Kumar & Associates, Inc.®
Geotechnical and Materials Engineers
and Environmental Scientists

800 Stockton Avenue, #4
Fort Collins, CO 80524
phone: (970) 416-9045
fax: (970) 416-9040
email: kaftcollins@kumarusa.com
www.kumarusa.com

An Employee Owned Company

Office Locations: Denver (HQ), Parker, Colorado Springs, Fort Collins, Glenwood Springs, and Summit County, Colorado

# GEOTECHNICAL ENGINEERING STUDY AND PAVEMENT THICKNESS DESIGN HOFFMAN WAY PARALLEL DRAINAGE 88TH AVENUE TO 90TH AVENUE THORNTON, COLORADO

Prepared By:

Jacob A. Hanson, P.E.

COLORADO REGISTERED
JACOB ALEXANDER HANSON
54404
12-11-20
PROFESSIONAL ENGINEER

Reviewed By:

Joshua L. Barker, P.E.

*Prepared For:*

Martin/Martin
12499 West Colfax Avenue
Lakewood, CO 80215

Attention: Mr. Ryan Byrne

Project No. 20-3-151

June 11, 2020
Revised: December 11, 2020

TABLE OF CONTENTS

## SUMMARY

1. A total of four (4) borings were drilled for this study. The borings generally encountered a thin layer of sod underlain by man-placed fill consisting of lean clay with sand to clayey sand that extended to depths of about 1.5 to 5 feet below the ground surface. The man-placed fill was underlain by natural clayey soils consisting of lean clay with sand to sandy lean clay with occasional layers of clayey sand which was in turn underlain by interbedded claystone and sandstone bedrock that extended to the explored depths of about 20 feet. Boring 2 encountered a layer of weathered claystone overlying the interbedded claystone and sandstone bedrock that continued to the explored depth of about 20 feet. Boring 4 encountered a thin layer of topsoil overlying approximately 5 feet of man-placed fill material. The man-placed fill was underlain by natural clayey soils that extended to a depth of about 17 feet below the ground surface. The natural overburden soils were underlain by interbedded claystone and sandstone bedrock which was in turn underlain by claystone bedrock that continued to the explored depth of about 30 feet.

   Groundwater was encountered in the borings at depths ranging from about 12 to 14 feet at the time of drilling. During a follow-up measurement made 8 days after drilling, stabilized groundwater was encountered in the borings at depths ranging from about 7.5 to 11.5 feet below the ground surface.

2. Shallow spread footings or raft/matt type foundations placed on natural soils or properly compacted fill extending to natural soils are feasible for the structures constructed on the site. Spread footings may be designed for a net allowable bearing pressure of 1,500 psf. Subgrade preparation considerations are provided in the body of the report.

3. We recommend a modulus of soil reaction, E', of 1,500 psi for areas well above the groundwater table and 100 psi for areas within 2 feet of the groundwater table be used for the design of pipe-zone material placed on the sides of the pipe, provided the pipe-zone material is compacted following the requirements presented in this report. For evaluating the load on the pipe due to the backfill above the pipe, we recommend using a compacted moist unit weight of 125 pcf and a Rankine's ratio of 0.37 for compacted trench-zone backfill consisting of existing on-site soils. We recommend using a coefficient of friction of 0.32 between backfill consisting of excavated on-site soils.

4. Flexible pavement sections are shown in the table below. Additional pavement design and construction criteria are presented in the body of this report.

| LOCATION | Pavement Section Thicknesses (inches) | |
|---|---|---|
| | Full-Depth Hot Mix Asphalt | Hot Mix Asphalt over Aggregate Base Course |
| East 88$^{th}$ Avenue | 13.0 | 9 over 16 |
| Hoffman Way | 8.5 | 6 over 10 |

## PURPOSE AND SCOPE OF WORK

This report presents the results of a geotechnical engineering study and pavement thickness design for the proposed Hoffman Way Parallel Drainage project to be constructed between 88$^{th}$ Avenue and 90$^{th}$ Avenue in Thornton, Colorado. The study was conducted for the purpose of providing geotechnical engineering recommendations and site grading considerations related to the project. The study was conducted in general accordance with the scope of work in our Proposal No. P3-19-160 dated April 25, 2019.

A field exploration program consisting of drilling exploratory borings was conducted to develop information on subsurface conditions at the site. Samples of the soils and bedrock collected during the field exploration were tested in the laboratory to determine their classification and relevant engineering characteristics. The results of the field exploration and laboratory testing were analyzed to develop recommendations for foundation types, depths and allowable pressures for the proposed building foundations, pavements, and site grading. The results of the field exploration and laboratory testing are presented herein.

This report has been prepared to summarize the data obtained during this study and to present our conclusions and recommendations based on the proposed construction and the subsurface conditions encountered. Design parameters and a discussion of geotechnical engineering considerations related to construction of the proposed project are included in the report.

## PROPOSED CONSTRUCTION

We understand the project includes the addition of storm water drains as well as the replacement of the existing reinforced concrete pipe with concrete box culverts. Multiple Type R inlets will be constructed along the proposed alignment. Head wall/wing walls will also be constructed on the south side of 88$^{th}$ Avenue with and will be approximately 10 feet tall.

If the proposed construction varies significantly from that described above or depicted in this report, we should be notified to reevaluate the recommendations provided herein.

## SITE CONDITIONS

At the time of the field exploration, Hoffman Way consisted of an asphalt paved roadway with a landscaped median that contained sod and trees. The overall vertical profile of the roadway slopes moderately down towards 88th Avenue. The area surrounding Hoffman Way generally consists of single-family residential neighborhoods.

The area south of 88th Avenue contained sparse weeds and grasses. The area was relatively flat with a slight slope down to the south and steeper slopes to the west towards the drainage outlet.

## SUBSURFACE CONDITIONS

The subsurface conditions at the site were explored by drilling four (4) exploratory borings at the approximate locations shown on Fig. 1. The logs of the borings are shown on Fig. 2, a legend and explanatory notes are provided on Fig. 3.

The borings generally encountered a thin layer of sod underlain by man-placed fill consisting of lean clay with sand to clayey sand that extended to depths of about 1.5 to 5 feet below the ground surface. The man-placed fill was underlain by natural clayey soils consisting of lean clay with sand to sandy lean clay with occasional layers of clayey sand which was in turn underlain by interbedded claystone and sandstone bedrock that extended to the explored depths of about 20 feet. Boring 2 encountered a layer of weathered claystone overlying the interbedded claystone and sandstone bedrock that continued to the explored depth of about 20 feet. Boring 4 encountered a thin layer of topsoil overlying approximately 5 feet of man-placed fill material. The man-placed fill was underlain by natural clayey soils that extended to a depth of about 17 feet below the ground surface. The natural overburden soils were underlain by interbedded claystone and sandstone bedrock which was in turn underlain by claystone bedrock that continued to the explored depth of about 30 feet.

The man-placed fill material contained a fine to coarse grained sand fraction and was moist and brown to dark brown. The natural clayey overburden soils contained a fine to coarse grained sand fraction and were moist to wet below groundwater and brown to gray. The weathered claystone was fine to medium grained, moist and brown. The interbedded claystone and sandstone bedrock was fine to coarse grained moist and brown to gray. The claystone bedrock was fine to medium grained, moist, and gray to dark gray. Based on sampler penetration resistance, the natural clays had consistencies ranging from very soft to stiff and the bedrock was medium hard to very hard.

Groundwater was encountered in the borings at depths ranging from about 12 to 14 feet at the time of drilling. During a follow-up measurement made 8 days after drilling, stabilized groundwater was encountered in the borings at depths ranging from about 7.5 to 11.5 feet below the ground surface. Groundwater levels are expected to fluctuate with time, and may fluctuate upward after wet weather or subsequent to landscape irrigation

## LABORATORY TESTING

Laboratory testing was performed on selected samples obtained from the borings to determine index and engineering properties of the soils at the site, including: in-situ moisture content and dry unit weight, Atterberg limits, percent passing the No. 200 sieve and/or particle-size analysis (gradation), swell-consolidation characteristics, and water-soluble sulfates. The results of the laboratory tests are shown on the boring logs in Fig. 2 and summarized in Table I. Results of laboratory tests are plotted on Figs. 4 through 7. The testing was conducted in general accordance with recognized test procedures, primarily those of ASTM International.

<u>Index Properties</u>: Samples were classified into categories of similar engineering properties in general accordance with the Unified Soil Classification System. This system is based on index properties, including liquid limit and plasticity index and gradation characteristics. Values for moisture content, dry density, liquid limit and plasticity index, and the percent of soil passing the No. 200 sieve are presented in Table I and adjacent to the corresponding sample on the boring logs.

