



APPROVED

By: Red Date: 11-4-15



City of Fort Collins
Engineering Department

**SUBGRADE INVESTIGATION
AND PAVEMENT DESIGN
CITY OF FORT COLLINS
UTILITIES ADMINISTRATION BUILDING
ALLEYWAY
FORT COLLINS, COLORADO**

Prepared For:

**CITY OF FORT COLLINS
300 Laporte Avenue
PO Box 580
Fort Collins, Colorado 80522**

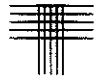
Project No. FC06486.001-135

**October 26, 2015
(Revised November 2, 2015)**



TABLE OF CONTENTS

SCOPE	1
SUMMARY OF CONCLUSIONS	1
SITE LOCATION AND PROJECT DESCRIPTION	2
FIELD AND LABORATORY INVESTIGATION	2
SUBSURFACE CONDITIONS	3
SUBGRADE PREPARATION	3
PAVEMENT DESIGN	4
Traffic Projections	4
Pavement Thickness Calculations	5
MAINTENANCE	5
SURFACE DRAINAGE	6
LIMITATIONS	6
FIGURE 1 – LOCATIONS OF EXPLORATORY BORINGS	
FIGURE 2 – SUMMARY LOGS OF EXPLORATORY BORINGS	
APPENDIX A – RESULTS OF LABORATORY TESTING	
APPENDIX B – PAVEMENT DESIGN CALCULATIONS	
APPENDIX C – SAMPLE SITE GRADING SPECIFICATIONS	
APPENDIX D – PAVEMENT CONSTRUCTION RECOMMENDATIONS	
APPENDIX E – MAINTENANCE PROGRAM	



SCOPE

This report presents the results of our subgrade investigation and pavement design for the planned roadway improvements at the City of Fort Collins Utilities Administration Building (UAB) alleyway. The purpose of our subgrade investigation was to determine the subsurface conditions and to evaluate pavement support characteristics. The report was conducted in general conformance with the Chapters 5 and 10 of the *Larimer County Urban Areas Street Standards (LCUASS)* dated January 2, 2001 (repealed and reenacted April 1, 2007) as adopted by the City of Fort Collins (City).

This report was prepared from data developed during field exploration, laboratory testing, engineering analysis, and experience with similar conditions. The report includes a description of the subsurface conditions found in exploratory borings and laboratory test results. If plans change significantly, we should be contacted to review our investigation and determine if our recommendations still apply. A brief summary of our conclusions is presented below, with more detailed criteria and recommendations contained in the report.

SUMMARY OF CONCLUSIONS

1. Our borings in the alleyway penetrated approximately 6 inches of existing asphaltic concrete overlying 8 to 10 feet of fill. The fill consisted of clayey, gravelly sand with cobbles. We recommend removal, moisture treatment, and recompaction of the existing fill to a depth of 24 inches, prior to new pavement construction.
2. The subgrade soils classified as A-2-6 materials according to AASHTO criteria, with expected subgrade support of fair to good.
3. Hot mix asphalt over aggregate base course or Portland cement concrete are appropriate pavement surfaces for this project. Minimum recommended section thicknesses are presented in this report.



SITE LOCATION AND PROJECT DESCRIPTION

The UAB alleyway extends north from Laporte Avenue on the west side of the 215 North Mason Street building in Fort Collins, Colorado. The existing alleyway is planned for reconstruction. The roadway is relatively flat. A landscaped green belt is located on the east side of the road.

FIELD AND LABORATORY INVESTIGATION

Our field investigation consisted of drilling three borings to a depth of approximately 10 feet or until practical auger refusal, logging the subsurface conditions, recording penetration-resistance tests, and acquiring samples of the subgrade materials. The approximate boring locations are shown on Figure 1. The borings were drilled with 4-inch diameter solid-stem augers and a truck-mounted drill. Our field representative directed the field investigation and collected samples. Bulk samples were obtained from the upper 4 feet of each boring. Drive samples were taken at selected intervals in each boring by driving a modified California sampler with blows from a 140-pound hammer falling 30 inches. Borings were backfilled following drilling. Summary logs of the borings, including results of field penetration resistance tests, are presented on Figure 2.

Samples were returned to our laboratory and examined by the geotechnical engineer for the project. Laboratory testing was performed in general accordance with AASHTO and ASTM methods to determine index properties, classification, and subgrade support values for those soil types influencing the pavement design. Laboratory tests and analysis included moisture content, gradation analyses, and Atterberg limits testing. A Hveem stabilometer test was conducted on a combined sample of the upper 4 feet of our borings. Results of our laboratory tests are presented in Appendix A and summarized in Table A-1.



SUBSURFACE CONDITIONS

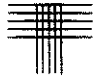
Our borings in the existing alleyway penetrated approximately 6 inches of asphaltic concrete overlying 8 to 10 feet of fill. The fill consisted of clayey, gravelly sand with cobbles. Groundwater was not encountered in our investigation.

A Hveem stabilometer test was conducted on a composite sample of material obtained from all three borings. The test indicated an R-value of 41, which we converted to a resilient modulus of 9,772 psi according to AASHTO criteria.

The fill material classified as loose to very dense based on field penetration test results. Laboratory testing indicates fines contents (percent passing No. 200 sieve) of 18 to 32 percent. Based on gradation and Atterberg limits testing, the pavement subgrade generally classifies as A-2-6 materials with expected subgrade support of fair to good. Samples of the fill were not sufficiently cohesive for swell-consolidation testing. Based on laboratory test results and our experience, we judge the subgrade to be low-swelling or non-expansive. Further description of the subsurface conditions is presented on our boring logs (Figure 2) and in our laboratory test results (Appendix A).

SUBGRADE PREPARATION

We believe the existing fill is of unknown age and origin. An excavation at the Utilities Administration Building construction site immediately west of the alleyway has uncovered significant quantities of debris. Uncontrolled fill and debris pose a threat of potentially large and uneven settlement to improvements. We recommend removal, moisture treatment and recompaction of the existing fill to a minimum depth of 24 inches. Recommendations for conventional moisture



treatment and compaction are presented in Appendix D. Preparation of the subgrade should extend from back-of-walk to back-of-walk where feasible.

Fill should be moisture conditioned to within 2 percent of optimum moisture content and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T99). The final subgrade surface must be protected from excessive drying or wetting until the pavement section is constructed. Maintaining moisture contents near optimum will be critical to avoid excessive deflections, rutting and pumping of the subgrade during subgrade preparation of streets.

