22. CIVIL ENGINEERING ASPECTS OF GROOVING

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INTRODUCTION

The grooving of runway and highway pavements has necessitated the Civil Engineering profession to develop methods and techniques to provide this requirement. The purpose of this paper is to discuss primarily the civil engineering aspects of runway grooving. However, most of the factors discussed have equal application to the grooving of highway pavements.

Significant items concerning design, preparation of plans and specifications, estimating, inspection of construction, and maintenance of grooving will be considered.

Data are based on experience gained as the result of grooving the portland cement concrete runway at Beale AFB with grooves 1/4 inch wide by 1/4 inch deep at 1 inch on centers. Beale AFB is a Strategic Air Command base located in a temperate climate approximately 50 miles north of Sacramento in California. Little or no freezing weather is encountered. The runway is extensively utilized by heavily loaded U.S. Air Force military aircraft including KC-135 tankers and B-52 bombers.

Prior to design of the grooving project, tests were conducted by the National Aeronautics and Space Administration on the Langley landing-loads track. In addition, available information was gathered concerning grooving both at Kansas City Municipal Airport and John F. Kennedy International Airport.

DESIGN

Design of a grooving project should consider groove configuration, location of grooving, runway pavement condition, and construction joints.

Groove Configuration

Groove configuration is dependent on the proposed purpose for the grooving. Spacing, width, and depth of grooves may be determined from tests or empirical calculations based on previous experience. Width of grooves should be based on standard blade widths of grooving equipment. Observations indicate that a minimum width of 1/8 inch is desirable to prevent premature filling of completed grooves and to allow necessary cleaning. Cost of grooving is a function of the volume of concrete removed.

Therefore, optimizing between groove configuration and volume of concrete removed should be considered.

Location of Grooving on Runways

The choice of location of grooving on runways should be made from a consideration of climatology, aircraft type, and use. With present-day and programed future high-performance aircraft, a minimum width of grooving of 100 feet is essential. Longitudinal placement is dependent on landing touchdown area and length of landing roll. At Beale AFB, the runway is 300 feet wide by 12 000 feet long with a 2000-foot overrun at the instrument end. The grooved area is 140 feet wide by 10 800 feet long, equidistant from both runway center line and runway midpoint. As an observation, grooving within 500 to 600 feet of each end of the runway should normally provide the optimum.

Correction of Defective Pavement Conditions

Correction of defective runway pavement conditions is essential prior to grooving. Therefore during design of grooving, provision should be made to repair spalls and to remove thin coatings of asphalt or rubber buildups. This repair-type work is probably best accomplished by utilizing runway maintenance forces. At Beale AFB spalling is repaired as part of a daily maintenance program. A "skid resistant" asphaltic seal coating approximately 1/4 inch to 5/8 inch thick had been previously applied to an area 150 feet wide by 4000 feet long in the landing touchdown area and had to be removed in addition to repairing the spalls. This asphaltic overlay was removed by using kerosene and mechanical road scrapers. A rubber buildup approximately 1/8 inch to 3/16 inch thick was under the overlay in some areas. This was removed by applying a rubber-dissolving chemical, by brushing, and by rinsing.

Existing Transverse Construction Joints

Existing transverse construction joints should be considered during design. At Beale a nominal 3 inches on either side of the joints was left ungrooved. Because of tolerances on groove alinement in some instances, actually only 1 inch was ungrooved.

PLANS AND SPECIFICATIONS

Plans and specifications adequately describing the following items are essential:

(1) Location of grooving on pavement keyed to some reference point

(2) Width, depth, spacing, and tolerances of grooves

(3) Type of concrete to be grooved including when constructed, class of concrete, aggregates utilized, slump, and compressive strength at 28 days

(4) Controls such as radio communication to be utilized during construction period

(5) Water supply – because of the large quantities used this is a very important item

(6) Power and lighting if work is to be accomplished at night

(7) Equipment – qualifications of bidders on proposed equipment to be used are important; provisions should be included to require the contractor to demonstrate cutting capability and control

(8) Patching of spalls as a result of contractor's operations

(9) Cleanup – this should be required continuously during grooving operations

(10) Traffic interruptions – time and compensation for removal of equipment is essential for this item.

