements, the pavement must be of such quality and thickness that it will not fail under the load imposed. In addition, it must posses sufficient inherent stability to withstand, without damage, the abrasive action of traffic, adverse weather conditions, and other deteriorating influences. To produce such pavements requires a coordination of many factors of design, construction, and inspection to assure the best possible combination of available materials and a high standard of workmanship.

**a. Types of Pavement.** Pavements discussed in this circular are flexible, rigid, bituminous overlays, and rigid overlays. Various combinations of pavement types and stabilized layers can result in complex pavements which would be classified in between flexible and rigid. The design and evaluation guidance in this circular can be adapted to any pavement type.

**b. Economic Analysis and Design Selection.** When properly designed and constructed, any pavement type (rigid, flexible, composite, etc.) can provide a satisfactory pavement for any civil aircraft. However, some designs may be more economical than others and still provide satisfactory performance. The engineer is required to provide a rationale for the selected design in the engineer's report (see AC 150/5300-9). Often this rationale will be based on economic factors derived from evaluating several design alternatives. Life-cycle cost analysis should be used if the design selection is based on least cost. An example of a life-cycle cost analysis of alternatives for pavement rehabilitation is shown in Appendix 5. More details on life-cycle cost analysis can be found in research report DOT/FAA/RD-81/78 (see Appendix 4). Many new developments in construction have evolved in recent times which can significantly affect pavement costs, such as, recycling. In instances where no clear cost advantage can be established in the design process, alternate bids should be taken. Design selection is not always controlled by economic factors. Operational constraints, funding limitations, future expansion, etc., can override economic factors in the design selection. These considerations should be addressed in the engineer's report. *

**c. Pavement Courses.**

**(1)** Surface courses include portland cement concrete, bituminous concrete, sand-bituminous mixture, and sprayed bituminous surface treatments.

**(2)** Base courses consist of a variety of different materials which generally fall into two main classes, treated and untreated. The untreated bases consist of crushed or uncrushed aggregates. The treated bases normally consist of a crushed or uncrushed aggregate that has been mixed with a stabilizer such as cement, bitumen, etc.

**(3)** Subbase courses consist of a granular material, a stabilized granular material, or a stabilized soil.

**2. STANDARDS AND SPECIFICATIONS.**

**a.** Reference is made by Item Number throughout the text to construction material standards contained in AC 150/5370-10, Standards for Specifying Construction of Airports.

**b.** Geometric standards concerning pavement lengths, widths, grades, and slopes are presented in advisory circulars listed in Appendix 4.

**3. SPECIAL CONSIDERATIONS.** Airport pavements should provide a surface which is not slippery and will provide good traction during any weather conditions. AC 150/5320-12, Measurement, Construction and Maintenance of Skid Resistant Airport Pavement Surfaces, presents information on skid resistant surfaces.

## 4. STAGE CONSTRUCTION OF AIRPORT PAVEMENTS.

a. In some instances it may be necessary to construct the airport pavement in stages; that is, to build up the pavement profile, layer by layer, as the traffic using the facility increases in weight and number. Lateral staging, i.e., planning for future widening of pavements is sometimes advantageous to accommodate larger aircraft. If stage construction is to be undertaken, the need for sound planning cannot be overemphasized. The complete pavement should be designed prior to the start of any stage, and each stage must provide an operational surface.

The planning of a stage constructed pavement should recognize a number of considerations such as the following:

(1) Careful economic studies are required to determine if staged construction is warranted. Construction materials and labor costs follow inflationary trends and can be expected to increased as later stages are constructed. The costs and time involved in any pavement shutdown or diversion of traffic necessitated by the construction of any stage should be considered. The costs of mobilizing construction equipment several times should be compared with mobilizing once. The costs of maintaining an intermediate stage should be considered.

(2) Each stage should be designed to adequately accommodate the traffic which will use the pavement until the next stage is constructed.

(3) The underlying layers and drainage facilities of a stage constructed pavement should be built to the standards required for the final cross section. Providing the proper foundation and drainage facilities in the first stage is mandatory as the underlying layers will not be readily accessible for upgrading in the future.

(4) All parties concerned and, insofar as practicable, the general public should be informed that staged construction is planned. Staged construction sometimes draws unjust criticism when relatively new facilities are upgraded for the next stage.

