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FLY ASH USE IN LEAN CONCRETE BASE

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16. Abstract

Flyash is a powdery by-product of coal combustion collected from flue gases. The Colorado Department of Highways (CDOH) has used fly ash as a cement substitute in concrete and as a mineral filler in asphalt mix. This research examines the use of flyash in lean concrete base (LCB).

LCB is concrete made with a low cement content and often contains local aggregates which do not meet conventional standards. CDOH has used LCB under concrete pavements and as a bedding material under culverts.

Tests show that 20% cement with 80% flyash is sufficient to control set. Cube tests provide an indication of strengths to be expected from a given cement-flyash combination. Trial mixes were conducted using a variety of aggregates to determine their suitability for LCB. These mixes indicate that fine aggregates such as AX sands and blowsands require high cementitious contents to obtain sufficient strengths. A more flexible specification for LCB was written, based on this research.

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INTRODUCTION

COMPOSITION OF FLYASH

Flyash is a powdery by-product of coal combustion collected from flue gases. Most flyash comes from power plants, which are required to collect such particulates for environmental reasons. The composition of flyash is variable and is most dependent on the source of coal and type of boiler unit. Physically flyash is mostly very small glassy spheres. The remainder is crystalline material and carbon. Chemically flyash is comprised of silica, alumina, ferric oxide, calcium oxide and smaller amounts of various oxides and alkalies. Flyashes are divided into classes based on their composition. Class C flyashes usually contain higher percentages of calcium oxide and thus are often cementitious by themselves. Class F flyashes usually require the addition of lime to be cementitious. High carbon content is an indication of inefficient coal burning. Flyashes with high carbon content reduce the effectiveness of admixtures in concrete mixes.

FLYASH DISPOSAL

If flyash is not put to beneficial use it presents a disposal problem. Dry flyash is subject to dusting and must be contained. Often water is added to flyash to facilitate handling. At the disposal site care must be taken to avoid leaching of soluble contents of the flyash into the groundwater.

HIGHWAY USES FOR FLYASH

Most flyash used by the Colorado Department of Highways (CDOH) is used in concrete as a cement substitute. Contractors are allowed to replace up to 20% by weight of cement with flyash. For concrete pavements in locations where alkali-silica reaction has been a problem 20% replacement of cement with Class F flyash is required.

Flyash is used occasionally in asphalt mixes for supplemental fines. The few times that undersealing grouts have been used by CDOH, they contained flyash. For one project, flyash was used to stabilize base material.

LEAN CONCRETE BASE

Lean concrete base (LCB) is concrete made with a low cement content and often contains local aggregates which do not meet conventional standards. Lean concrete is often referred to as "econocrete".

LCB normally contains about 200 to 400 pounds/cubic yard cementitious material, although higher or lower cement factors are not uncommon. Additional economy may be obtained by substituting large percentages of flyash for cement. In this research satisfactory mixes were obtained with flyash comprising 77% of the cementitious material. In normal classes of concrete CDOH allows a maximum of 20% substitution of flyash for cement. Strength requirements for LCB are usually 750 to 1500 psi. Strength requirements and aggregates used determine the amount of cementitious material needed.

Since LCB is not used as a surface course and has lower strength requirements, the aggregates do not need to meet many of the normal specifications for concrete aggregate. In particular aggregates which polish, abrade, pop out or cause surface scaling may be satisfactory for LCB. Recycled asphalt or concrete pavement may work well. Use of nearby materials which are not acceptable for normal concrete can provide substantial savings.

Low cement content in LCB can cause poor workability. This may be resolved by the substitution of flyash for cement, increase of fines in the aggregate, increase of entrained air and/or use of water reducing admixtures. These measures enhance workability and avoid excessive water requirements.

CDOH USE OF LEAN CONCRETE BASE

Most lean concrete base used by CDOH has been for base under concrete pavement. LCB has several advantages over conventional stabilized and unstabilized bases. Since LCB is watertight it protects the subgrade from moisture changes and is not subject to intrusion of fines from below. LCB is stronger than traditional stabilized bases and much stronger than unstabilized bases. Production and placement of LCB can be accomplished with the same equipment to be used for the concrete surfacing. LCB provides a smooth, all weather working platform for placement of the conventional concrete surface.