<u>Swell-Consolidation</u>: Swell-consolidation tests were conducted on samples of the man-placed fill, natural clay and bedrock. The swell-consolidation tests were performed in order to determine the compressibility and swell characteristics of the samples under loading and when submerged in water. Each sample was prepared and placed in a confining ring between porous discs, subjected to a surcharge pressure of 200- or 1,000-psf, and allowed to consolidate before being submerged. The sample height was monitored until deformation practically ceased under each load increment.

Results of the swell-consolidation tests are plotted as a curve of the final strain at each increment of pressure against the log of the pressure and are presented on Figs. 4 and 5. Based on the results of the laboratory swell-consolidation testing, a sample of man-placed fill exhibited low swell potential (1.7%) upon wetting under a 200-psf surcharge pressure, a sample of natural clayey soils exhibited low swell potential (1.2%) upon wetting under a surcharge pressure of 200-psf, and a sample of interbedded claystone and sandstone bedrock exhibited moderate swell potential (3.1%) upon wetting under a surcharge pressure of 1.000-psf.

## WATER-SOLUBLE SULFATES

The concentration of water-soluble sulfate measured for a sample of the overburden soils from this site are 0.00%. This concentration of water-soluble sulfates represents a Class S0 severity exposure of sulfate attack on concrete exposed to these materials. The degrees of attack are based on a range of Class S0, Class S1, Class S2, and Class S3 severity exposure as presented in ACI 201.2R-16.

Based on the laboratory test results, we believe special sulfate resistant cement will generally not be required for concrete exposed to the on-site soils.

## GEOTECHNICAL ENGINEERING CONSIDERATIONS

Without documentation of placement conditions including density testing documenting the degree of compaction, the existing fill materials are considered non-engineered and generally not suitable for support of foundations or rigid slabs.

Criteria for shallow spread footing and raft/mat foundations are presented below for the wing walls and inlets; however, it is very important to the long-term performance of the structure(s) that all of the existing fill materials be removed from below foundation elements and to a distance beyond the structure(s) area as outlined in Item 7 of the “Foundation Recommendations” section below. In our opinion, the removed fill, excluding deleterious materials, is suitable to be moisture conditioned and recompacted as structural fill below foundation elements. We have no way to accurately predict the total magnitude of potential settlements if the existing fill is left in place; however, movements exceeding 1-inch are possible. As discussed above, to reduce settlement potential, all existing fills beneath planned foundations should be removed and replaced with structural fill.

Excavated existing fills and natural overburdens soils should be suitable for use as site grading fill and may be suitable for use as structural fill beneath buildings and other structures, provided they can be properly moisture conditioned and compacted.

LATERAL EARTH PRESSURES

Retaining structures should be designed for the lateral earth pressure generated by the backfill materials, which is a function of the degree of rigidity of the retaining structure and the type of backfill material used. Retaining structures that are laterally supported and can be expected to undergo only a moderate amount of deflection, such as basement or vault walls, should be designed for a lateral earth pressure based on the following equivalent at-rest fluid pressures:

CDOT Class 1 (<20% passing No. 200 Sieve) ............................................ 60 pcf
Imported, non-expansive, silty or clayey sand ............................................ 65 pcf
On-site or imported, moisture-conditioned clay backfill* .............................. 85 pcf
* Swell potential less than 2%

Cantilevered retaining structures that can be expected to deflect sufficiently to mobilize the full active earth pressure condition should be designed for the following equivalent fluid pressures:

CDOT Class 1 (<20% passing No. 200 Sieve) ............................................ 40 pcf
Imported, non-expansive, silty or clayey sand ............................................ 45 pcf
On-site or imported, moisture-conditioned clay backfill* .............................. 60 pcf
* Swell potential less than 2%

The equivalent fluid pressures recommended above assume drained conditions behind retaining structures and a horizontal backfill surface. The buildup of water behind a retaining structure or an upward sloping backfill surface will increase the lateral pressure imposed on the retaining structure. All retaining structures should also be designed for appropriate surcharge pressures such as traffic, construction materials and equipment.

Retaining structures that are constructed near or below groundwater should be designed for a lateral earth pressure based on the following equivalent submerged fluid pressures:

| | Active | At-Rest |
|---|---|---|
| CDOT Class 1 (<20% passing No. 200 Sieve) | 80 pcf | 100 pcf |
| Imported, non-expansive, silty or clayey sand | 85 pcf | 105 pcf |
| On-site or imported, moisture-conditioned clay backfill* | 120 pcf | 110 pcf |

* Swell potential less than 2%

The zone of backfill placed behind retaining structures to within 2 feet of the ground surface should be sloped upward from the base of the structure at an angle no steeper than 45 degrees measured from horizontal. To reduce surface water infiltration into the backfill, the upper 2 feet of the backfill should consist of a relatively impervious imported soil containing at least 30% passing the No. 200 sieve, or the backfill zone should be covered by a slab or pavement structure.

We have assumed a 25° friction angle and a moist unit weight of 125 pcf for onsite soils.

Backfill should be compacted to at least 95% of the standard Proctor (ASTM D698) maximum dry density at moisture contents within 2 percentage points of optimum for granular materials and between 0 and +3 percentage points of optimum for clay materials. Care should be taken not to over compact the backfill since this could cause excessive lateral pressure on the wall. Hand compaction procedures, if necessary, should be used to prevent lateral pressures from exceeding the design values.

## FOUNDATION RECOMMENDATIONS

Considering the subsurface conditions encountered in the exploratory borings and the nature of the proposed construction, we recommend the proposed structures be founded on spread footings or rigid slabs (such as a mat/raft or precast concrete culverts) placed on undisturbed natural soils or properly compacted structural fill material extending to natural soils/bedrock.

The design and construction criteria presented below should be observed for a spread footing foundation system. The construction details should be considered when preparing project documents.

1. Footings or rigid slabs (including mat/raft slabs and precast concrete structures) placed on the undisturbed natural soils and/or structural fill extending to natural soils/bedrock should be designed for a net allowable bearing pressure of 1,500 psf above groundwater

and 500 psf below groundwater. The allowable bearing pressure of soft soils may be improved by providing a 2-foot layer of crushed rock. Structural fill should meet the material and placement requirements provided in the "Site Grading" section of this report.

2. Based on experience, we estimate total settlement for footings designed and constructed as discussed in this section will be less than 1 inch. Differential settlements between individual foundations are estimated to be approximately ½ to ¾ of the total settlement. Due to the presence of near-surface granular soils, settlements should occur during or shortly after construction.

3. Spread footings should have a minimum footing width of 16 inches for continuous footings and of 24 inches for isolated pads.

4. Exterior footings and footings beneath unheated areas should be provided with adequate soil cover above their bearing elevation for frost protection. Placement of foundations at least 36 inches below the exterior grade is typically used in this area.

5. The lateral resistance of a spread footing supported as recommended herein will be a combination of the sliding resistance of the footing on the foundation materials and passive earth pressure against the side of the footing. Resistance to sliding at the bottoms of the footings can be calculated based on a coefficient of friction of 0.3. Passive pressure against the sides of the footings can be calculated using an equivalent fluid unit weight of 175 pcf above the groundwater table and 125 pcf below the groundwater table. The above values are working values. Structural fill placed against the sides of footings to resist lateral loads should meet the material and placement requirements provided in the "Site Grading" section of this report.

6. Continuous foundation walls should be reinforced top and bottom to span an unsupported length of at least 10 feet.

7. Areas of existing fill, loose and/or soft material, or deleterious substances encountered within footing excavations should be removed and replaced with structural fill. New fill should extend down from the edges of the footings at a 1 horizontal to 1 vertical projection.

8. Care should be taken when excavating the foundations to avoid disturbing the supporting materials.

9. A representative of the geotechnical engineer should observe all footing excavations prior to concrete placement.

## PIPELINE DESIGN PARAMETERS

We recommend a modulus of soil reaction, E', of 1,500 psi for areas well above the groundwater table and 100 psi for areas within 2 feet of the groundwater table be used for the design of pipe-zone material placed on the sides of the pipe, provided the pipe-zone material is compacted following the requirements presented in the "Site Grading and Earthwork" section of this report. This modulus of soils reaction assumes the pipe will be buried between 10 to 15 feet below the ground surface and will be constructed in the bedrock or native clay soils. For evaluating the load on the pipe due to the backfill above the pipe, we recommend using a compacted unit weight of 125 psf and 65 psf as a buoyant unit weight below groundwater and a Rankine's ratio of 0.37 for compacted trench-zone backfill consisting of existing on-site soils. We recommend using a coefficient of friction of 0.32 between backfill consisting on excavated on-site soil materials and the exposed and the trench walls.

Thrust blocks used to resist thrust forces at horizontal bends, if constructed, in the pipeline should be designed using a passive bearing pressure determined based on an equivalent fluid density of 200 pcf. The allowable horizontal bearing pressure should be calculated by multiplying the equivalent fluid density value by the depth, in feet, below ground surface corresponding to the mid-point height of the face of the thrust block. The bearing pressure should be limited to an allowable value of 1,600 psf.