# APPENDIX 4—RELATED READING MATERIAL

1. The latest issuance of the following free publications may be obtained from the Department of Transportation, Utilization and Storage Section, M-443.2, Washington, D.C. 20590. Advisory Circular 00-2, updated triannually, contains the listing of all current issuances of these circulars and changes thereto.

**a.** AC 00-2, Federal Register, Advisory Circular Checklist and Status of Federal Aviation Regulations.

**b.** AC 150/5320-12, Measurement, Construction, and Maintenance of Skid Resistant Airport Pavement Surfaces.

**c.** AC 150/5325-5, Aircraft Data.

**d.** AC 150/5335-2, Airport Aprons.

**e.** AC 150/5370-11, Use of Nondestructive Testing Devices in the Evaluation of Airport Pavements.

**f.** AC 150/5380-6, Guidelines and Procedures for Maintenance of Airport Pavements.

**g.** AC 150/5300-9, Predesign, Prebid, and Preconstruction Conferences for Airport Grant Projects.

**h.** AC 150/5300-12, Airport Design Standards--Transport Airports.

**NOTE: AC 150/5300-12 cancelled AC 150/5325-2, AC 150/5325-6, AC 150/5335-1, and AC 150/5335-4.** *

2. The following advisory circulars which can be found in AC 00-2 may be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Use the Superintendent of Documents stock number when ordering, along with the AC number and title. Send a check or money order in the amount listed for each document. No. c.o.d. orders are accepted.

**a.** AC 150/5320-5B, Airport Drainage, dated July 1, 1970.

**b.** AC 150/5370-10, Standards for Specifying Construction of Airports, dated October 24, 1974.

3. Copies of the following reports may be obtained from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161.

**a.** FAA-RD-73-169, Review of Soil Classification Systems Applicable to Airport Pavement Design, May 1974, by Yoder; AD-783-190.

**b.** FAA-RD-74-30, Design of Civil Airfield Pavement for Seasonal Frost and Permafrost Conditions, October 1974, by Berg; ADA-006-284.

**c.** FAA-RD-74-36, Field Survey and Analysis of Aircraft Distribution on Airport Pavements, February 1975, by Ho Sang; ADA-011-488.

**d.** FAA-RD-76-66, Design and Construction of Airport Pavements on Expansive Soils, January 1976, by McKeen; ADA-28-094.

**e.** FAA-RD-73-198-I, Design and Construction and Behavior Under Traffic of Pavement Test Sections, June 1974, by Burns, Rone, Brabston, Ulery; AD-785-024.

**f.** FAA-RD-74-33, III, Design Manual for Continuously Reinforced Concrete Pavements, May 1974, by Treybig, McCullough, Hudson; AD-780-512.

**g.** FAA-RD-75-110-II, Methodology for Determining, Isolating and Correcting Runway Roughness, June 1977, by Seeman, Nielsen; ADA-44-378.

h. FAA-RD-73-198-III, Design and Construction of MESL, December 1974 by Hammitt; AD-005-893.

i. FAA-RD-76-179, Structural Design of Pavements for Light Aircraft December 1976, by Ladd, Parker, Percira; ADA-041-300.

j. FAA-RD-74-39, Pavement Response to Aircraft Dynamic Loads, Volume II - Presentation and Analysis of Data, by Ledbetter; ADA-22-806.

k. FAA-RD-81-78, Economic Analysis of Airport Pavement Rehabilitation Alternatives, October 1981, by Epps and Wootan. *

4. Copies of ASTM standards may be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

5. Copies of AASHTO standards may be obtained from the American Association of State Highway and Transportation Officials, 314 National Press Building, Washington, D.C. 20004.

6. Copies of the following publications may be obtain from: Commander, U.S. Army, A.G. Publication Center, 1655 Woodson Road, St. Louis, Missouri 63114.

a. TM5-824-2, Flexible Airfield Pavements, Department of the Army Technical Manual, February 1969.

b. TM5-824-3, Rigid Pavements for Airfields other than Army, Departments of the Army and the Air Force, Technical Manual, December 1970.

c. TM5-818-2, Pavement Design for Frost Conditions, Department of the Army, Technical Manual, July 1965.

7. Copies of MS-11, Full Depth Asphalt Pavements for Air Carrier Airports, January 1973, IS-154, Full Depth Asphalt Pavements for General Aviation, January 1973, and MS-10, Soils Manual, February 1969, may be obtained from the Asphalt Institute, Asphalt Institute Building, College Park, Maryland 20740.