ESTIMATING

Currently three methods of estimating cost of grooving are utilized for bidding purposes:

(1) Hourly – this method includes an hourly rate for cost of all equipment with operators, overhead (maintenance, rental, and adminstrative), and profit

(2) Unit price – this method is a cost per unit area to be grooved (usually 1 square foot); price includes all cost pertaining to equipment, operators, overhead, and profit

(3) Lump sum – this method is a lump-sum bid for all work to be performed; by necessity the contractor must include all of his cost including equipment, operation, overhead, and profit

Regardless of the method employed for bidding purposes, the actual direct cost of grooving is a function of the volume of concrete to be removed.

Data have been assembled by Beale AFB concerning the sawing characteristics of various portland cement concrete grooved pavements throughout the United States. This information presents comparative characteristics of each pavement as well as averages of all pavements analyzed. Beale conducted actual saw tests to compare its runway with California Freeways and the runways at Kansas City Municipal Airport, John F. Kennedy International Airport, and NASA Wallops Station. A 12-inch electric handsaw was placed in a guide for measuring saw cuts. Time required for a 12-inch-long cut was determined for cuts 1/8 inch wide by 1/8 inch deep and for cuts 1/4 inch wide by

1/4 inch deep. The 1/4-inch-wide cuts were made by placing two $\frac{1}{8}$-inch blades on the saw arbor. The same horizontal force was applied to the saw in all cases by means of a weight (19 lb, 7.51 oz) attached to the saw by a cable run through pulleys. Electric power was supplied to the saw from a gasoline-engine-driven electric generator (3000 watts, 115/230 volts, 26/13 amperes, 3600 rpm). Voltage and amperage were measured during each cut. At each location test cuts were made on at least two concrete slabs. A minimum of three cuts of each dimension were made in each slab.

The equipment utilized gave readings with an estimated accuracy of 95 percent. Variations in accuracy of readings generally were related to the roughness of pavements on which tests were made.

Measurements of voltage and amperage indicated that there was not a significant difference between start and finish of saw cuts for consideration in computation of comparative data. The only significant variations observed were during the cutting of aggregate embedded in the concrete. In all instances at all locations where large aggregate was encountered, there was a visible slowing of the saw as well as an increase in power requirement. These variations were particularly noticeable in the 1/4-inch-wide by 1/4-inch-deep cuts where more large aggregate was encountered at the 1/4-inch depth than at the 1/8-inch depth in all instances; also, at the 1/4-inch depth the size of aggregate was increased. These aggregate characteristics are normal for all the concrete pavements observed.

Results of comparative saw cuts for 12 locations are given in tables I, II, III, and IV.

Table I gives average volume, average of actual cutting times, and comparative time for 1 cubic inch of concrete removed for all cuts 1/4 by 1/4 by 12 inches. Table II gives the same information as table I but for cuts 1/8 by 1/8 by 12 inches. Table III gives average volume, average of actual cutting time, and comparative time for 1 cubic inch of concrete removed for all cuts within a tolerance of ±1/32 inch of the depth for 1/4- by 1/4- by 12-inch grooves. Table IV gives the same information as table III but for cuts 1/8 by 1/8 by 12 inches within a tolerance of 1/32 inch of the depth.

Time for cutting grooves is directly related to volume of concrete removed. This conclusion is based on the following calculations:

(1) The ratio of average volume for 1/4- by 1/4- by 12-inch grooves (table I) to average volume for 1/8- by 1/8- by 12-inch grooves (table II) is 0.747 cu in./0.216 cu in. or 3.4. The ratio of average time for cutting the same grooves is 17.1 sec/5.2 sec or 3.3.

(2) The ratio of average volume for 1/4- by 1/4- by 12-inch grooves ±1/32 inch (table III) to average volume for 1/8- by 1/8- by 12-inch grooves ±1/32 inch (table IV)

is 0.763 cu in./0.200 cu in. or 3.8. The ratio of average time for cutting the same grooves is 17.4 sec/4.8 sec or 3.6. These two values are considered the same since they fall within the accuracy of the test equipment.