Care should be taken during excavation to avoid disturbing the supporting materials. Excavation methods that minimize soil disturbance, such as hand excavation or careful soil removal with a backhoe positioned outside of the excavation may be required.

<u>Pipe Bedding and Backfill Material</u>: Bedding material supporting the pipe bottom should consist of a layer of imported granular material meeting the manufacturer's recommendations or local criteria for pipe bedding. The storm water pipeline pipe bedding should be a clean well-graded sand or squeegee sand meeting the City of Thornton requirements, if applicable.

The bedding layer should be of adequate thickness to fully support the pipe when seated on top of the bedding, and should have a minimum thickness based on the proposed pipe diameter and criteria established by American Water Works Association (AWWA). We recommend considering a minimum uncompacted thickness of 6 inches. Prior to placing the bedding, the subgrade should be excavated and loose or soft material removed to provide firm subgrade support.

The pipe-zone (embedment) material placed above the bedding and surrounding the pipe should consist of granular material similar to that described above for pipe bedding, and should be compacted to at least 75% relative density (ASTM D2049). The pipe-zone material should also be placed and compacted in accordance with the requirements of the pipe manufacturer. Special care should be taken to provide adequate compaction below the haunches of the pipe using a concrete vibrator, vibratory plates, or other light compaction equipment, as needed. In confined areas of the pipeline where compaction is difficult, placement of a cementitious flow fill around the pipe should be considered.

Backfill placed above the pipe-zone (embedment) materials to the pavement subgrade should consist of suitable on-site soil obtained from the pipeline excavation. Suitable soils should have a maximum size of 3 inches and should be generally free of organics, wood, or other deleterious material that could decay over time. Most of the soils encountered in the exploratory borings should satisfy these material requirements. The backfill should be compacted to at least 95% of the standard Proctor (ASTM D698) maximum dry density at a moisture content within 2 percentage points of optimum for granular soils and within 0 to +3 percentage points of optimum for clay soils.

## SITE SEISMIC CRITERIA

The Colorado Front Range is located in a low seismic activity area. The soil profile within the explored depths generally consists of relatively stiff clayey overburden soils. The overburden soils classify as IBC Site Class D and the bedrock classifies as IBC Site Class C. Based on our experience on sites with similar profiles, IBC Site Class C should be used for design. Based on the subsurface profile and site seismicity, liquefaction is not a design consideration.

SITE GRADING

Excavation Considerations: Trench excavations for the storm sewer pipeline is anticipated to range from about 10 to 15 feet below the ground surface. We assume the trench excavation will be protected using trench boxes and/or open cut. Based on the subsurface conditions encountered and the standard penetration testing performed in the exploratory borings, we anticipate the pipe line trenches can be excavated in the existing fill, native clay soils, and bedrock using conventional, large hydraulic excavators. If the very hard well cemented sandstone bedrock is encountered, large heavy hydraulic excavators utilizing ripper teeth chiseling or light blasting may be required.

Pipe trenches should be excavated in accordance with all OSHA requirements, and other applicable local and state requirements. For temporary unshored excavations, the man-placed fill and cohesive soils will likely classify as Type C soils in accordance with OSHA regulations. The bedrock at the site will classify as Type B. Excavations encountering groundwater could require much flatter side slopes than those allowed by OSHA, and require temporary shoring and/or dewatering. If temporary shoring is used, it is typically designed and built by specialty contractors and that the designers will typically develop their own design criteria based on soil data presented in the owner's geotechnical study report.

Surface water runoff into the excavations can act to erode and potentially destabilize the trench slopes and result in soft ground conditions along the trench bottom, and should not be allowed. Diversion berms and other measures should be used to prevent surface water runoff into the trenches from occurring. If significant runoff into the excavations does occur, further excavation to remove and replace the soft subgrade materials or stabilize the slopes may be required.

Dewatering Considerations: Groundwater may be encountered in excavations extending to or below depths of about 10 feet. Excavations extending below groundwater should be properly dewatered prior to, and during the excavation process to help maintain the stability of the excavation side slopes and stable subgrade conditions for construction and fill placement.

Excavations extending a few feet or more below groundwater may require more extensive dewatering. Selection of a dewatering system should be the responsibility of the contractor. Dewatering quantities will depend on excavation size, water table drawdown, and soil permeability. Accordingly, low quantities should be anticipated at the site. Dewatering systems should also be properly designed to prevent piping and removal of soil particles which could have damaging effects.

Subgrade Preparation: Subgrade preparation should consist of removal of the muck, soft soil, and organics in the bottom. The earthwork may have to be performed by low ground pressure track construction equipment to prevent deflection of the subgrade.

After the muck and soft soil is removed, the underlying subgrade should be scarified and recompacted to at least 95% of the standard Proctor (ASTM D698) maximum dry density at a moisture content near optimum. The prepared subgrade zone should be stable prior to application of the liner and/or additional fill placement. Soft or mucky subgrade soils may need to be stabilized with a layer of crushed rock or other means.

If required, any fill placed on the reconditioned subgrade may consist of materials similar to the on-site soils less organic material. New fills should be placed and compacted as indicated above. The prepared subgrade and fill placement should be observed by a representative of the geotechnical engineer.

Material Specifications: Unless specifically modified in the preceding sections of this report, the following recommended material and compaction requirements are presented for compacted fills on the project site. The geotechnical engineer should evaluate the suitability of all proposed fill materials for the project prior to placement.

1. *Structural Fill beneath Spread Footing, Rigid Slabs, and Settlement-Sensitive Exterior Flatwork*: Structural fill should consist of the on-site overburden soils, or if needed, imported structural fill materials that are non-expansive soils with a maximum of 60% passing the No. 200 sieve and a maximum liquid limit and plasticity index of 30 and 12, respectively. Imported fill materials not meeting these criteria may be acceptable if they meet the swell criteria presented in Item 6 below.

2. *General Site Grading Fill*: Fill placed for general site grading or beneath pavements and exterior flatwork that is not sensitive to settlement should consist of on-site overburden soils or imported materials if required.

3. *Pipe Bedding Material*: Pipe bedding material should be an imported free-draining, coarse-grained sand and/or fine gravel. The on-site soils are not considered suitable for use as pipe bedding.

4. *Utility Trench Backfill*: Materials excavated from the utility trenches may be used for trench backfill above the pipe bedding provided they are; not frozen, do not contain unsuitable material or particles larger than 4 inches, and can be placed and compacted as recommended herein.

5. *Base Course*: Base course material(s), if needed, should meet the specifications for Class 6 Aggregate Base Course stated in the current Colorado Department of Transportation (CDOT) *"Standard Specifications for Road and Bridge Construction"*.

6. *Material Suitability*: Unless otherwise defined herein, all fill material should be a non-expansive soil free of vegetation, brush, sod, trash and debris, and other deleterious substances, and should not contain rocks or lumps greater than 4 inches in diameter. Fill material should be considered non-expansive if the material does not swell more than 0.5%, when remolded to 95% of the maximum dry unit weight at optimum moisture content as determined by ASTM D698 and wetted under a 200 psf surcharge pressure.

   The existing on-site overburden soils should be suitable for use as general site grading and structural fill beneath exterior slabs, and pavements provided any organic or other deleterious material or debris are removed. The geotechnical engineer should evaluate the suitability of proposed import fill materials prior to placement. Evaluation of potential structural fill sources, particularly those not meeting the above liquid limit and plasticity index criteria, should include determination of laboratory moisture-density relationships and swell-consolidation tests on remolded samples prior to acceptance.

<u>Moisture Content and Compaction Requirements</u>: We recommend the following moisture content and compaction criteria be used on the project:

1. *Moisture Content*: Prior to compaction, fill materials should be adjusted to within 0 to + 3 percentage points of optimum moisture content for clayey soils and within ± 2 percentage points of the optimum moisture content for predominantly granular materials.

2. *Placement and Degree of Compaction*: Unless otherwise defined herein, compacted fill should be placed in maximum 8-inch-thick loose lifts. The following compaction criteria should be followed during construction:

| Fill Location | Percent Compaction[1] |
|---|---|
| Beneath Foundations | 98 |
| Beneath Settlement-Sensitive Flatwork and Pavements: | |
| Less than 8 feet below subgrade elevation | 95 |
| More than 8 feet below subgrade elevation | 98 |
| Utility Trenches: | |
| Less than 8 feet below subgrade elevation | 95 |
| More than 8 feet below subgrade elevation | 98 |
| Beneath Pavements: | |
| Less than 8 feet below subgrade elevation | 95 |
| More than 8 feet below subgrade elevation | 98 |
| Aggregate Base Course | 95 [2] |

[1] Relative to the maximum dry unit weight as determined by ASTM D 698.
[2] Relative to the maximum dry unit weight as determined by ASTM D 1557.