8. Copies of Engineering Bulletin, Design of Concrete Airport Pavement, by Robert G. Packard can be obtained from the Portland Cement Association, Old Orchard Road, Skokie, Illinois 60076.

# APPENDIX 5—ECONOMIC ANALYSIS

**1. BACKGROUND.** The information presented in this appendix was developed from research report DOT/FAA/RD-81/78. The cost data used are probably not current, however, the principles and procedures are applicable. An example is given for illustrative purposes.

**2. ANALYSIS METHOD.**

**a.** Present worth or present value economic analyses are considered the best methods for evaluating airport pavement design or rehabilitation alternatives. A discount rate of 4 percent is suggested together with an analysis period of 20 years. Residual salvage values should be calculated on the straight-line depreciated value of the alternative at the end of the analysis period. The initial cost and life expectancy of the various alternatives should be based on the engineer's experience with consideration given to local materials, environmental factors and contractor capability.

**b.** The basic equation for determining present worth is shown below:

$$PW = C + M_1 \left(\frac{1}{1+r}\right)^{n_1} + \ldots\ldots\ldots M_i \left(\frac{1}{1+r}\right)^{n_i} - S\left(\frac{1}{1+r}\right)^{z}$$

Where:

- PW = Present worth
- C = Present cost of initial design or rehabilitation activity
- $M_i$ = Cost of the ith maintenance or rehabilitation alternative in terms of present costs, i.e., constant dollars.
- r = Discount rate (four percent suggested)
- $n_i$ = Number of years from the present of the ith maintenance or rehabilitation activity.
- S = Salvage value at the end of the analysis period
- z = Length of analysis period in years (20 years suggested)

The term

$$\left(\frac{1}{1+r}\right)^{n}$$

is commonly called the single payment present worth factor in most engineering economic textbooks. From a practical standpoint, if the difference in the present worth of costs between two design or rehabilitation alternatives is 10 percent or less, it is normally assumed to be insignificant and the present worth of the two alternatives can be assumed to be the same.

**3. STEP BY STEP PROCEDURE.** The information presented in this appendix is intended to demonstrate how to calculate cost comparisons for airport pavement alternatives using the present worth method. The following is a step by step procedure illustrating the analysis method.

**a.** Identify and record key project descriptions such as:

**(1)** Project Number and Location

**(2)** Type of Facility

(3) Design Aircraft

(4) Annual Departures of Design Aircraft

(5) Subgrade Strength

b. If appropriate, determine the condition of existing pavement and record data such as:

(1) Existing Pavement Layers (thicknesses, etc.)

(2) Condition of Pavement (description of distress, pavement condition index, P.C.I., [see AC 150/5380-6], etc.)

(3) Skid Resistance

(4) Required Thickness of New Pavement

c. Identify what feasible alternatives are available.

d. Determine costs associated with each feasible alternative in terms of present day costs.

(1) Initial Cost

(2) Maintenance

(3) Future Rehabilitation

e. Calculate life-cycle cost for each alternative to be evaluated.

f. Summarize life-cycle costs, length of time required to perform and the chance for success for each alternative.

g. Evaluate the most promising alternatives based on costs, time required, operational constraints, chance for success, etc.

h. If the selection cannot be narrowed to one alternative in the evaluation process, the most promising alternatives should each be bid and the selection made on the basis of the lowest bid.

4. **EXAMPLE PROBLEM.** An example problem is discussed below which illustrates the use of the present worth life-cycle costing techniques described above.

**Example - Light-Load General Aviation Airport.**

a. A general aviation airport runway is in need of rehabilitation. The existing pavement contains alligator, transverse, and longitudinal cracking. The design aircraft for the facility has a gross weight of 24,000 lbs (10 890 kg). Using the procedures in Chapter 5 of this circular, a 3 inch (76 mm) thick bituminous overlay is required to rehabilitate the pavement. Pertinent data are presented in the Project Summary.