PAVEMENT DESIGN

We understand roadway improvements in the project area are regulated by the City of Fort Collins, which requires the use of the AASHTO and CDOT pavement design methods for their roadways. These design methods require input parameters for traffic projections for a specified design life, roadway classification, characteristics of the subgrade materials, type and strength characteristics of pavement materials, groundwater conditions, drainage conditions, minimum pavement sections, and statistical data.

Traffic Projections

Traffic projections are expressed as an 18-kip Equivalent Daily Load Application (EDLA) for a single day and as an 18-kip Equivalent Single Axle Load (ESAL) for the design period, which is typically 20 years. The City of Fort Collins has requested use of an EDLA of 10 for pavement design at this site, corresponding to an ESAL of 73,000 over a 20-year design life.



Pavement Thickness Calculations

We used DARWin™ software to develop our HMA over ABC pavement thickness calculations with input values provided by the City, LCUASS, and our laboratory tests and observations. Computer generated printouts of the DARWin™ calculations are presented in Appendix B. Portland cement concrete recommendations were based on the supplemental AASHTO design method for rigid pavements and our experience. Our pavement thickness alternatives are presented in Table A below.

TABLE A
MINIMUM PAVEMENT THICKNESS RECOMMENDATIONS

Roadway	Portland Cement Concrete (PCC) + Moisture Treated, Recompacted Subgrade (MTS)	Hot Mix Asphalt (HMA) + Aggregate Base Course (ABC) + Moisture Treated, Recompacted Subgrade (MTS)
UAB Alleyway ESAL = 73,000	6" PCC + 24" MTS	4" HMA + 6" ABC+ 24" MTS

MAINTENANCE

Routine maintenance, such as sealing and repair of cracks, is necessary to achieve the long-term life of a pavement system. We recommend a preventive maintenance program be developed and followed for all pavement systems to assure the design life can be realized. Choosing to defer maintenance usually results in accelerated deterioration leading to higher future maintenance costs, and/or repair. A recommended maintenance program is outlined in Appendix E.

Excavation of completed pavement for utility construction or repair can destroy the integrity of the pavement and result in a severe decrease in service-



ability. To restore the pavement top original serviceability, careful backfill compaction before repaving is necessary.

SURFACE DRAINAGE

A primary cause of premature pavement deterioration is infiltration of water into the pavement system. This increase in moisture content usually results in the softening of base course and subgrade soil and eventual failure of the pavement. In addition, parts of Colorado experience many freeze-thaw cycles each season that can result in deterioration of the pavement. We recommend that subgrade, pavement, and surrounding ground surface be sloped to cause surface water to run off rapidly and away from pavements. Backs of curbs and gutters should be backfilled with compacted fill and sloped to prevent ponding adjacent to backs of curbs and to paving. The final grading of the subgrade should be carefully controlled so the pavement design cross-section can be maintained. Low spots in the subgrade that can trap water should be eliminated. Seals should be provided within the curb and pavement and in all joints to reduce the possibility of water infiltration.

LIMITATIONS

Our borings were spaced to obtain a reasonably accurate indication of subgrade and/or pavement conditions for the proposed construction. The borings are representative of conditions encountered only at the exact boring locations. Variations in the subsurface conditions not indicated by our borings are always possible. A representative of our firm should observe subgrade preparation, subgrade stabilization and pavement construction.



This report was prepared from data developed during our field exploration, laboratory testing, engineering analysis, and experience with similar conditions. The recommendations contained in this report were based upon our understanding of the planned construction. If plans change or differ from the assumptions presented herein, we should be contacted to review our recommendations.

We believe this investigation was conducted with that level of skill and care ordinarily used by geologists and geotechnical engineers practicing in this area at this time. No warranty, express or implied, is made.

If we can be of further service in discussing the contents of this report or in the analysis of the influence of subsoil conditions on design of the pavements, please call the undersigned.

CTL | THOMPSON, INC. by:

Brendan P. Moran, EI
Staff Geotechnical Engineer

BPM:SAS

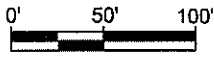
(2 Copies)