(3) Comparative average times computed for cuts of 1 cubic inch all fall within the accuracy of the test equipment:

1/4- by 1/4- by 12-inch grooves	22.9 sec
1/8- by 1/8- by 12-inch grooves	23.9 sec
1/4- by 1/4- by 12-inch grooves ±1/32	22.7 sec
1/8- by 1/8- by 12-inch grooves ±1/32	24.2 sec

The fact that time for cutting is a function of volume is useful in calculating required time for cutting. Information is available from various governmental agencies indicating rate of advance of cutting machines. By correlating rate of advance with volume removed, the time required for any future work can be estimated very closely.

For example

Ventura Freeway
Grooves 1/8 by 1/8 inch at 3/4 inch on centers
Rate of advance of equipment, 5.2 ft/min

Beale AFB Runway
Grooves 1/4 by 1/4 inch at 1 inch on centers
Rate of advance of equipment, 1.7 ft/min

$$1/8 \times 1/8 \times \frac{12}{3/4} = 1/4$$

$$1/4 \times 1/4 \times \frac{12}{1} = 3/4$$

Therefore, three times the volume per unit width is removed when cutting the same length for a 1/4- by 1/4-inch groove at 1 inch on centers as compared with a 1/8- by 1/8-inch groove at 3/4 inch on centers. Since the rate of advance of the equipment used for cutting the 1/8- by 1/8-inch grooves was 5.2 ft/min, then

$$\frac{5.2 \text{ ft/min}}{3} = 1.7 \text{ ft/min}$$

which corresponds to the rate of advance of the equipment used to cut the 1/4- by 1/4-inch grooves at 1 inch on centers. The same equipment was used at both locations. Therefore, if this same equipment is used, the time required to cut the grooves can be estimated from the volume of material to be removed per cut.

INSPECTION

Inspection of actual contract grooving operations is extremely important. Particular emphasis is required in the following areas:

(1) Measurement of depth and width of cuts to assure accomplishment within tolerances specified

(2) Production rate. Sample timing of advance of grooving equipment during each shift is recommended. Observations should include location, pavement grade where sample is taken, and an estimate of percent and grading of aggregate exposed by cutting within sample area. Note that the production rate will vary from slab to slab because of the amount and size of aggregate encountered and the grade on which the machine is operating, that is, plus, minus, or level.

(3) Cleanup. The inspector should insure that cleanup proceeds continuously in accordance with specifications. Improper cleanup may seriously damage jet aircraft utilizing the grooved area.

MAINTENANCE

Nine months' experience at Beale AFB indicates that for the 1/4- by 1/4-inch groove pattern at 1 inch on centers, spalling due to grooving is not a factor. However, grooves in the landing touchdown area do fill with rubber at such a rate that approximately semiannual cleaning for rubber removal is anticipated. Rubber removal is accomplished by mixing one part cresylic acid (ref. 1) with three parts water. The mixture is applied by means of a liquid asphalt distributor equipped with a rear-mounted spray bar at a speed of 2 to 5 miles per hour. It is essential that this emulsion be pumped through the spray bar, not gravity fed.

Most effective results are obtained with air temperatures ranging between 65° and 85° F. The chemical emulsion is allowed to remain on the pavement surface 25 to 40 minutes, depending upon surface and temperature conditions. A metal-broom power sweeper is utilized to assist the chemical in loosening the rubber from the runway surface. The mixed solution is milky white and has the consistency of a very heavy, thick fluid. Simple spot checking with a stick or similar implement indicates the exact soak time. It is quite apparent when the rubber has been loosened from the runway.

The loosened rubber is rinsed off with water from tank trucks equipped with spray nozzles. The nozzles are pointed almost directly downward; thus a cutting action is created and the loosened rubber deposits are washed off the runway.

CONCLUDING REMARKS

Grooving at Beale AFB has eliminated the hydroplaning problems encountered previously with ungrooved runways. Also, the runway is completely drained in the grooved area even during heavy precipitation. No significant differences are discernible between the dry grooved runway and the wet grooved runway.

Nine months' experience with the grooved runway at Beale AFB has presented no particular problem to date from the civil-engineering aspect.

REFERENCE

1. Anon.: Carbon Removal Compound, Orthodichlorobenzene, for Engine Parts. Mil. Specif. MIL-C-25107(USAF), Apr. 18, 1955.