Lean concrete has also been used as a bedding material under culverts. For precast concrete box culverts LCB is an alternative to compacted aggregate base course. For large corregated metal pipe LCB is an alternative to shaping the base to fit the pipe or pouring clean aggregate around the pipe. The materials costs for LCB are higher than the other alternatives but less labor is required than with compacted aggregate or shaping. LCB used for bedding has a minimum cement content of 250 pounds specified and the following gradation requirements:

Passing 2 inch sieve - 100%
Passing No. 4 sieve - 20% to 70%
Passing No. 200 sieve - 5% to 15%

PROBLEMS WITH PREVIOUS LCB SPECIFICATION

In 1982 a LCB was used as a base under concrete pavement on I-76 northeast of Denver. The specifications listed in Appendix B were used on this project. There were many problems in establishing a mix design for this project. The water-cement ratio limit of 1.1 was difficult to meet. Other portions of the specification such as a maximum cement content did not make sense. The problems encountered on this project led to this research.

RESEARCH OBJECTIVES

1. Examine the use of cube tests and the Vicat needle to predict the strength and set properties of various cement-flyash combinations. These tests might be used to screen out poor combinations before trial mixes are conducted.
2. Check the suitability of various aggregates for use in LCB. Trial mixes should indicate how much cement and flyash are needed to produce sufficient strength when used with each aggregate.
3. Develop specifications which allow use of a wide range of aggregates with flexible use of cement and flyash but still insure a LCB with acceptable performance.

DESCRIPTION OF TEST USED

Cube Test

Cube tests to evaluate cement are conducted by molding 2" cubes of cement, water and standard silica sand. The compressive strength of the cubes must meet a minimum specification and also provide an indication of the strength to be expected when the cement is used in concrete. ASTM C 109 describes this procedure.

Cube tests are also used to evaluate flyash. Cubes are molded using cement, water and silica sand as above. Additional cubes are molded with part of the cement replaced by flyash. The relative strength of the part flyash cubes to the straight cement cubes, expressed as a percent is the pozzolanic index. ASTM C 618 requires a minimum pozzolanic index of 75. This study used substitution percentages different from that used to determine pozzolanic index. This type of test indicates the effect of flyash substitution on strength.

Time of Set

Time of set tests employ the Vicat needle to determine the time required for initial and final set. A paste of cement and water is prepared with the amount of water determined by AASHTO T 129 "Normal Consistency of Hydraulic Cement". Initial set time is the time after specimen molding at which a 1mm diameter Vicat needle penetrates 25mm. The final set is when the needle does not sink visibly into the paste. ASTM C 191 describes this procedure and the equipment used in detail.

Trial Mixes

Trial mixes are conducted to determine the properties and suitability of a particular cement, flyash, admixture and aggregate combination. During the conduct of the mix the amounts of water and admixtures needed to produce the required consistency (slump) and air content are determined. Compressive strength of cylinders molded from the mix concrete establish the strength to be expected from each mix.

TESTS CONDUCTED AND RESULTS

Cube Tests

Cube tests were conducted using one cement combined with each of seven flyashes at each of five substitution percentages. Flyash was substituted for an equal amount of cement by weight. For each combination six cubes were molded with compressive strengths of three being determined at 3 days and three at 7 days. Results are listed in Table 1.

TABLE 1

CUBE TEST RESULTS

SOURCE	COMANCHE	PAWNEE	WHEATLAND	NEBRASKA	J. BRIDGER	CRAIG	NIXON
CLASS	C	C	C	C	F	F	F
% CEMENT	3 DAY COMPRESSIVE STRENGTH (psi)						
100	3890	3890	3640	3640	3800	3800	3770
80	3470	3260	3020	3180	2930	3180	3030
60	2950	2450	2060	2130	2030	2100	1960
40	2080	1330	810	1090	1130	1190	1000
20	1500	560	70	60	400	360	280
% CEMENT	7 DAY COMPRESSIVE STRENGTH (psi)						
100	5730	5730	5410	5410	5550	5550	5600
80	4780	4900	4730	5180	4450	4840	4470
60	4030	4040	3680	3830	3330	3380	2900
40	2960	2460	1850	2130	1970	2100	1600
20	1930	980	90	240	790	700	530