3. *Subgrade Preparation*: All areas to receive new fill should be cleared and grubbed of vegetation, topsoil and organics, and other deleterious materials and then be prepared as recommended in the specific sections of this report to provide a uniform base for placement of new fill. Areas to receive new fill not specifically addressed herein should be scarified to a depth of at least 12 inches and recompacted to at least 95% of the maximum dry unit weights as determined by ASTM D698 at moisture contents recommended above.

   Subgrade preparation should include proof-rolling with a heavily loaded pneumatic-tired vehicle or a heavy, smooth-drum vibratory roller. Areas that deform excessively during proof-rolling should be removed and replaced to achieve a reasonably stable subgrade prior to placement of compacted fill or construction of slabs, flatwork or pavements.

## SURFACE DRAINAGE

Proper surface drainage is very important for acceptable performance of the structures (including buried and pavements) during construction and after construction has been completed. Drainage recommendations provided by local, state and national entities should be followed based on the intended use of the structure. The following recommendations should be used as guidelines and changes should be made only after consultation with the geotechnical engineer.

1. Excessive wetting or drying of the foundation and slab subgrades should be avoided during construction.

2. Exterior backfill should meet the material criteria and be adjusted in moisture content and compacted as indicated in the "SITE GRADING" section of this report.

3. Care should be taken when compacting around the foundation walls and underground structures to avoid damage to the structure. Hand compaction procedures, if necessary, should be used to prevent lateral pressures from exceeding the design values.

4. Ponding of water should not be allowed in backfill material or in a zone within 10 feet of the foundation walls, whichever is greater.

## PAVEMENT THICKNESS DESIGN

A pavement section is a layered system designed to distribute concentrated traffic loads to the subgrade. Performance of the pavement structure is directly related to the physical properties of the subgrade soils and traffic loadings. Soils are represented for pavement design purposes by means of the subgrade resilient modulus, $M_R$, for flexible pavements and the modulus of subgrade reaction, $k$, for rigid pavements. Both values are empirically related to strength.

Subgrade Materials: The results of the field and laboratory studies indicate the pavement subgrade materials across the site are expected to consist predominantly of claystone and sandy clay fill. Based on laboratory test results, the subgrade materials at the site generally classify between A-6 and A-7-6 soils with group indices between 9 and 19 in accordance with the AASHTO soil classification system. For design purposes, an $M_R$ value of 3,025 psi was selected for flexible pavements.

Design Traffic: It appears that traffic at the site will include automobiles and heavy vehicles such as school busses, trash trucks and delivery trucks. At the time of this report, we were not provided with a traffic information for East 88th Avenue but no traffic data was available for Hoffman Way. Based on the traffic counts, our estimated 18-kip daily equivalent single axle loading applications

(ESAL) values were significantly lower than the ESAL values required based on the roadway classification. Therefore, the (ESAL) values were determined in accordance with Table 500-4 of Thornton-Standards and Specifications. We understand that East 88th Avenue classifies as "Major Arterial" roadway and the designated and an ESAL of 4,526,000 was specified for the pavement design. We understand that Hoffman Way classifies as "Minor Collector" roadway and the designated and an ESAL of 365,000 was specified for the pavement design. If traffic or roadway classification is anticipated to be different that the assumed values above, we should be notified to reevaluate the pavement thickness sections provided below.

Pavement Design: Alternatives for flexible pavements of full-depth hot mix asphalt (HMA) or a composite section of HMA over aggregate base course (ABC) are presented in the table below. The pavement sections were determined in accordance with the 1993 AASHTO pavement design procedures.

| LOCATION | Pavement Section Thicknesses (inches) | |
|---|---|---|
| | Full-Depth Hot Mix Asphalt | Hot Mix Asphalt over Aggregate Base Course |
| East 88th Avenue | 13.0 | 9 over 16 |
| Hoffman Way | 8.5 | 6 over 10 |

Pavement Materials: The following are recommended material and placement requirements for pavement construction for this project site. We recommend that properties and mix designs for all materials proposed to be used for pavements be submitted for review to the geotechnical engineer prior to placement.

1. *Aggregate Base Course*: Aggregate base course (ABC) used beneath HMA pavements should meet the material specifications for Class 6 ABC stated in the current CDOT *"Standard Specifications for Road and Bridge Construction"*. The ABC should be placed and compacted as outlined in the "SITE GRADING" section of this report.

2. *Hot Mix Asphalt:* Hot mix asphalt (HMA) materials and mix designs should meet the applicable requirements indicated in the current CDOT *"Standard Specifications for Road and Bridge Construction"*. We recommend that the HMA used for this project is designed in accordance with the SuperPave gyratory mix design method. The mix should meet

Grading S specifications with a SuperPave gyratory design revolution (*NDESIGN*) of 75. A mix meeting Grading SX specification can be used for the top lift wearing course, however, this is optional. The mix design(s) for the HMA should use a performance grade (PG) asphalt binder of PG 64-22. Placement and compaction of HMA should follow current CDOT standards and specifications.

Subgrade Preparation: The pavement subgrade within 2 feet of subgrade elevation should be properly moisture conditioned and compacted as outlined in the "SITE GRADING" section of this report. Prior to placing new fill for the pavement section, the entire subgrade area should be thoroughly scarified and well-mixed to a minimum depth of 12 inches, adjusted in moisture content and compacted as indicated in the "SITE GRADING" section of this report. Fill placed beneath the pavement should meet the material and compaction requirements for structural fill presented in the "SITE GRADING" section of this report.

Pavement design procedures assume a stable subgrade and the pavement subgrade should be proof-rolled, preferably within 48 hours prior to paving. The proof-roll should be performed using a heavily loaded pneumatic-tired vehicle such as a loaded water truck or large front-end loader. Areas that deform under wheel loads that are not stable should be removed and replaced to achieve a stable subgrade prior to paving. The contractor should be aware that the clay soils may become somewhat unstable and deform under wheel loads if placed near the upper end of the moisture content range.

Drainage: The collection and diversion of surface drainage away from paved areas is extremely important to the satisfactory performance of pavement. Drainage design should provide for the removal of water from paved areas and prevent the wetting of the subgrade soils.

## DESIGN AND CONSTRUCTION SUPPORT SERVICES

Kumar & Associates, Inc. should be retained to review the project plans and specifications for conformance with the recommendations provided in our report. We are also available to assist the design team in preparing specifications for geotechnical aspects of the project, and performing additional studies if necessary, to accommodate possible changes in the proposed construction.

We recommend that Kumar & Associates, Inc. be retained to provide construction observation and testing services to document that the intent of this report and the requirements of the plans and specifications are being followed during construction. This will allow us to identify possible variations in subsurface conditions from those encountered during this study and to allow us to re-evaluate our recommendations, if needed. We will not be responsible for implementation of the recommendations presented in this report, if we are not retained to provide construction observation and testing services.

LIMITATIONS

This study has been conducted in accordance with generally accepted geotechnical engineering practices in this area for exclusive use by the client for design purposes. The conclusions and recommendations submitted in this report are based upon data obtained from the exploratory borings at the locations indicated on Fig. 1, and the proposed construction. This report may not reflect subsurface variations that occur between exploratory borings, and the nature and extent of variations across the site may not become evident until site grading and excavations are performed. If during construction, fill, soil, rock or water conditions appear to be different from those described herein, Kumar & Associates, Inc. should be advised at once so that a re-evaluation of the recommendations presented in this report can be made. Kumar & Associates, Inc. is not responsible for liability associated with interpretation of subsurface data by others.

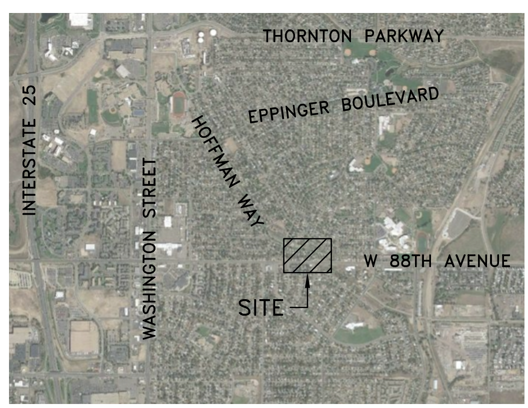
Swelling soils and bedrock occur on this site. Such soils are stable at their natural moisture content but can undergo high volume changes with changes in moisture content. The extent and amount of perched water beneath the building site as a result of area irrigation and inadequate surface drainage is difficult, if not impossible, to foresee.

The recommendations presented in this report are based on current theories and experience of our engineers on the behavior of swelling soil in this area. The owner should be aware that there is risk of movement and possible damage to foundations, interior slab-on-grade floors, and exterior slabs and pavements on sites where expansive soils and/or bedrock occur. Following the recommendations given by a geotechnical engineer, careful construction practice and prudent maintenance by the owner can, however, decrease this risk.