TABLE I.- $\frac{1}{4}$- BY $\frac{1}{4}$- BY 12-INCH GROOVES

Location	(A) Average volume, cu in.	(B) Average time, sec	$\frac{1.00}{(A)} \times (B)$ Comparative time for 1 cu in., sec
Sacramento Freeway	0.751	22.6	30.1
Ventura 101 Freeway	.734	18.6	25.4
Laguna Freeway	.742	15.3	20.6
San Diego Freeway	.777	16.8	21.6
Kennedy Airport	.805	16.8	20.9
Beale Runway	.682	13.9	20.4
Kansas City Airport	.735	17.0	23.1
Donner 1-80 Freeway	.751	22.6	30.1
Los Angeles 10 Freeway	.744	17.5	23.5
Los Angeles 405 Freeway	.750	15.9	21.2
Wallops Station	.813	14.9	18.3
Beale Taxiway	.685	13.5	19.7
Average of all locations	.747	17.1	22.9
Average of all locations excluding Beale	.760	17.8	23.5

TABLE II.- $\frac{1}{8}$- BY $\frac{1}{8}$- BY 12-INCH GROOVES

Location	(A) Average volume, cu in.	(B) Average time, sec	$\frac{1.00}{(A)} \times (B)$ Comparative time for 1 cu in., sec
Sacramento Freeway	0.211	6.0	28.44
Ventura 101 Freeway	.230	5.7	24.78
Laguna Freeway	.204	5.1	25.00
San Diego Freeway	.195	4.5	23.08
Kennedy Airport	.211	4.5	21.33
Beale Runway	.244	5.5	22.54
Kansas City Airport	.272	5.9	21.69
Donner 1-80 Freeway	.201	6.2	30.85
Los Angeles 10 Freeway	.207	5.3	25.60
Los Angeles 405 Freeway	.192	4.5	23.44
Wallops Station	.192	3.5	18.23
Beale Taxiway	.229	5.1	22.27
Average of all locations	.216	5.2	23.9
Average of all locations excluding Beale	.212	5.1	24.2

TABLE III.- $\frac{1}{4}$- BY $\frac{1}{4}$- BY 12-INCH GROOVES $\pm\frac{1}{32}$ INCH OF THE DEPTH

Location	(A) Average volume, cu in.	(B) Average time, sec	$\frac{1.00}{(A)} \times (B)$ Comparative time for 1 cu in., sec
Sacramento Freeway	0.806	23.4	29.0
Ventura 101 Freeway	.750	19.0	25.3
Laguna Freeway	.742	15.3	20.6
San Diego Freeway	.777	16.8	21.6
Kennedy Airport	.788	16.6	21.1
Beale Runway	.722	14.5	20.1
Kansas City Airport	.735	17.0	23.1
Donner 1-80 Freeway	.805	23.4	29.1
Los Angeles 10 Freeway	.744	17.5	23.5
Los Angeles 405 Freeway	.750	15.9	21.2
Wallops Station	.813	14.9	18.3
Beale Taxiway	.726	14.2	19.6
Average of all locations	.763	17.4	22.7
Average of all locations excluding Beale	.771	18.0	23.3

TABLE IV.- $\frac{1}{8}$- BY $\frac{1}{8}$- BY 12-INCH GROOVES $\pm\frac{1}{32}$ INCH OF THE DEPTH

Location	(A) Average volume, cu in.	(B) Average time, sec	$\frac{1.00}{(A)} \times (B)$ Comparative time for 1 cu in., sec
Sacramento Freeway	0.197	5.7	28.9
Ventura 101 Freeway	.223	5.5	24.7
Laguna Freeway	.204	5.1	25.0
San Diego Freeway	.195	4.5	23.1
Kennedy Airport	.183	3.9	21.3
Beale Runway	.192	4.8	25.0
Kansas City Airport	.200	4.4	22.0
Donner 1-80 Freeway	.201	6.2	30.8
Los Angeles 10 Freeway	.207	5.3	25.6
Los Angeles 405 Freeway	.192	4.5	23.4
Wallops Station	.192	3.5	18.2
Beale Taxiway number 3	.208	4.6	22.1
Average of all locations	.200	4.8	24.2
Average of all locations excluding Beale	.199	4.9	24.3