TABLE 2

PERTINENT GRADATION SPECIFICATIONS

AX AGGREGATE	
Sieve	% Passing
1"	100
½"	65-90
4	45-70
8	35-55
16	20-45
30	5-25
100	0-5

AASHTO No. 67 3/4" to #4	
Sieve	% Passing
1"	100
3/4"	90-100
3/8"	20-55
4	0-10
8	0-5

CLASS 6 Agg. Base Course	
Sieve	% Passing
3/4"	100
4	30-65
8	25-55
200	3-12

TABLE 3

TRIAL MIX RESULTS

Mix No.	Cement Lbs.	Flyash Lbs.	W/C	Weight in Pounds - Aggregate Source	AEA oz/cy	WRA oz/cy	Slump Inches	Air Content Percent	Compressive Str. PS		
									7 day	28 day	45 d
1	120	400	.73	3000 - AX Sand	4	0	1.75	2.4	1070	1760	1900
2	120	400	.65	2994 - AX Sand	12	0	4.0	5.2	840	1460	1580
3	120	400	.50	3039 - AX Sand	18	0	4.5	6.6	810	1330	1460
4	120	400	.53	3105 - AX Sand	18	0	0.25	3.1	1610	2140	--
5	90	310	.67	3080 - AX Sand	18	0	1.0	5.0	470	780	840
6	90	310	.67	3130 - AX Sand	12	32	1.25	7.0	100	125	720
7	120	400	.53	1207-PSI 748-Sq 1 1036-3/4	18	0	1.5	7.0	1090	1730	--
8	120	400	.49	1008-PSI 1837-Sq 1	16	0	1.25	6.7	1050	1790	1940
9	120	400	.56	1358-PSI 1628-Sq 1	16	0	1.0	7.0	720	1325	1480
10	120	400	.62	1584-PSI 1272-Sq 1	16	0	1.5	8.0	280	850	960
11	120	400	.68	1842-PSI 873-Sq 1 356-3/4	12	0	1.0	7.6	230	760	860
12	90	310	.61	1226-PSI 1052-Sq 1 761-3/4	12	0	1.75	7.6	390	760	870
13	175	175	1.00	1390-Spayd 1670-Sq 2	16	16	0.0	3.7	580	860	--
14	175	175	1.00	1430-PS2 1750-Sq 2	16	16	1.0	12.5	590	840	940
15	175	175	.78	1397-PS2 1750-Sq 2	4	16	1,5	9.4	890	1080	--
16	175	175	.80	1633- Class 6 1400-Asphalt	4	16	1.5	3.5	550	770	--
17	175	175	.87	3200 - Class 6	6	16	2.0	2.1	1360	2030	--
18	125	225	.80	1410-PS2 1710-Sq 2	4	16	1.0	8.5	710	950	1100
19	150	200	.80	1200-PS 2 1880-Sq 2	2	16	1.0	7.9	860	1210	1310
20	125	335	.79	3200 - Class 6	6	16	8.5	1.7	1160	1880	--
21	125	235*	.83	1410-PS 2 1710-Sq 2	4	10	1.5	9.0	590	710	860

* Wheatland Flyash

TABLE 4

AGGREGATE GRADATIONS

Frei-Pittinger AX Sand	
Sieve	% Pass
3/4"	100
½"	83
3/8"	73
4	56
8	44
16	33
30	23
50	15
100	10
200	5.2

Pittinger Blowsand		
Sieve	% Passing	
	#1	#2
16	100	100
30	94	93
50	51	56
100	15	22
200	6.1	7

3/4" Aggregate (No. 67)	
Sieve	% Passing
1"	100
3/4"	97
½"	64
3/8"	37
4	1

MOBILE PREMIX Squeegy		
Sieve	% Passing	
	#1	#2
3/8"	100	100
4	73	81
8	22	39
16	8	18
30	2	7
50	.7	1.8