Spencer Schram, PE
Geotechnical Department Manager

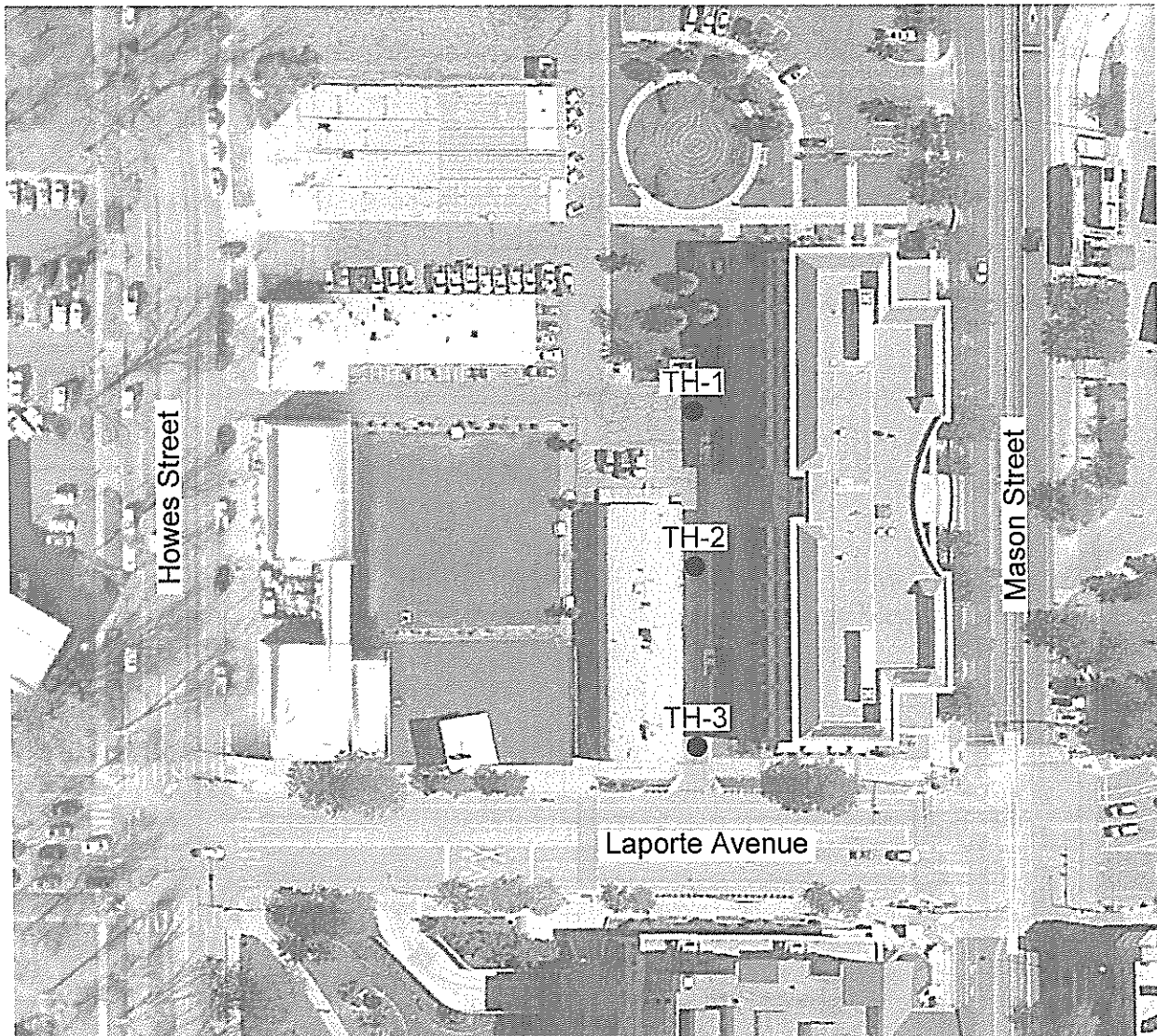


APPROXIMATE
SCALE: 1" = 100'



LEGEND:


- TH-1 INDICATES APPROXIMATE LOCATION OF EXPLORATORY BORING



Locations of Exploratory Borings



LEGEND:

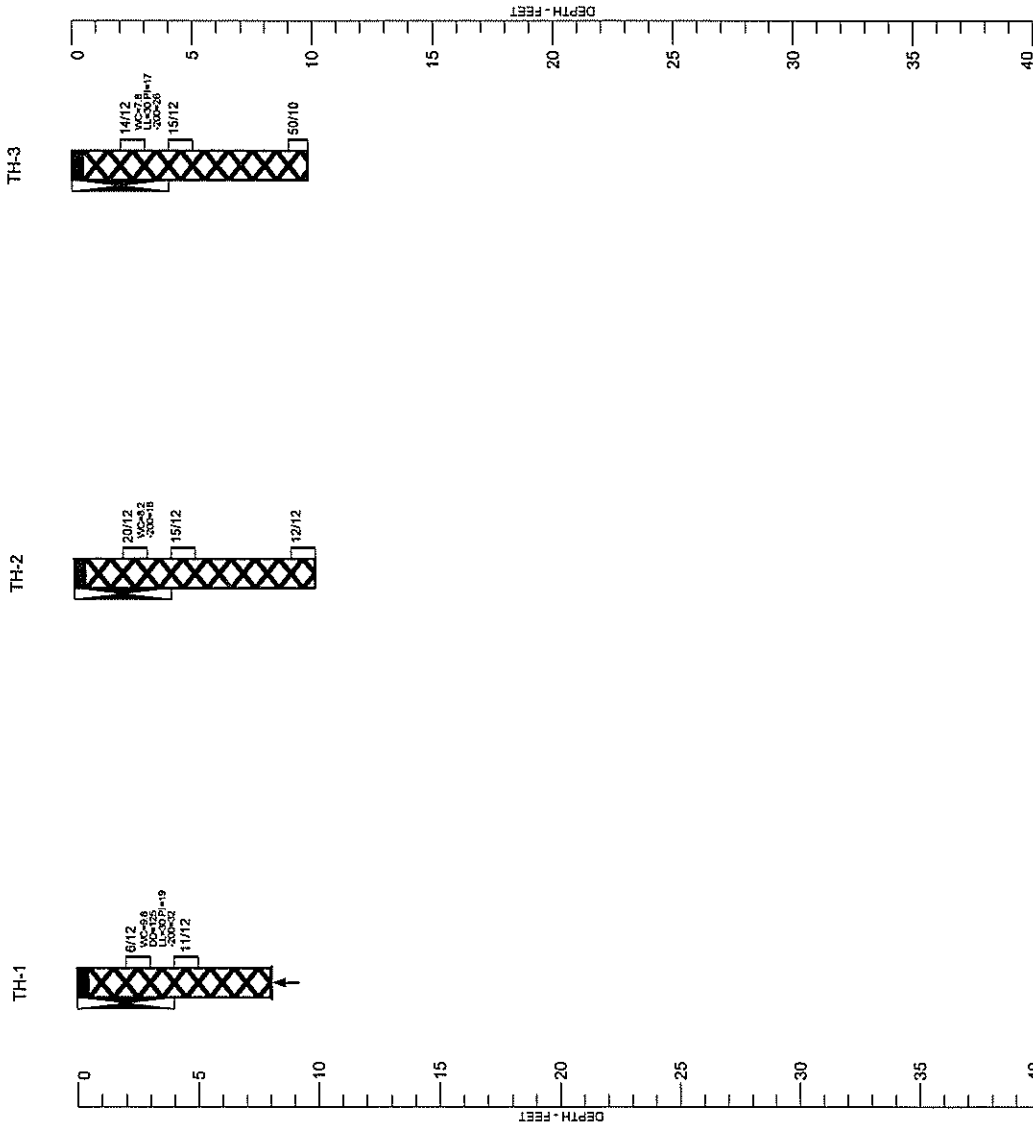
 ASPHALTIC CONCRETE, APPROXIMATE THICKNESS 6 INCHES

 FILL, SAND, CLAYEY, GRAVELLY WITH COBBLES, MOIST, LOOSE TO VERY DENSE, BROWN, DARK BROWN (SC)

 DRIVE SAMPLE, THE SYMBOL #12 INDICATES 6 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE A 2.5-INCH O.D. SAMPLER 12 INCHES.

 BULK SAMPLE FROM AUGER CUTTINGS.

 PRACTICAL DRILL REFUSAL.