JAH/js
Rev. by: JLB
cc: book, file


50 0 50 100

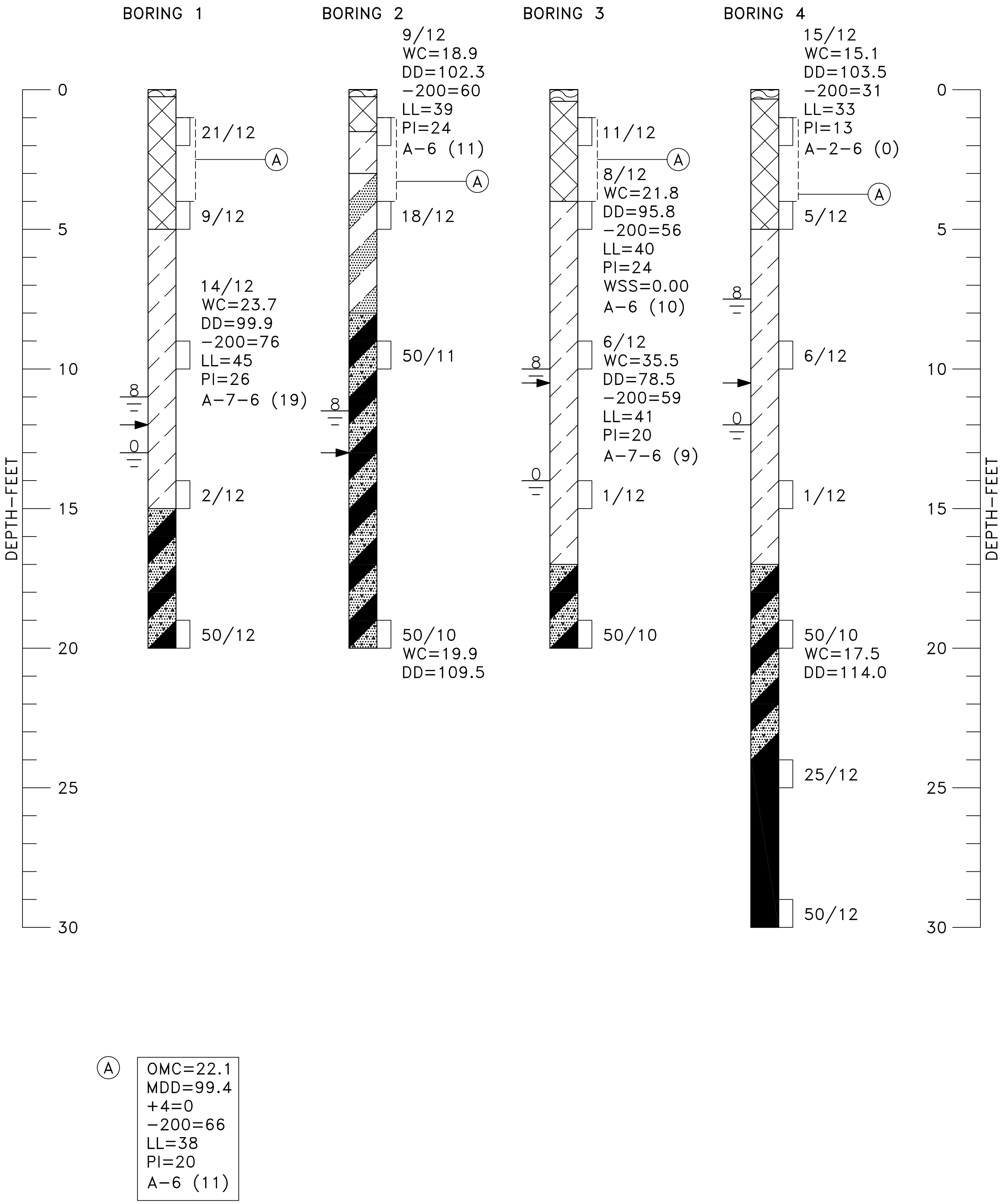
APPROXIMATE SCALE–FEET




VICINITY MAP
NOT TO SCALE

| 20–3–151 | Kumar & Associates | LOCATION OF EXPLORATORY BORINGS | Fig. 1 |
|---|---|---|---|

June 10, 2020 – 08:28am
V:\Projects\2020\20-3-151 Hoffman Way Parallel Drainage\Drafting\203151-01.dwg




| 20-3-151 | Kumar & Associates | LOGS OF EXPLORATORY BORINGS | Fig. 2 |
|---|---|---|---|

June 10, 2020 - 08:28am
V:\Projects\2020\20-3-151 Hoffman Way Parallel Drainage\Drafting\203151-02 to 03.dwg

## LEGEND

TOPSOIL.

FILL: LEAN CLAY WITH SAND (CL) TO CLAYEY SAND (SC), FINE TO COARSE GRAINED SAND FRACTION WITH GRAVEL, MOIST, BROWN TO DARK BROWN.

LEAN CLAY WITH SAND (CL) TO SANDY LEAN CLAY (CL) WITH OCCASIONAL LAYERS OF CLAYEY SAND (SC), FINE TO COARSE GRAINED SAND FRACTION, VERY SOFT TO STIFF, MOIST TO WET BELOW GROUNDWATER, BROWN TO GRAY.

WEATHERED CLAYSTONE, FINE TO MEDIUM GRAINED, MOIST, BROWN.

INTERBEDDED CLAYSTONE AND SANDSTONE BEDROCK, FINE TO COARSE GRAINED, HARD, MOIST, BROWN TO GRAY.

CLAYSTONE BEDROCK, FINE TO MEDIUM GRAINED, MEDIUM HARD TO VERY HARD, MOIST, GRAY TO DARK GRAY.

DRIVE SAMPLE, 2-INCH I.D. CALIFORNIA LINER SAMPLE.

DISTURBED BULK SAMPLE.

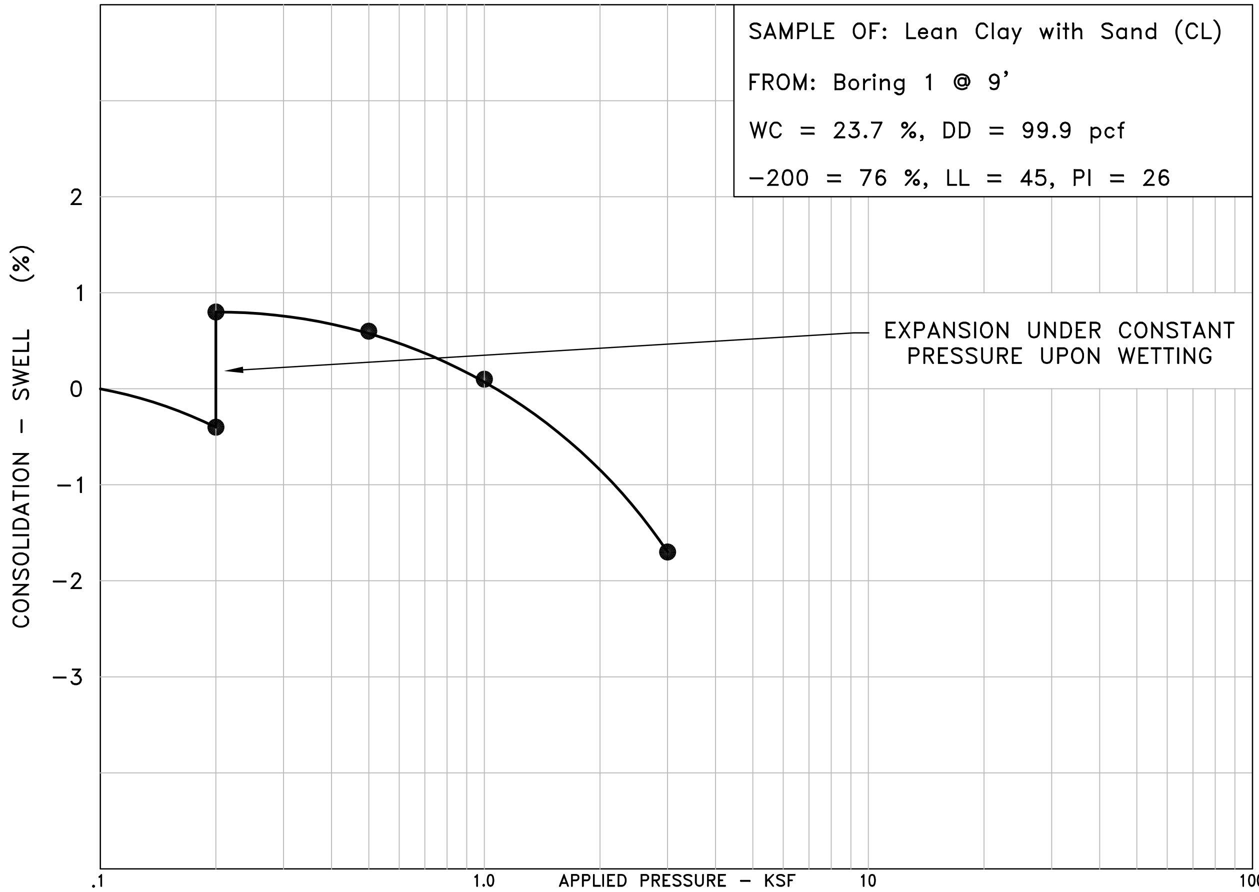
21/12 DRIVE SAMPLE BLOW COUNT. INDICATES THAT 21 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE THE SAMPLER 12 INCHES.