SPAYD Blowsand	
Sieve	% Passing
16	100
30	99
50	63
100	24
200	14

KEY TO AGGREGATE SOURCES FOR TABLE 3

AX Sand.........Frei Pittinger AX Sand
PS 1............Pittinger Blowsand 1st Sampling
PS 2............Pittinger Blowsand 2nd Sampling
Sq 1............Mobile Premix Squeegy 1st Sampling
Sq 2............Mobile Premix Squeegy 2nd Sampling
Spayd...........Spayd Blowsand
Asph............Asphalt pavement grindings

For each flyash source an increase in the percentage of flyash resulted in a decrease in strength. Wheatland and Nebraska flyash had very low strengths when substituted for 80% of the cement. Strengths were 90 and 240 psi respectively compared to 5410 psi for cubes with 100% cement.

Time of Set

It was originally intended to conduct time of set testing to determine what percentage of cement is required to control the set of various flyashes. However, tests conducted on undersealing grouts indicated that 20% cement was sufficient to avoid excessively fast setting. In addition, while conducting the cube tests it was noted that 20% cement provided ample set control. For these reasons time of set tests were not conducted.

Trial Mixes

Twenty trial mixes were conducted using Ideal Portland Type I cement, Commanche flyash and various aggregates. All mixes contained Protex air entraining agent and some contained Procrete water-reducer. One trial mix contained all the ingredients described above except that Wheatland flyash was used in place of Commanche flyash. The goal was to obtain 1000 psi compressive strengths at 28 days using a minimum of cementitious material and using marginal aggregates. A minimum air content of 5% for durability was sought. Results are listed in Table 3.

Frei-Pittenger sand was used as the aggregate in mix numbers one through six. Aggregate gradations are shown in Table 4. This local aggregate is used with imported coarse aggregate to produce Class AX concrete. (See Concrete Table in Appendix C.) Mixes one through four attained ample strength by use of a high cementitious content. Each contained 120 pounds of cement and 400 pounds of flyash. In mixes five and six the cementitious was reduced to 90 pounds cement and 310 pounds flyash. The resulting strengths of 780 and 125 psi are insufficient even with the use of a water reducer in mix number six.

In mix numbers seven through twelve the aggregate was a combination of the first sampling of Pittinger Blowsand, Mobile Premix (MPM) squeegy and in three mixes 3/4" rock. Squeegy is a reject material available at many aggregate processing plants. With a high cementitious content ample strengths were obtained with and without the 3/4" rock as shown by mixes seven and eight.

Mixes nine through eleven indicate that an increase in sand percentage decreases strength substantially. Mix twelve shows that with lower sand the cementitious material can be lowered without reducing strengths.

For the remaining mixes a water reducer was used in an attempt to lower water cement ratios and thus obtain sufficient strengths with less cementitious content.

Mixes thirteen through seventeen contained 175 pounds of cement and 175 pounds of flyash. Mix thirteen used Spayd blowsand and the second sampling of Mobile Premix squeegy. Despite zero slump and low air this mix had insufficient strength, probably due to the fineness of the spayd blowsand. Mixes fourteen and fifteen contained the second sampling of Pittinger blowsand and MPM squeegy. Considering the high air content these mixes produced good strength. Mix sixteen contained Class 6 and asphalt pavement grindings. Class 6 is a well graded aggregate used for base course. The asphalt pavement grindings were the result of milling the surface of an asphalt pavement with a rotomill. This mix had low strength despite low air content.

Mixes seventeen and twenty contained straight Class 6 with different combinations of cementitious material. Both mixes had excellent strengths.

Mixes eighteen and nineteen contained Pittinger blowsand and MPM squeegy with a greater percentage of flyash in the cementitious material. Both mixes had good strength despite slightly high air content.

Mix twenty one was identical to mix eighteen except that Wheatland flyash was substituted for the Commanche flyash. The lower strength obtained with Wheatland was expected in light of the cube test results.