NOTES:

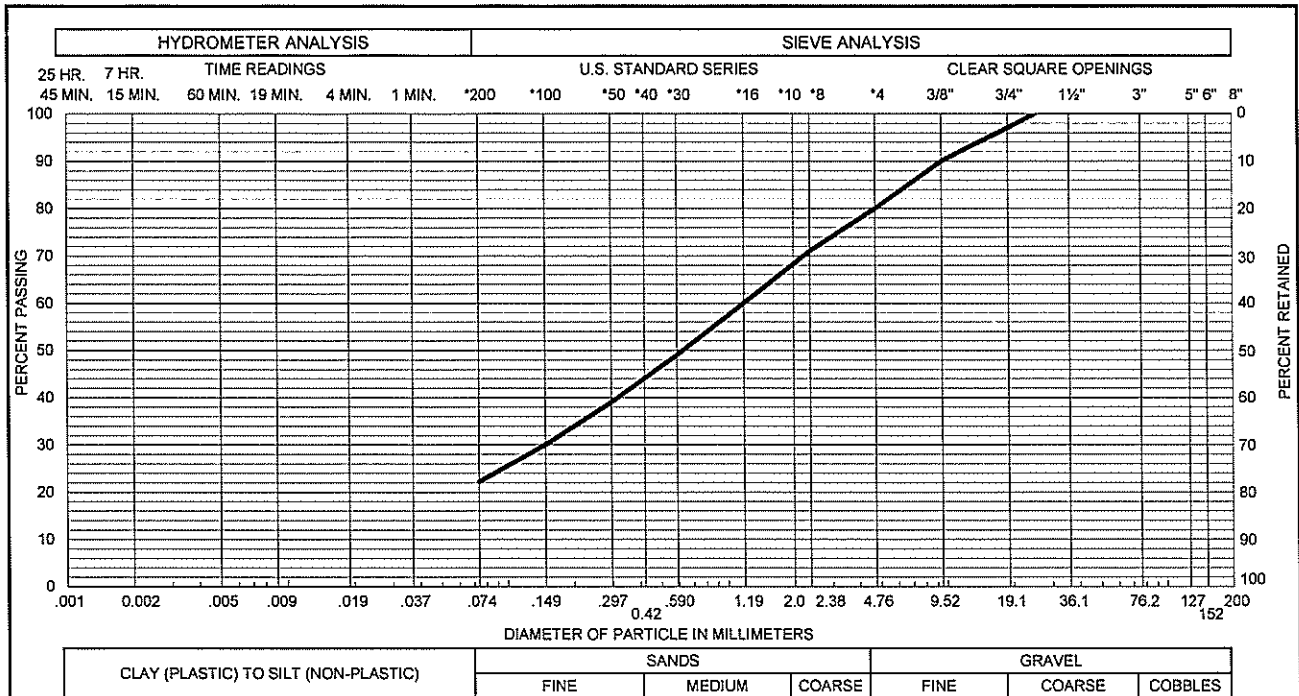
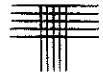
1. THE BORINGS WERE DRILLED ON SEPTEMBER 25, 2015, USING 4-INCH DIAMETER CONTINUOUS-FLIGHT AUGERS AND A TRUCK-MOUNTED DRILL RIG.
2. THESE LOGS ARE SUBJECT TO THE EXPLANATIONS, LIMITATIONS AND CONCLUSIONS IN THIS REPORT.
3. WC - INDICATES MOISTURE CONTENT (%).
 DD - INDICATES DRY DENSITY (PCF).
 -200 - INDICATES PASSING NO. 200 SIEVE (%).
 LL - INDICATES LIQUID LIMIT.
 PI - INDICATES PLASTICITY INDEX.
 UC - INDICATES UNCONFINED COMPRESSIVE STRENGTH (psf).
 SS - INDICATES SOLUBLE SULFATE CONTENT (%).
 SW - INDICATES SWELL WHEN WETTED UNDER APPROXIMATE OVERBURDEN PRESSURE (%).