# PROJECT SUMMARY

Location - Muddville, TX
Number - A.I.P. 12-34-567

Type of Facility: General Aviation Runway
length=3,200 ft. (75 m)
width =75 ft. (23 m)

Design Aircraft: 24,000 lbs. (10,890 kg)

Annual Departures of Design Aircraft: 3,000

Subgrade Strength: CBR = 4

Existing Pavement:

| Layer and Type | Thickness | Condition |
|---|---|---|
| AC Surface | 4 in. (102 mm) | Poor |
| Untreated Base | 10 in. (254 mm) | Good |

Condition of Existing Pavement:
Condition Survey: Alligator cracking, moderate 15% of area
Trans. cracking, moderate, 350'/station
Long. cracking, moderate, 400'/station
P.C.I. = 35
Skid Resistance: Good
Req'd. Thickness New Pave. = 18 in. (457 mm) total
2 in. (51 mm) surf.
5 in. (127 mm) base
11 in. (279 mm) subbase

b. Seven rehabilitation alternatives including surface, in-place, and hot-mix recycling are considered feasible. The alternatives under consideration are:

(1) Asphalt-rubber chip seal to delay overlay.

(2) Full width 3-inch (76 mm) direct overlay

(3) Surface recycle 1-inch (25 mm) deep + 2-inch (51 mm) overlay

(4) Asphalt-rubber interlayer + 3-inch (76 mm) overlay

(5) Fabric interlayer + 3-inch (76 mm) overlay

(6) Cold recycle with asphalt emulsion 6-inch (152 mm) deep + 2-inch (51 mm) overlay

(7) Hot recycle and rework base

c. The present day costs of various activities associated with these alternatives are estimated as shown in Table 1.

## TABLE 1. COSTS OF REHABILITATION ACTIVITIES

| Rehabilitation Activity | Cost | |
|---|---|---|
| | $/sq. yd. | $/sq. m) |
| Asphalt-Rubber Chip Seal | 1.25 | (1.50) |
| Asphalt-Rubber Interlayer | 1.25 | (1.50) |
| Fabric Interlayer | 1.20 | (1.44) |
| Surface Recycling | 0.90 | (1.08) |
| Asphaltic Concrete - 1 in. (25 mm) | 1.65 | (1.97) |
| Cold Recycle + 2-in. (51 mm) Overlay | 6.60 | (7.89) |
| Hot Recycle + Rework Base | 8.10 | (9.69) |

d. The life-cycle costs for each alternative are calculated. This example shows the calculation for only one alternative, the asphalt-rubber chip seal. The calculations are shown in Table 2. Some of the important aspects of this analysis are discussed further below.

## TABLE 2. PRESENT WORTH LIFE-CYCLE COSTING

EXAMPLE 1. ALTERNATIVE 1 ASPHALT-RUBBER CHIP SEAL

| Year | | Cost, $/sq. yd. | Present Worth Factor, 4% | Present Worth Dollars |
|---|---|---|---|---|
| 0 | A-R Chip Ceal | 1.25 | 1.0000 | 1.25 |
| 1 | | | 0.9615 | |
| 2 | | | 0.9246 | |
| 3 | Maintenance | 0.25 | 0.8890 | 0.22 |
| 4 | 3" Overlay | 4.95 | 0.8548 | 4.23 |
| 5 | | | 0.8219 | |
| 6 | | | 0.7903 | |
| 7 | | | 0.7599 | |
| 8 | | | 0.7307 | |
| 9 | | | 0.7026 | |
| 10 | Maintenance | 0.10 | 0.6756 | 0.07 |
| 11 | Maintenance | 0.10 | 0.6496 | 0.06 |
| 12 | Maintenance | 0.10 | 0.6246 | 0.06 |
| 13 | Maintenance | 0.10 | 0.6006 | 0.09 |
| 14 | Maintenance | 0.25 | 0.5775 | 0.14 |
| 15 | 1½" Overlay | 2.48 | 0.5553 | 1.38 |
| 16 | | | 0.5339 | |
| 17 | | | 0.5134 | |
| 18 | | | 0.4936 | |
| 19 | Maintenance | 0.10 | 0.4746 | 0.05 |
| 20 | Maintenance | 0.15 | 0.4564 | 0.07 |
| Sub Total | | 9.88 | | |
| Salvage Value | | -0.71 | 0.4564 | -0.32 |
| Total | | 9.17 | | 7.300 |

Note: To convert from $/sq.yd. to $/sq. m, divide by 0.8361.