At this point considerable time and effort had been expended conducting trial mixes. Some mixes had to be repeated several times with adjustments before obtaining reportable results. Ample data was available to support writing of a new specification. In addition the most available marginal material had been examined in trial mixes. For these reasons no additional trial mixes were conducted.

CONCLUSIONS

Cube tests can provide an indication of how a particular cement-flyash combination will perform. However, they are no substitute for trial mixes.

The cube tests and previous results with undersealers indicate that 20% cement in the cementitious provides adequate set control.

The trial mixes show that if the aggregate is too fine a large amount of cementitious material is needed for adequate strength. This was evident with the AX sand mixes and with mixes containing high percentages of blowsand.

Marginal materials such as blowsand and squeegy can be effectively used to produce lean concrete base. It is advisable to use an air-entraining agent to improve workability and durability and a water-reducer to lower the water-cement ratio.

For each project it is essential to conduct sufficient trial mixes to determine the most economical combination of materials which result in adequate strength and workability.

IMPLEMENTATION

The materials portion of the existing specification was modified based on this study and other recent experience. (Appendix A.) In general the specification was made less stringent to allow greater flexibility when establishing an acceptable mix design. Eliminated from the specification were the number 4 sieve limits, cement content limits, maximum air content, maximum slump and maximum water cement ratio. A field compressive strength of 750 psi was made a requirement and minimum air content was increased to 5%. The strength and air content will be sufficient to insure performance. Elimination of unnecessary specifications will simplify mix design and quality control.

The new specification is available for project use.

R E F E R E N C E S

1. W. V. Whalin, "Fly Ash Base Stabilization in Colorado", Colorado Department of Highways, April 1981.

2. "Lean Concrete (Econocrete) Base for Pavements: Current Practices", Portland Cement Association, 1980.

3. James F. Meyers, Ramon Pichumani and Bernadette S. Knapples, "Fly Ash - A Highway Construction Material", U.S. Department of transportation, Federal Highway Administration, June 1976.

4. Michael J. Maloney, "Evaluation of Fly Ash as an Admixture in Portland Cement Concrete", Oregon Department of Transportation, July 1984.

SECTION 309
Lean Concrete Base

The following is hereby added to the Standard Specifications for this project:

DESCRIPTION

309.01 This work shall consist of constructing a rigid concrete base of aggregate, portland cement, fly ash, water and admixtures, on a prepared subgrade in accordance with the specifications and in reasonably close conformity with the lines, grades, thicknesses and typical sections shown on the plans or established.

MATERIALS

309.02 Aggregates for lean concrete base shall conform to subsection 703.03 with the following changes:

The aggregate may contain crushed portland cement concrete or reclaimed asphalt pavement. The plasticity index shall not exceed 6 when tested according to AASHTO T-90. Gradation requirements of the aggregate shall conform to the following:

Passing 2" sieve	-	100%
Passing #200 sieve	-	12% max.

Other materials shall conform to the requirements specified in the following subsections of Section 700:

Cement (Type I or II)	701.01
Fly Ash	701.02
Curing Materials	711.01
Air Entraining Admixture	711.02
Chemical Admixture	711.03
Water	712.01

CONSTRUCTION REQUIREMENTS

309.03 Proportioning

Proportioning for lean concrete base shall conform to the following:

Concrete Class	LCB
Min. Field Compressive Strength, 28-day, psi	750
% Total Air (Entrained and Entrapped)	5% min.

The Contractor shall be responsible for the mix proportions and all subsequent adjustments necessary to produce the lean concrete base within the above specifications. The cementitious portion of the mix must be a minimum of 25% cement. There is no minimum percentage of flyash.

The Contractor shall submit the mix proportions and sufficient materials to be tested to CDOH Laboratory for a trial mix a minimum of 40 days before production is schedlued to begin. The Division will process a maximum of three trial mixes at no charge to the Contractor. In the event that additional design mix tests are required, the costs of such tests shall be borne by the Contractor and will be deducted from payments made to him. The Contractor may submit satisfactory laboratory test results to the Engineer in lieu of materials to be tested.