**Summary Logs of
Exploratory Borings**

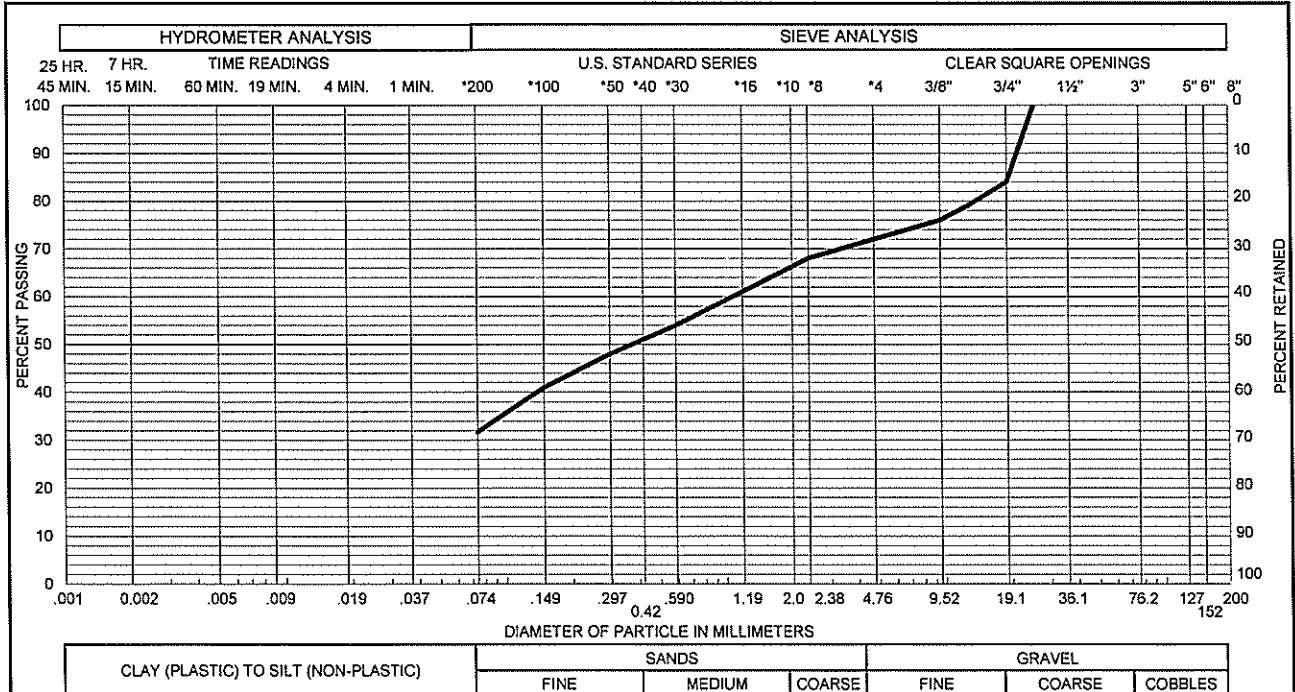
FIGURE 2



APPENDIX A
RESULTS OF LABORATORY TESTING



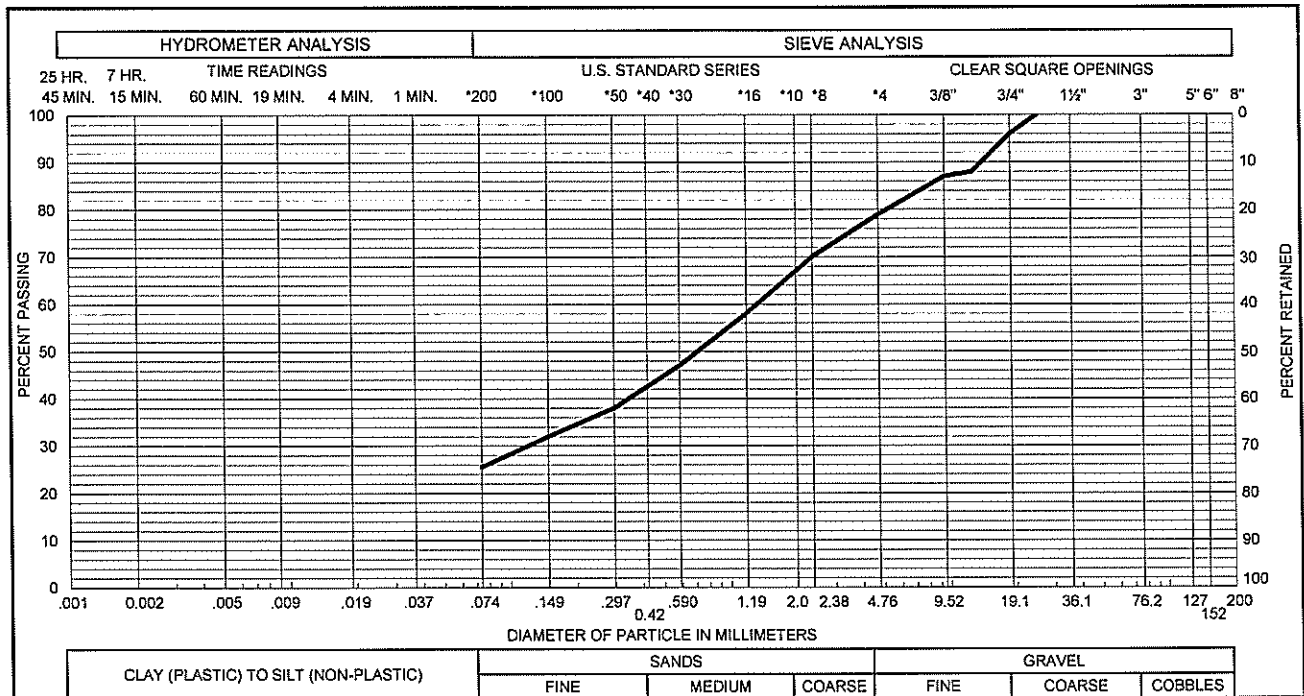
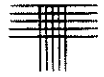
Sample of SAND, CLAYEY, GRAVELLY (SC) GRAVEL 20 % SAND 58 %
 From S - 1 AT 1-4 FEET SILT & CLAY 22 % LIQUID LIMIT 27 %
 PLASTICITY INDEX 18 %



Sample of SAND, CLAYEY, GRAVELLY (SC) GRAVEL 28 % SAND 40 %
 From TH - 1 AT 2 FEET SILT & CLAY 32 % LIQUID LIMIT 30 %
 PLASTICITY INDEX 19 %