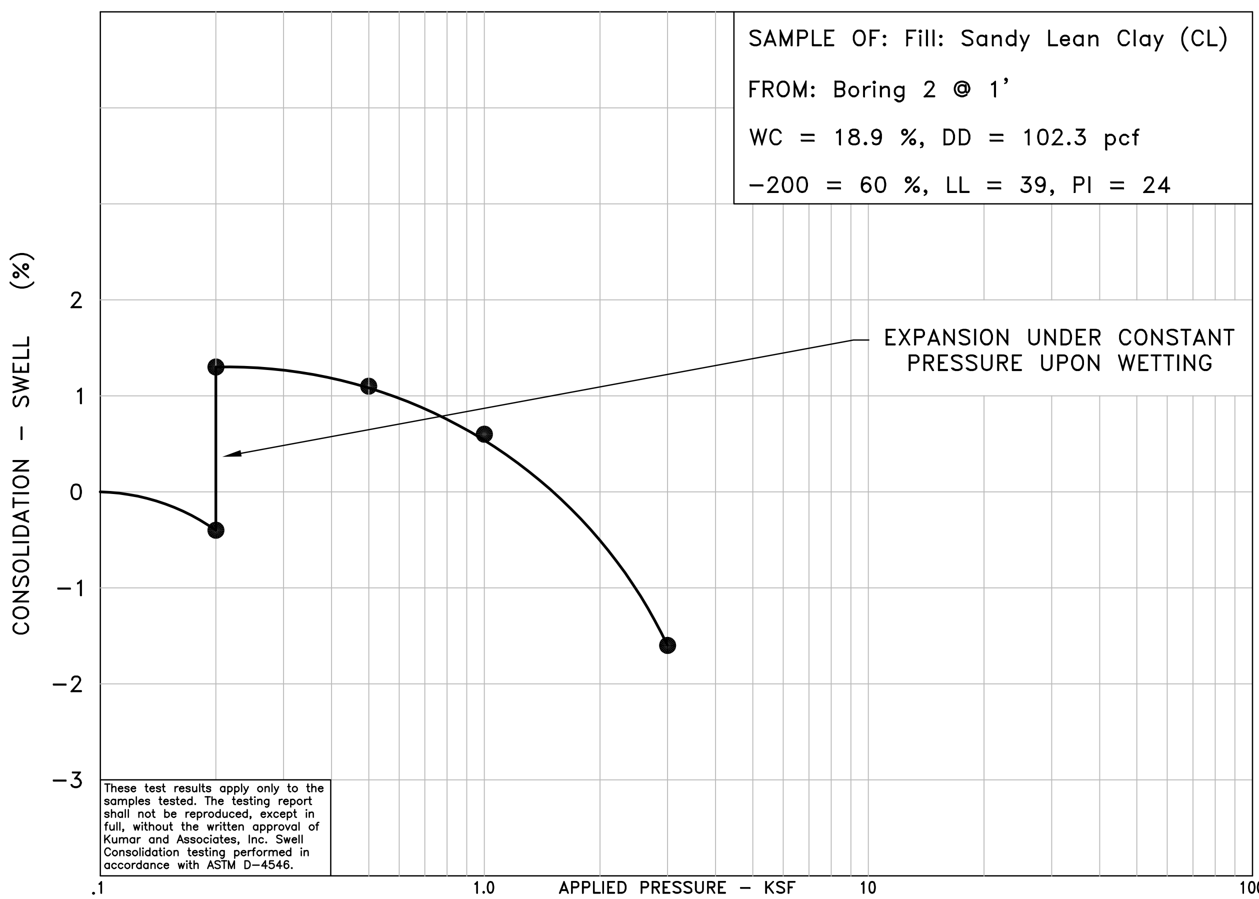
8 DEPTH TO WATER LEVEL AND NUMBER OF DAYS AFTER DRILLING MEASUREMENT WAS MADE.

→ DEPTH AT WHICH BORING CAVED.

## NOTES

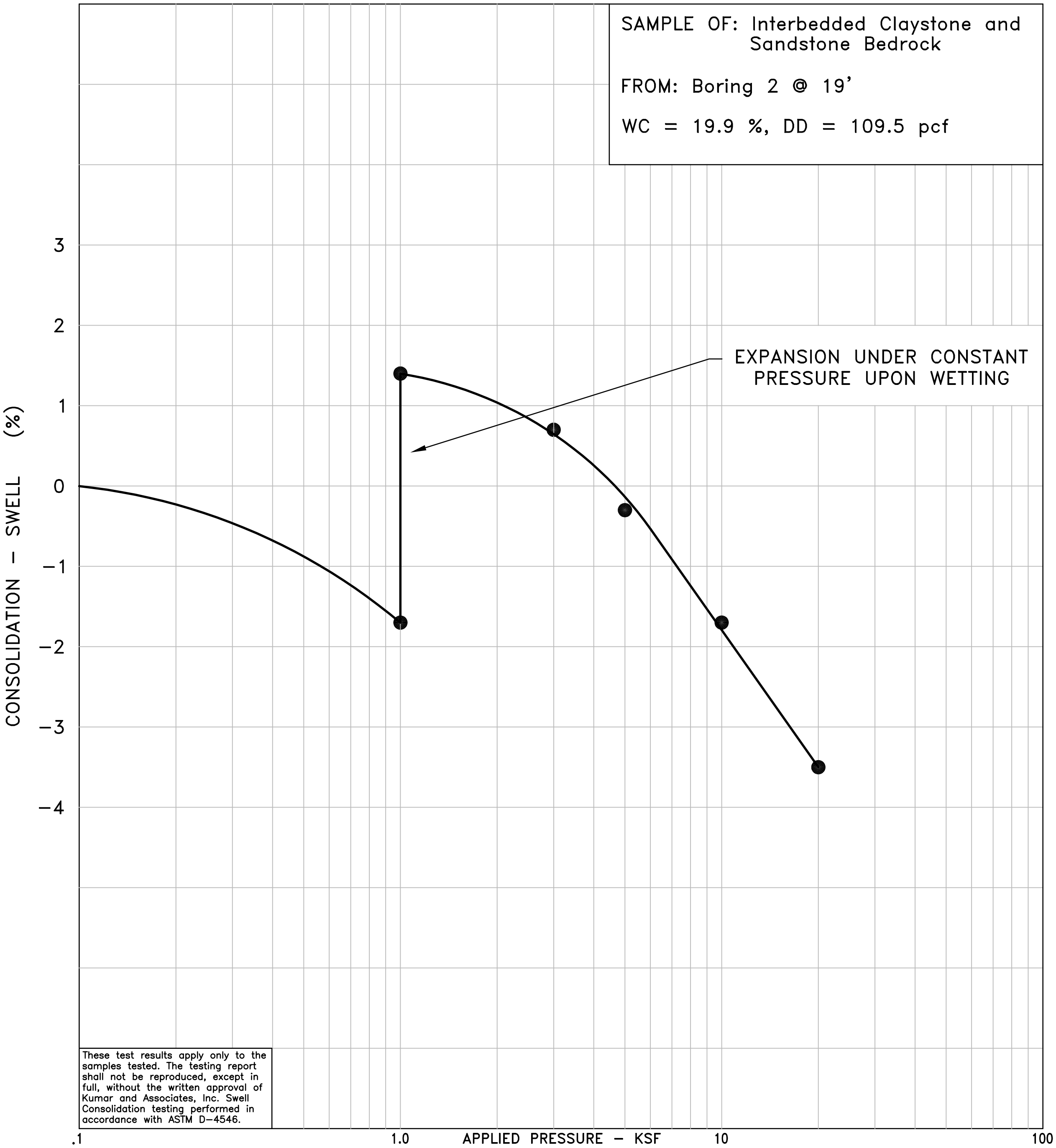
1. THE EXPLORATORY BORINGS WERE DRILLED ON MAY 19, 2020 WITH A 4-INCH-DIAMETER CONTINUOUS-FLIGHT POWER AUGER.
2. THE EXPLORATORY BORINGS WERE MEASURED APPROXIMATELY BY USING A HANDHELD GPS DEVICE WITH ESTIMATED COORDINATES USING ON-LINE AERIAL MAPPING SOFTWARE COMBINED WITH THE SITE PLAN PROVIDED.
3. THE ELEVATIONS OF THE EXPLORATORY BORINGS WERE NOT MEASURED AND THE LOGS OF THE EXPLORATORY BORINGS ARE PLOTTED TO DEPTH.
4. THE EXPLORATORY BORING LOCATIONS SHOULD BE CONSIDERED ACCURATE ONLY TO THE DEGREE IMPLIED BY THE METHOD USED.
5. THE LINES BETWEEN MATERIALS SHOWN ON THE EXPLORATORY BORING LOGS REPRESENT THE APPROXIMATE BOUNDARIES BETWEEN MATERIAL TYPES AND THE TRANSITIONS MAY BE GRADUAL.
6. GROUNDWATER LEVELS SHOWN ON THE LOGS WERE MEASURED AT THE TIME AND UNDER CONDITIONS INDICATED. FLUCTUATIONS IN THE WATER LEVEL MAY OCCUR WITH TIME.
7. LABORATORY TEST RESULTS:
   WC = WATER CONTENT (%) (ASTM D2216);
   DD = DRY DENSITY (pcf) (ASTM D2216);
   +4 = PERCENTAGE RETAINED ON NO. 4 SIEVE (ASTM D6913);
   -200= PERCENTAGE PASSING NO. 200 SIEVE (ASTM D1140);
   LL = LIQUID LIMIT (ASTM D4318);
   PI = PLASTICITY INDEX (ASTM D4318);
   WSS = WATER SOLUBLE SULFATES (%) (CP-L 2103);
   A-7-6 (19) = AASHTO CLASSIFICATION (GROUP INDEX) (AASHTO M 145);
   OMC = OPTIMUM MOISTURE CONTENT (%) (ASTM D698);
   MDD = MAXIMUM DRY DENSITY (pcf) (ASTM D698).