SECTION 309
LEAN CONCRETE BASE
COLORADO PROJECT NO. I 76-1(58)24

The following is hereby added to the Standard Specifications for this project:

DESCRIPTION

309.01 This work shall consist of constructing a Lean Concrete Base of graded pit run aggregate and portland cement on a prepared subgrade in accordance with these specifications and in reasonably close conformity with the lines, grades, thicknesses and typical sections shown on the plans or established.

MATERIALS

309.02 Aggregates for Lean Concrete Base shall conform to subsection 703.03 of Section 700 with the following changes:

Gradation requirements of the aggregate shall conform to the following:

Passing 2" Sieve	-	100%
Passing #4 Sieve	-	20 - 70%
Passing #200 Sieve	-	5 - 15%

Other materials shall conform to the requirements specified in the following subsections of Section 700:

Cement (Type I or II)	701.01
Water	712.01
Air Entraining Admixture	711.02
Curing Materials	711.01
Chemical Admixtures	711.03

CONSTRUCTION REQUIREMENTS

309.03 Proportioning

Proportioning for Lean Concrete Base shall conform to the following:

Concrete Class	LCB
Laboratory Design, Min. (a) Compressive Strength, 28 days, psi	1150
Cement Content, Lbs. per Cubic Yard	225 - 350 (40% Fly Ash - Max.
% Entrained and Entrapped Air	4 - 9
Consistency, AASHTO T 119, Inches	4" Max.
Water Cement Ratio	1.1 Max.

(a) Ultimate Field Strength, 750 psi. Not a Specification requirement.

The mix design shall be established by the Division using the above criteria.

SECTION 309
LEAN CONCRETE BASE
COLORADO PROJECT NO. I 76-1(58) 24

309.04 Batching

Aggregate and cement will be batched by weight. Water may be measured either by weight or volume. Air entraining admixture will be added in an approved dispenser as part of the mixing water. Water reducing admixture, if used, will be dispensed after all other ingredients are in the mixer and 30 seconds of mixing time has elapsed.

309.05 Mixing and Transporting

(a) Stationary Mixing

The plant shall be equipped with weighing and metering devices that will introduce cement, aggregate and water into the mixer in the quantities specified. Mixing shall continue until a uniform mixture of aggregate, cement and water has been obtained. Mixing may be done with an on-site mixing plant with the approval of the Engineer. The minimum mixing time shall be 45 seconds after all ingredients are in the mixer. The maximum slump shall be 4".

Lean Concrete Base may be transported in non-agitating trucks provided it can be placed on the subgrade within 60 minutes after discharge from the mixer. Haul time of up to 90 minutes may be allowed if haul units are equipped with agitators.

(b) Transit Mixing

1. The final 30 mixing revolutions shall occur at the delivery site before discharge of the concrete. Mixing revolutions shall be increased if determined by the Engineer to be inadequate.

2. For shrink-mixed concrete the mixing time in the stationary mixer may be reduced to a minimum of 15 seconds. Mixing shall be completed in a truck mixer by not less than 15 revolutions of the drum at mixing speed, at the delivery site. Mixing time and/or revolutions shall be increased if determined by the Engineer to be inadequate.

309.06 Placing

The subgrade shall be uniformly moist when the Lean Concrete Base is placed. The subgrade shall be kept continuously moist ahead of placement by sprinkling, and the sprinkling shall be so controlled as not to form mud or pools of water. Lean Concrete Base shall be placed with approved concrete placing equipment and consolidated by internal vibration.

(continued)

309.07 Finishing

The finished surface shall have a uniformly closed texture. After strike-off, no additional finishing will be required except that needed to maintain grade alignment. Areas higher than 1/2 inch above established grade shall either be removed and replaced with Lean Concrete Base to the required grade or ground to proper grade with approved grinding equipment. Low areas may either be removed and replaced or filled with paving concrete.

309.08 Joints

Longitudinal weakened plane joints shall be formed by the insertion of an acceptable plastic parting strip and offset one foot laterally (right EB and left WB) from the longitudinal weakened plane joints to be formed in the concrete pavement. Longitudinal construction joints shall be constructed as per Standard M-412-AB (Special this project) Longitudinal Construction Joint (L) detail, except bars will not be required.