(1) The asphalt-rubber chip seal is estimated to delay the need for an overlay for 4 years. In the third year the asphalt-rubber chip seal will need maintenance costing $0.25/sq yd. ($0.29/sq m).

(2) In the fourth year a 3-inch (76 mm) overlay will be required. This overlay will require maintenance starting in the 10th year and will require progressively more maintenance as time goes on. In the 14th year maintenance will reach $0.25/sq. yd. ($0.29/sq. m).

(3) In the 15th year a 1.5-inch (38 mm) leveling course will be required. This leveling course will not require maintenance until the 19th year. Maintenance costs begin to escalate again as time goes on.

(4) The 20th year marks the end of the analysis period. The salvage value of the leveling course is: the ratio of the life remaining/to how long it will last; multiplied by its cost. The leveling course, constructed in the 15th year, is expected to have a life of 7 years. It was used for only 5 years during the analysis period. Thus, the leveling course had 2 years of life remaining at the end of the analysis period. The salvage value is 2/7 x $2.48 = $0.71. Discounting the salvage value to the 20th year yields a salvage value of $0.32. Since the salvage value is an asset rather than a cost, it is shown as a negative cost in Table 2. All other activities are assumed to have no salvage value since their useful lives have been exhausted during the analysis period. In this example, a discount rate of 4% was assumed. The present worth calculations for the other six alternatives should be calculated in a similar fashion.

e. A final summary of all alternatives considered in this example is shown in Table 3. This summary shows initial costs, life-cycle costs, construction times, and the probability for success in percent. This final summary is a convenient method of presenting all alternatives for evaluation. In this example a discount rate of 4% was used in all calculations. Maintenance and need for rehabilitation in future years are the engineer's estimates.

## TABLE 3. SUMMARY OF ALTERNATIVES

| Alternatives | | First Cost $/ sq.yd. | Present Worth Life Cycle $/sq.yd. | Time | Success Chance for % |
|---|---|---|---|---|---|
| #1 | Asph-Rub Chip Seal | 1.25 | 7.30 | 2 days | 90 |
| #2 | 3-in. Direct Overlay | 4.95 | 7.29 | 5 days | 95 |
| #3 | Surf. Recycle + Overlay | 4.20 | 6.22 | 4 days | 97 |
| #4 | A-R Layer + Overlay | 6.20 | 7.39 | 4 days | 97 |
| #5 | Fabric + Overlay | 6.15 | 7.74 | 4 days | 97 |
| #6 | Cold Recycle | 6.60 | 7.41 | 6 days | 97 |
| #7 | Hot Recycle | 8.10 | 8.46 | 6 days | 99 |

NOTE: To convert from $/sq.yd. to $/sq. m, divide by 0.8361.

f. Comparing and ranking the various alternatives shown in Table 3 yields the following results:

## TABLE 4. COMPARATIVE RANKING OF ALTERNATIVES

| First Cost | Life-Cycle Cost | Time | Chance for Success |
|---|---|---|---|
| #1 | #3 | #1 | #7 |
| #3 | #2 | #3 | #3 |
| #2 | #1 | #4 | #4 |
| #5 | #4 | #5 | #5 |
| #4 | #6 | #2 | #6 |
| #6 | #5 | #6 | #2 |
| #7 | #7 | #7 | #1 |

The average life-cycle cost of all 7 alternatives is $7.40/sq. yd. ($8.85/sq m). Adding and subtracting 10% to the average life-cycle cost yields a range of $6.66/sq. yd. to $8.14/sq. yd. ($7.97/sq m to $9.74/sq m).

Alternative #3, surface recycling with an overlay, is lowest in life-cycle costs. Life-cycle costs for alternatives #1, 3, 4, 5, and 6 are within the 10% range of the average cost. Alternative #7 is the most costly and exceeds 10% of the average cost. Alternative #3 appears to be the most promising as it ranks high in three of the four categories considered. The decision to select alternative #3 must consider the availability of contractors capable of performing surface recycling and the time required for completion.

5. **SUMMARY.** This Appendix presents an economic procedure for evaluating a wide variety of airport pavement design strategies. While the design example addresses a rehabilitation project, the principles are applicable to designs of new pavements as well. Cost data used in the example are out of date and should be updated with more current local costs before individual evaluations leading to strategy selection are undertaken. Whenever possible, local costs should be used in all alternative analyses as local conditions sometimes vary considerably from broad overall averages.

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