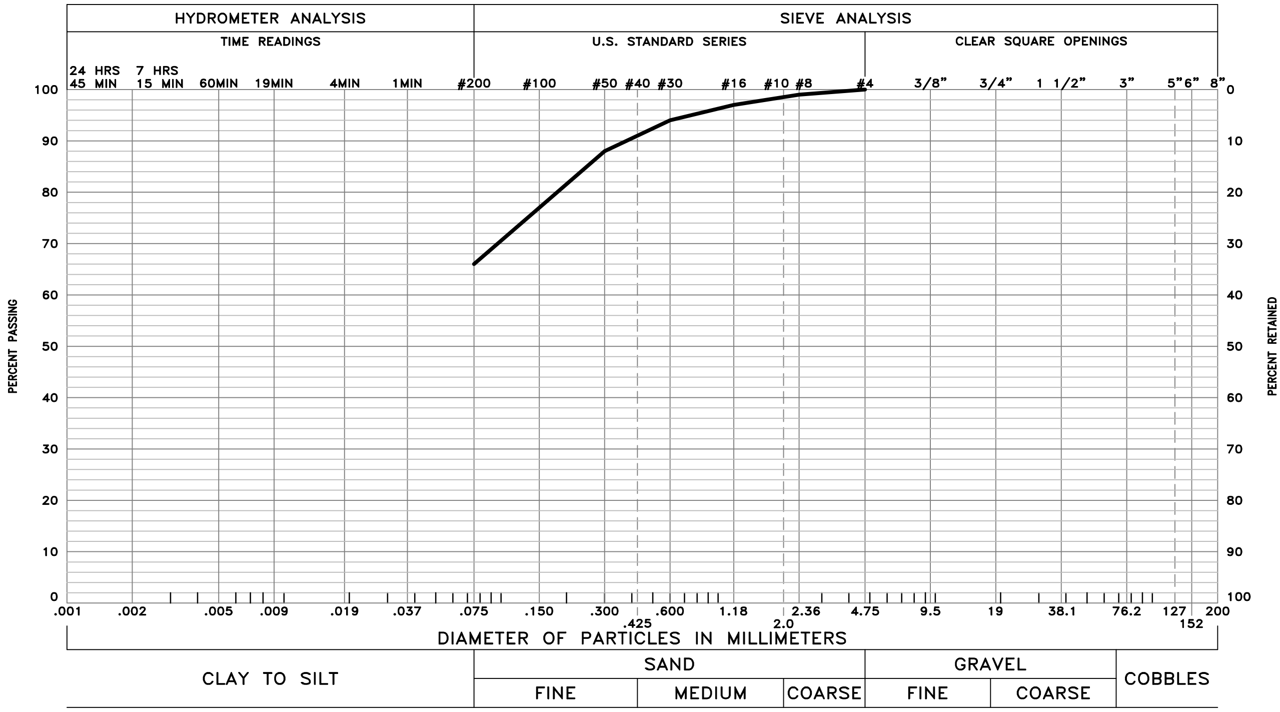

| 20−3−151 | Kumar & Associates | SWELL−CONSOLIDATION TEST RESULTS | Fig. 4 |
|---|---|---|---|

June 10, 2020 − 08:28am
V:\Projects\2020\20−3−151 Hoffman Way Parallel Drainage\Drafting\203151−04 to 05.dwg




June 10, 2020 - 08:28am
V:\Projects\2020\20-3-151 Hoffman Way Parallel Drainage\Drafting\203151-04 to 05.dwg

| 20-3-151 | Kumar & Associates | SWELL-CONSOLIDATION TEST RESULTS | Fig. 5 |
|---|---|---|---|




GRAVEL 0 % SAND 34 % SILT AND CLAY 66 %

LIQUID LIMIT 38 PLASTICITY INDEX 20

SAMPLE OF: Fill: Sandy Lean Clay (CL) FROM: Boring 1-4 @ 1'-4'

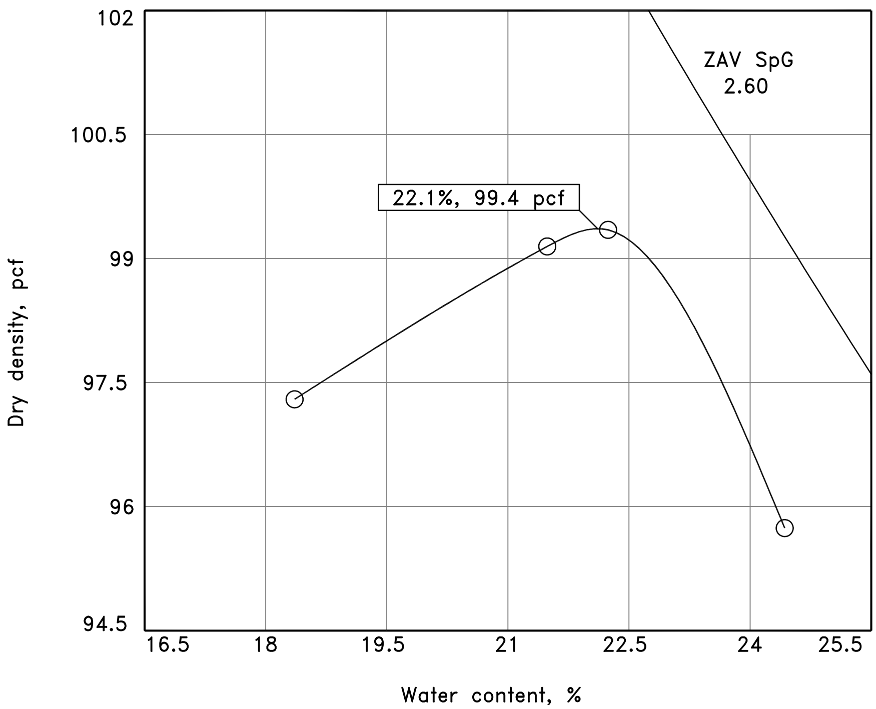
These test results apply only to the samples which were tested. The testing report shall not be reproduced, except in full, without the written approval of Kumar & Associates, Inc. Sieve analysis testing is performed in accordance with ASTM D6913, ASTM D7928, ASTM C136 and/or ASTM D1140.