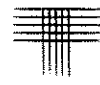
Gradation Test Results

FIGURE A-1

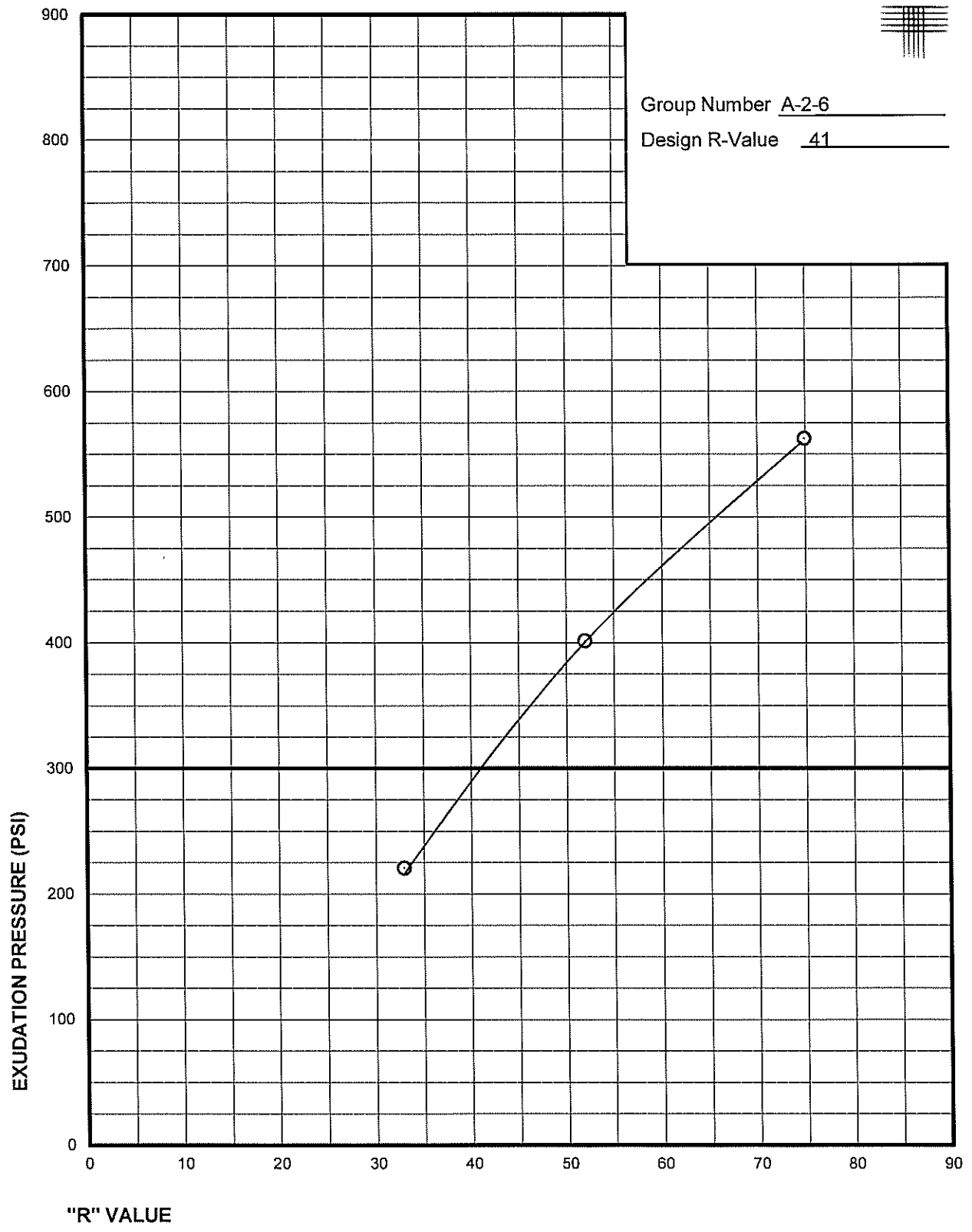


Sample of SAND, CLAYEY, GRAVELLY (SC)
 From TH - 3 AT 2 FEET

GRAVEL 21 % SAND 53 %
 SILT & CLAY 26 % LIQUID LIMIT 30 %
 PLASTICITY INDEX 17 %



Group Number A-2-6
Design R-Value 41



Hveem Stabilometer Test Results

CITY OF FORT COLLINS
UTILITIES ADMINISTRATION BUILDING ALLEYWAY
CTL | T PROJECT NO. FC06486-135

FIGURE A-3



TABLE A-I

SUMMARY OF LABORATORY TESTING

BORING	DEPTH (FEET)	MOISTURE CONTENT (%)	DRY DENSITY (PCF)	ATTERBERG LIMITS		R-VALUE	DESCRIPTION
				LIQUID LIMIT	PLASTICITY INDEX		
S-1	1-4	5.0		27	18	41	SAND, CLAYEY, GRAVELLY (SC)
TH-1	2	9.8	125	30	19		SAND, CLAYEY, GRAVELLY (SC)
TH-2	2	8.2					SAND, CLAYEY, GRAVELLY (SC)
TH-3	2	7.8		30	17		SAND, CLAYEY, GRAVELLY (SC)

* NEGATIVE VALUE INDICATES COMPRESSION.



APPENDIX B
PAVEMENT DESIGN CALCULATIONS

1993 AASHTO Pavement Design

DARWin Pavement Design and Analysis System

A Proprietary AASHTOWare
Computer Software Product

Flexible Structural Design Module

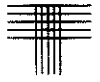
UAB ALLEYWAY
CITY OF FORT COLLINS
CTL/T PROJECT NO. FC06486.001-135

Flexible Structural Design

18-kip ESALs Over Initial Performance Period	73,000
Initial Serviceability	4.5
Terminal Serviceability	2
Reliability Level	80 %
Overall Standard Deviation	0.44
Roadbed Soil Resilient Modulus	9,772 psi
Stage Construction	1
Calculated Design Structural Number	1.85 in

Specified Layer Design

<u>Layer</u>	<u>Material Description</u>	Struct Coef. <u>(Ai)</u>	Drain Coef. <u>(Mi)</u>	Thickness <u>(Di)(in)</u>	Width <u>(ft)</u>	Calculated <u>SN (in)</u>
1	HMA	0.44	1	4	24	1.76
2	ABC	0.11	1.05	6	24	0.69
Total	-	-	-	10.00	-	2.45



APPENDIX C
SAMPLE SITE GRADING SPECIFICATIONS



SAMPLE SITE GRADING SPECIFICATIONS

1. DESCRIPTION

This item shall consist of the excavation, transportation, placement, and compaction of materials from locations indicated on the plans, or staked by the Engineer, as necessary to achieve site elevations.

2. GENERAL

The Soils Engineer shall be the Owner's representative. The Soils Engineer shall approve fill materials, method of placement, moisture contents, and percent compaction, and shall give written approval of the completed fill.

3. CLEARING JOB SITE

The Contractor shall remove all trees, brush, and rubbish before excavation or fill placement is begun. The Contractor shall dispose of the cleared material to provide the Owner with a clean, neat appearing job site. Cleared material shall not be placed in areas to receive fill or where the material will support structures of any kind.

4. SCARIFYING AREA TO BE FILLED

All topsoil and vegetable matter shall be removed from the ground surface upon which fill is to be placed. The surface shall then be plowed or scarified to a depth of 8 inches until the surface is free from ruts, hummocks or other uneven features, which would prevent uniform compaction by the equipment to be used.

5. COMPACTING AREA TO BE FILLED

After the foundation for the fill has been cleared and scarified, it shall be disked or bladed until it is free from large clods, brought to the proper moisture content and compacted to not less than 95 percent of maximum density as determined in accordance with ASTM D 698.

6. FILL MATERIALS

Materials classifying as CL, SC, SM, SW, SP, GP, GC, and GM are acceptable. Fill soils shall be free from organic matter, debris, or other deleterious substances, and shall not contain rocks or lumps having a diameter greater than three (3) inches.



7. MOISTURE CONTENT

Fill materials shall be moisture treated. Clay soils should be moisture-treated to between optimum and 3 percent above optimum moisture content as determined from Standard Proctor compaction tests. Sand soils should be moistened to within 2 percent optimum moisture content. Sufficient laboratory compaction tests shall be made to determine the optimum moisture content for the various soils encountered in borrow areas.

The Contractor may be required to add moisture to the excavation materials in the borrow area if, in the opinion of the Soils Engineer, it is not possible to obtain uniform moisture content by adding water on the fill surface. The Contractor may be required to rake or disk the fill soils to provide uniform moisture content through the soils.

The application of water to embankment materials shall be made with any type of watering equipment approved by the Soils Engineer, which will give the desired results. Water jets from the spreader shall not be directed at the embankment with such force that fill materials are washed out.

Should too much water be added to any part of the fill, such that the material is too wet to permit the desired compaction from being obtained, rolling, and all work on that section of the fill shall be delayed until the material has been allowed to uniformly dry to the required moisture content. The Contractor will be permitted to rework wet material in an approved manner to hasten its drying.

8. COMPACTION OF FILL AREAS

Selected fill material shall be placed and mixed in evenly spread layers. After each fill layer has been placed, it shall be uniformly compacted to not less than the specified percentage of maximum density. Fill materials shall be placed such that the thickness of loose material does not exceed 8 inches and the compacted lift thickness does not exceed 6 inches.