Transverse construction joints shall be constructed as per Standard M-412-AB (Special this project) Construction Joint Detail (TC). Transverse weakened plane joints (Detail C) will not be required.

309.09 Curing

Lean Concrete Base shall be cured by the Type 2, white pigmented curing membrane method conforming to AASHTO M 148. Application rate shall be 200 sq. ft./gal. The cure shall be maintained for a period of 7 days.

309.10 Opening to Traffic

Traffic or Contractor's equipment will not be permitted on Lean Concrete Base before a period of 72 hours has elapsed after placement. After 72 hours, trucks hauling paving concrete will be permitted to maneuver on the base for the minimum time necessary to get into position in front of the spreading equipment to deposit their loads. After 7 days of curing the Lean Concrete Base may be used as a haul road to place the concrete pavement.

Should block cracking or other distress occur, the Engineer may reduce the axle loads or prohibit further use.

(continued)

309.11 Field Control

Total air content range: 4% to 9%

Test Frequency

Gradation: 1/5000 Sq. Yd.

Compressive Strength: 1 set/10,000 Sq. Yds.

Thickness: 1/2000 Lin. Ft. for each traffic lane on freshly finished concrete and one core per 2 lane mile.

Test frequency for slump and air content shall be the same as described in Section 412.

METHOD OF MEASUREMENT

309.12 The yardage to be paid for under this item will be the number of square yards of Lean Concrete Base completed and accepted. The width for measurement will be the width of the base shown on the typical cross section of the plans, including additional widening where called for, or as otherwise directed in writing by the Engineer. The length will be measured horizontally along the centerline of each roadway or ramp.

BASIS OF PAYMENT

309.13 (a) General

The accepted quantities of lean concrete base will be paid for at the contract unit price per square yard which price and payment shall be full compensation for furnishing and placing all materials.

No additional payment over the unit contract bid price will be made for any base which has an average thickness in excess of that shown on the plans.

Payment will be under:

Pay Item	Pay Unit
Lean Concrete Base	Square Yard

(continued)

SECTION 309
LEAN CONCRETE BASE
COLORADO PROJECT NO. I 76-1(58) 24

A Type 2, bond release (wax base) liquid membrane forming curing compound, conforming to AASHTO M 148, shall be applied to the cured Lean Concrete Base at a rate of 200 sq. ft./gal. not more than 24 hours prior to placement of Concrete Pavement over the base. This bond release membrane is in addition to the curing membrane application and payment is included in the work.

Tie bars and other joint materials will not be measured and paid for separately but shall be included in the work.

APPENDIX C - CONCRETE TABLE

TABLE 601-1

CONCRETE CLASSES with Field Compressive Strength and Brief Description	CONCRETE SPECIFICATIONS					
	Cement (Lbs./cu. yd.)	Maximum Water/Cement Ratio (lbs. H^2O/lb of Cement)	Air Content % Range (Total)	Maximum Slump (inches)	Coarse Aggregate Section 703, Table 703- (Size No.)	Fine Aggregate (Maximum % of Total Aggregate)
A 3000 Psi 1½" Aggregate	565	0.50	4-8	4	467	45%
AX 4000 Psi Local Aggregate	610	0.45	5-8	3	See Gradation in subsection 601.03	
AZ 4000 Psi 1½" Aggregate	610	0.45	5-8	4	467	45%
B 3000 Psi ¾" Aggregate	565	0.53	5-8	4	67	50%
BZ 4000 Psi ¾" Aggregate	610	0.48	5-8	4	67	50%
D 4500 Psi Deck	660	0.44	5-8	2.5 (Design) 3.25 (Field)	67	50%
DT 4500 Psi Deck Topping	700	0.44	5-9	2.5	7	50%
DX 4500 Psi Local Aggregate Deck	660	0.44	5-8	2.5 (Design) 3.25 (Field)	See Gradation in subsection 601.03	
EA 3000 Psi Exposed Aggregate	565	0.53	5-8	4	6 or 67	40%
P 3000 Psi Pavement	565	0.50	4-8	3	467 or 357	45%
S specified on plans Prestressed	660	--	specified on plans	--	--	--