June 10, 2020 - 08:28am
V:\Projects\2020\20-3-151 Hoffman Way Parallel Drainage\Drafting\203151-06.dwg

| 20-3-151 | Kumar & Associates | GRADATION TEST RESULTS | Fig. 6 |
|---|---|---|---|

# COMPACTION TEST REPORT

Curve No. 0525




| | |
|---|---|
| Preparation Method | |
| Rammer: Wt. | 5.5 lb. |
| Drop | 12 in. |
| Type | Manual |
| Layers: No. | 3 |
| Blows per | 25 |
| Mold Size | 0.03333 cu. ft. |
| Test Performed on Material Passing | #4 Sieve |
| %>#4 | 0 |
| %<No.200 | 66 |
| Atterberg (D 4318): LL | 38 |
| PI | 20 |
| NM (D 2216) | |
| Sp.G. (D 854) | 2.6 |
| USCS (D 2487) | CL |
| AASHTO (M 145) | A-6(11) |
| Date: Sampled | 5-22-2020 |
| Received | 5-22-2020 |
| Tested | 5-27-2020 |
| Tested By | AS |

COMPACTION TESTING DATA
ASTM D 698-12 Method A Standard

| | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| WM + WS | 6055.0 | 6135.0 | 6150.0 | 6115.0 | | |
| WM | 4314.0 | 4314.0 | 4314.0 | 4314.0 | | |
| WW + T #1 | 424.6 | 441.0 | 445.3 | 462.6 | | |
| WD + T #1 | 382.8 | 391.3 | 391.3 | 400.6 | | |
| TARE #1 | 155.1 | 160.0 | 148.5 | 146.8 | | |
| WW + T #2 | | | | | | |
| WD + T #2 | | | | | | |
| TARE #2 | | | | | | |
| MOIST. | 18.4 | 21.5 | 22.2 | 24.4 | | |
| DRY DENS. | 97.3 | 99.1 | 99.3 | 95.7 | | |

SIEVE TEST RESULTS
ASTM D-422 ASTM D-1140

| Opening Size | % Passing | Specs. |
|---|---|---|
| #4 | 100 | |
| #8 | 99 | |
| #16 | 97 | |
| #30 | 94 | |
| #50 | 88 | |
| #100 | 77 | |
| #200 | 66 | |

## TEST RESULTS

Maximum dry density = 99.4 pcf

Optimum moisture = 22.1 %

## Material Description

Fill: Sandy Lean Clay (CL)

Project No. 20-3-151 Client:

Project: Hoffman Way

○ Location: B1 - B4 Depth: 1'-4' Sample Number: 0525

Remarks:
These test results apply only to the samples which were tested. the testing report shall not be reproduced, except in full, without the written approval of Kumar and Associates, Inc. Moisture/density relationships performed in accordance with ASTM D698, D1557. Atterberg limits performed in accordance with ASTM D4318 sieve analysis performed in accordance with ASTM D422, D1140.

Checked by: DS

Title: Lab Manager

Table I
Summary of Laboratory Test Results

Project No.: 20-3-151
Project Name: Hoffman Way Parallel Drainage
Date Sampled: May 19, 2020
Date Received: May 20, 2020

| Sample Location | | Date Tested | Natural Moisture Content (%) | Natural Dry Density (pcf) | Gradation | | Percent Passing No. 200 Sieve | Atterberg Limits | | Water Soluble Sulfates (%) | AASHTO Classification (Group Index) | Soil or Bedrock Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Boring | Depth (Feet) | | | | Gravel (%) | Sand (%) | | Liquid Limit (%) | Plasticity (%) | | | |
| 1 | 9 | 5/22/20 | 23.7 | 99.9 | | | 76 | 45 | 26 | | A-7-6 (19) | Lean Clay with Sand (CL) |
| 2 | 1 | 5/22/20 | 18.9 | 102.3 | | | 60 | 39 | 24 | | A-6 (11) | Fill: Sandy Lean Clay (CL) |
| 2 | 19 | 5/22/20 | 19.9 | 109.5 | | | | | | | | Interbedded Claystone and Sandstone Bedrock |
| 3 | 4 | 5/22/20 | 21.8 | 95.8 | | | 56 | 40 | 24 | 0.00 | A-6 (10) | Sandy Lean Clay (CL) |
| 3 | 9 | 5/22/20 | 35.5 | 78.5 | | | 59 | 41 | 20 | | A-7-6 (9) | Sandy Lean Clay (CL) |
| 4 | 1 | 5/22/20 | 15.1 | 103.5 | | | 31 | 33 | 13 | | A-2-6 (0) | Fill: Clayey Sand (SC) |
| 4 | 19 | 5/22/20 | 17.5 | 114.0 | | | | | | | | Interbedded Claystone and Sandstone Bedrock |
| 1 to 4 | 1-4 | 5/22/20 | 22.1* | 99.4* | 0 | 34 | 66 | 38 | 20 | | A-6 (11) | Fill: Sandy Lean Clay (CL) |

* - Optimum moisture content and maximum dry density as determined by standard Proctor (ASTM D 698)

# APPENDIX A

## DARWin$^{TM}$ PAVEMENT DESIGN CALCULATIONS

# 1993 AASHTO Pavement Design

# DARWin Pavement Design and Analysis System

## A Proprietary AASHTOWare Computer Software Product

Kumar & Associates, Inc.
2390 South Lipan Street
Denver, Colorado

## Flexible Structural Design Module

East 88th Avenue
Thornton, Colorado

## Flexible Structural Design

| | |
|---|---|
| 18-kip ESALs Over Initial Performance Period | 4,526,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Roadbed Soil Resilient Modulus | 3,025 psi |
| Stage Construction | 1 |
| | |
| Calculated Design Structural Number | 5.64 in |

## Specified Layer Design

| Layer | Material Description | Struct Coef. (Ai) | Drain Coef. (Mi) | Thickness (Di)(in) | Width (ft) | Calculated SN (in) |
|---|---|---|---|---|---|---|
| 1 | HMA | 0.44 | 1 | 13 | - | 5.72 |
| Total | - | - | - | 13.00 | - | 5.72 |

# 1993 AASHTO Pavement Design

# DARWin Pavement Design and Analysis System

## A Proprietary AASHTOWare Computer Software Product

Kumar & Associates, Inc.
2390 South Lipan Street
Denver, Colorado

## Flexible Structural Design Module

East 88th Avenue
Thornton, Colorado

## Flexible Structural Design

| | |
|---|---|
| 18-kip ESALs Over Initial Performance Period | 4,526,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2.5 |
| Reliability Level | 90 % |
| Overall Standard Deviation | 0.44 |
| Roadbed Soil Resilient Modulus | 3,025 psi |
| Stage Construction | 1 |
| | |
| Calculated Design Structural Number | 5.64 in |

## Specified Layer Design

| Layer | Material Description | Struct Coef. (Ai) | Drain Coef. (Mi) | Thickness (Di)(in) | Width (ft) | Calculated SN (in) |
|---|---|---|---|---|---|---|
| 1 | HMA | 0.44 | 1 | 9 | - | 3.96 |
| 2 | Aggregate Base Course | 0.11 | 1 | 16 | - | 1.76 |
| Total | - | - | - | 25.00 | - | 5.72 |

# 1993 AASHTO Pavement Design

# DARWin Pavement Design and Analysis System

## A Proprietary AASHTOWare Computer Software Product

Kumar & Associates, Inc.
2390 South Lipan Street
Denver, Colorado

## Flexible Structural Design Module

Hoffman Way
Thornton, Colorado

## Flexible Structural Design

| | |
|---|---|
| 18-kip ESALs Over Initial Performance Period | 365,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2 |
| Reliability Level | 85 % |
| Overall Standard Deviation | 0.44 |
| Roadbed Soil Resilient Modulus | 3,025 psi |
| Stage Construction | 1 |
| | |
| Calculated Design Structural Number | 3.66 in |

## Specified Layer Design

| Layer | Material Description | Struct Coef. (Ai) | Drain Coef. (Mi) | Thickness (Di)(in) | Width (ft) | Calculated SN (in) |
|---|---|---|---|---|---|---|
| 1 | HMA | 0.44 | 1 | 6 | - | 2.64 |
| 2 | Aggregate Base Course | 0.11 | 1 | 10 | - | 1.10 |
| Total | - | - | - | 16.00 | - | 3.74 |

# 1993 AASHTO Pavement Design

# DARWin Pavement Design and Analysis System

## A Proprietary AASHTOWare Computer Software Product

Kumar & Associates, Inc.
2390 South Lipan Street
Denver, Colorado

## Flexible Structural Design Module

Hoffman Way
Thornton, Colorado

## Flexible Structural Design

| | |
|---|---|
| 18-kip ESALs Over Initial Performance Period | 365,000 |
| Initial Serviceability | 4.5 |
| Terminal Serviceability | 2 |
| Reliability Level | 85 % |
| Overall Standard Deviation | 0.44 |
| Roadbed Soil Resilient Modulus | 3,025 psi |
| Stage Construction | 1 |
| | |
| Calculated Design Structural Number | 3.66 in |

## Specified Layer Design

| Layer | Material Description | Struct Coef. (Ai) | Drain Coef. (Mi) | Thickness (Di)(in) | Width (ft) | Calculated SN (in) |
|---|---|---|---|---|---|---|
| 1 | HMA | 0.44 | 1 | 8.5 | - | 3.74 |
| Total | - | - | - | 8.50 | - | 3.74 |