Compaction, as specified above, shall be obtained by the use of sheepsfoot rollers, multiple-wheel pneumatic-tired rollers, or other equipment approved by the Engineer. Compaction shall be accomplished while the fill material is at the specified moisture content. Compaction of each layer shall be continuous over the entire area. Compaction equipment shall make sufficient trips to insure that the required density is obtained.



9. COMPACTION OF SLOPES

Fill slopes shall be compacted by means of sheepfoot rollers or other suitable equipment. Compaction operations shall be continued until slopes are stable, but not too dense for planting, and there is no appreciable amount of loose soil on the slopes. Compaction of slopes may be done progressively in increments of three to five feet (3' to 5') in height or after the fill is brought to its total height. Permanent fill slopes shall not exceed 3:1 (horizontal to vertical).

10. DENSITY TESTS

Field density tests shall be made by the Soils Engineer at locations and depths of his choosing. Where sheepfoot rollers are used, the soil may be disturbed to a depth of several inches. Density tests shall be taken in compacted material below the disturbed surface. When density tests indicate that the density or moisture content of any layer of fill or portion thereof is below that required, the particular layer or portion shall be reworked until the required density or moisture content has been achieved.

11. COMPLETED PRELIMINARY GRADES

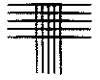
All areas, both cut and fill, shall be finished to a level surface and shall meet the following limits of construction:

- A. Overlot cut or fill areas shall be within plus or minus 2/10 of one foot.
- B. Street grading shall be within plus or minus 1/10 of one foot.

The civil engineer, or duly authorized representative, shall check all cut and fill areas to observe that the work is in accordance with the above limits.

12. SUPERVISION AND CONSTRUCTION STAKING

Observation by the Soils Engineer shall be continuous during the placement of fill and compaction operations so that he can declare that the fill was placed in general conformance with specifications. All site visits necessary to test the placement of fill and observe compaction operations will be at the expense of the Owner. All construction staking will be provided by the Civil Engineer or his duly authorized representative. Initial and final grading staking shall be at the expense of the owner. The replacement of grade stakes through construction shall be at the expense of the contractor.



13. SEASONAL LIMITS

No fill material shall be placed, spread or rolled while it is frozen, thawing, or during unfavorable weather conditions. When work is interrupted by heavy precipitation, fill operations shall not be resumed until the Soils Engineer indicates that the moisture content and density of previously placed materials are as specified.

14. NOTICE REGARDING START OF GRADING

The contractor shall submit notification to the Soils Engineer and Owner advising them of the start of grading operations at least three (3) days in advance of the starting date. Notification shall also be submitted at least 3 days in advance of any resumption dates when grading operations have been stopped for any reason other than adverse weather conditions.

15. REPORTING OF FIELD DENSITY TESTS

Density tests made by the Soils Engineer, as specified under "Density Tests" above, shall be submitted progressively to the Owner. Dry density, moisture content, of each test taken, and percentage compaction shall be reported for each test taken.

16. DECLARATION REGARDING COMPLETED FILL

The Soils Engineer shall provide a written declaration stating that the site was filled with acceptable materials, or was placed in general accordance with the specifications.



APPENDIX D
PAVEMENT CONSTRUCTION RECOMMENDATIONS



SUBGRADE PREPARATION

Moisture Treated Subgrade (MTS)

1. The subgrade should be stripped of organic matter, scarified, moisture treated and compacted to the specifications stated below in Item 2. The compacted subgrade should extend at least 3 feet beyond the edge of the pavement where no edge support, such as curb and gutter, are to be constructed.
2. Sandy and gravelly soils (A-1-a, A-1-b, A-3, A-2-4, A-2-5, A-2-6, A-2-7) should be moisture conditioned near optimum moisture content and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99). Clayey soils (A-6, A-7-5, A-7-6) should be moisture conditioned between optimum and 3 percent above optimum moisture content and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99).
3. Utility trenches and all subsequently placed fill should be properly compacted and tested prior to paving. As a minimum, fill should be compacted to 95 percent of standard Proctor maximum dry density.
4. Final grading of the subgrade should be carefully controlled so the design cross-slope is maintained and low spots in the subgrade that could trap water are eliminated.
5. Once final subgrade elevation has been compacted and tested to compliance and shaped to the required cross-section, the area should be proof-rolled using a minimum axle load of 18 kips per axle. The proof-roll should be performed while moisture contents of the subgrade are still within the recommended limits. Drying of the subgrade prior to proof-roll or paving should be avoided.
6. Areas that are observed by the Engineer that have soft spots in the subgrade, or where deflection is not uniform of soft or wet subgrade shall be ripped, scarified, dried or wetted as necessary and recompact to the requirements for the density and moisture. As an alternative, those areas may be sub-excavated and replaced with properly compacted structural backfill. Where extensively soft, yielding subgrade is encountered; we recommend a representative of our office observe the excavation.



PAVEMENT MATERIALS AND CONSTRUCTION

Aggregate Base Course (ABC)

1. A Class 5 or 6 Colorado Department of Transportation (CDOT) specified ABC should be used. Reclaimed asphalt pavement (RAP) or reclaimed concrete pavement (RCP) alternative which meets the Class 5 or 6 designation and design R-value/strength coefficient is also acceptable.
2. Bases should have a minimum Hveem stabilometer value of 72, or greater. ABC, RAP, and RCP must be moisture stable. The change in R-value from 300-psi to 100-psi exudation pressure should be 12 points or less.
3. ABC, RAP or RCP bases should be placed in thin lifts not to exceed 6 inches and moisture treated to near optimum moisture content. Bases should be moisture treated to near optimum moisture content, and compacted to at least 95 percent of standard Proctor maximum dry density (ASTM D 698, AASHTO T 99).
4. Placement and compaction of ABC, RAP, or RCP should be observed and tested by a representative of our firm. Placement should not commence until the underlying subgrade is properly prepared and tested.

Hot Mix Asphalt (HMA)

1. HMA should be composed of a mixture of aggregate, filler, hydrated lime and asphalt cement. Some mixes may require polymer modified asphalt cement, or make use of up to 20 percent reclaimed asphalt pavement (RAP). A job mix design is recommended and periodic checks on the job site should be made to verify compliance with specifications.
2. HMA should be relatively impermeable to moisture and should be designed with crushed aggregates that have a minimum of 80 percent of the aggregate retained on the No. 4 sieve with two mechanically fractured faces.
3. Gradations that approach the maximum density line (within 5 percent between the No. 4 and 50 sieves) should be avoided. A gradation with a nominal maximum size of 1 or 2 inches developed on the fine side of the maximum density line should be used.



4. Total void content, voids in the mineral aggregate (VMA) and voids filled should be considered in the selection of the optimum asphalt cement content. The optimum asphalt content should be selected at a total air void content of approximately 4 percent. The mixture should have a minimum VMA of 14 percent and between 65 percent and 80 percent of voids filled.
5. Asphalt cement should meet the requirements of the Superpave Performance Graded (PG) Binders. The minimum performing asphalt cement should conform to the requirements of the governing agency.
6. Hydrated lime should be added at the rate of 1 percent by dry weight of the aggregate and should be included in the amount passing the No. 200 sieve. Hydrated lime for aggregate pretreatment should conform to the requirements of ASTM C 207, Type N.
7. Paving should be performed on properly prepared, unfrozen surfaces that are free of water, snow and ice. Paving should only be performed when both air and surface temperatures equal, or exceed, the temperatures specified in Table 401-3 of the 2006 Colorado Department of Transportation Standard Specifications for Road and Bridge Construction.
8. HMA should not be placed at a temperature lower than 245°F for mixes containing PG 64-22 asphalt, and 290°F for mixes containing polymer-modified asphalt. The breakdown compaction should be completed before the HMA temperature drops 20°F.
9. Wearing surface course shall be Grading S or SX for residential roadway classifications and Grading S for collector, arterial, industrial, and commercial roadway classifications.
10. The minimum/maximum lift thicknesses for Grade SX shall be 1½ inches/2½ inches. The minimum/maximum lift thicknesses for Grade S shall be 2 inches/3½ inches. The minimum/maximum lift thicknesses for Grade SG shall be 3 inches/5 inches.
11. Joints should be staggered. No joints should be placed within wheel paths.
12. HMA should be compacted to between 92 and 96 percent of Maximum Theoretical Density. The surface shall be sealed with a finish roller prior to the mix cooling to 185°F.



13. Placement and compaction of HMA should be observed and tested by a representative of our firm. Placement should not commence until approval of the proof rolling as discussed in the Subgrade Preparation section of this report. Sub base, base course or initial pavement course shall be placed within 48 hours of approval of the proof rolling. If the Contractor fails to place the sub base, base course or initial pavement course within 48 hours or the condition of the subgrade changes due to weather or other conditions, proof rolling and correction shall be performed again.

Portland Cement Concrete (PCC)

1. Portland cement concrete should consist of Class P of the *2005 CDOT - Standard Specifications for Road and Bridge Construction* specifications for normal placement or Class E for fast-track projects. PCC should have a minimum compressive strength of 4,200 psi at 28 days and a minimum modulus of rupture (flexural strength) of 600 psi. Job mix designs are recommended and periodic checks on the job site should be made to verify compliance with specifications.
2. Portland cement concrete should not be placed when the subgrade or air temperature is below 40°F.
3. Concrete should not be placed during warm weather if the mixed concrete has a temperature of 90°F, or higher.
4. Mixed concrete temperature placed during cold weather should have a temperature between 50°F and 90°F.
5. Free water should not be finished into the concrete surface. Atomizing nozzle pressure sprayers for applying finishing compounds are recommended whenever the concrete surface becomes difficult to finish.
6. Curing of the portland cement concrete should be accomplished by the use of a curing compound. The curing compound should be applied in accordance with manufacturer recommendations.
7. Curing procedures should be implemented, as necessary, to protect the pavement against moisture loss, rapid temperature change, freezing, and mechanical injury.
8. Construction joints, including longitudinal joints and transverse joints, should be formed during construction or sawed after the concrete has begun to set, but prior to uncontrolled cracking.



9. All joints should be properly sealed using a rod back-up and approved epoxy sealant.
10. Traffic should not be allowed on the pavement until it has properly cured and achieved at least 80 percent of the design strength, with saw joints already cut.
11. Placement of portland cement concrete should be observed and tested by a representative of our firm. Placement should not commence until the subgrade is properly prepared and tested.



APPENDIX E
MAINTENANCE PROGRAM



MAINTENANCE RECOMMENDATIONS FOR FLEXIBLE PAVEMENTS

A primary cause for deterioration of pavements is oxidative aging resulting in brittle pavements. Tire loads from traffic are necessary to "work" or knead the asphalt concrete to keep it flexible and rejuvenated. Preventive maintenance treatments will typically preserve the original or existing pavement by providing a protective seal or rejuvenating the asphalt binder to extend pavement life.

1. Annual Preventive Maintenance
 - a. Visual pavement evaluations should be performed each spring or fall.
 - b. Reports documenting the progress of distress should be kept current to provide information on effective times to apply preventive maintenance treatments.
 - c. Crack sealing should be performed annually as new cracks appear.

2. 3 to 5 Year Preventive Maintenance
 - a. The owner should budget for a preventive treatment at approximate intervals of 3 to 5 years to reduce oxidative embrittlement problems.
 - b. Typical preventive maintenance treatments include chip seals, fog seals, slurry seals and crack sealing.

3. 5 to 10 Year Corrective Maintenance
 - a. Corrective maintenance may be necessary, as dictated by the pavement condition, to correct rutting, cracking and structurally failed areas.
 - b. Corrective maintenance may include full depth patching, milling and overlays.
 - c. In order for the pavement to provide a 20-year service life, at least one major corrective overlay should be expected.



MAINTENANCE RECOMMENDATIONS FOR RIGID PAVEMENTS

High traffic volumes create pavement rutting and smooth, polished surfaces. Preventive maintenance treatments will typically preserve the original or existing pavement by providing a protective seal and improving skid resistance through a new wearing course.

1. Annual Preventive Maintenance
 - a. Visual pavement evaluations should be performed each spring or fall.
 - b. Reports documenting the progress of distress should be kept current to provide information of effective times to apply preventive maintenance.
 - c. Crack sealing should be performed annually as new cracks appear.

2. 4 to 8 Year Preventive Maintenance
 - a. The owner should budget for a preventive treatment at approximate intervals of 4 to 8 years to reduce joint deterioration.
 - b. Typical preventive maintenance for rigid pavements includes patching, crack sealing and joint cleaning and sealing.
 - c. Where joint sealants are missing or distressed, resealing is mandatory.

3. 15 to 20 Year Corrective Maintenance
 - a. Corrective maintenance for rigid pavements includes patching and slab replacement to correct subgrade failures, edge damage and material failure.
 - b. Asphalt concrete overlays may be required at 15 to 20 year intervals to improve the structural capacity of the pavement.