



Geotechnical Engineering | Engineering Geology
Materials Testing | Environmental

Exhibit-A

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**SUBSOIL STUDY
FOR PAVEMENT AND GRADING DESIGNS
7TH STREET, BLAKE AVENUE TO GRAND AVENUE
GLENWOOD SPRINGS, COLORADO**

PROJECT NO. 16-7-637

FEBRUARY 2, 2017

PREPARED FOR:

**CITY OF GLENWOOD SPRINGS
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TABLE OF CONTENTS

PURPOSE AND SCOPE OF STUDY	- 1 -
PROPOSED CONSTRUCTION	- 1 -
SITE CONDITIONS.....	- 2 -
FIELD EXPLORATION	- 2 -
SUBSURFACE CONDITIONS	- 3 -
BEARING CONDITIONS	- 3 -
DESIGN RECOMMENDATIONS	- 4 -
FOUNDATIONS	- 4 -
RETAINING STRUCTURES	- 5 -
PAVEMENT SECTION	- 6 -
SUBDRAIN SYSTEM	- 8 -
SURFACE DRAINAGE.....	- 9 -
LIMITATIONS.....	- 9 -
FIGURE 1 - LOCATION OF EXPLORATORY BORINGS	
FIGURE 2 - LOGS OF EXPLORATORY BORINGS	
FIGURE 3 - LEGEND AND NOTES	
FIGURES 4 AND 5 - GRADATION TEST RESULTS	
TABLE 1- SUMMARY OF LABORATORY TEST RESULTS	
TABLE 2 – PERCOLATION TEST RESULTS	

PURPOSE AND SCOPE OF STUDY

This report presents the results of a subsoil study for the proposed improvements to 7th Street between Blake Avenue and Grand Avenue, Glenwood Springs, Colorado. The project site is shown on Figure 1. The purpose of the study was to develop recommendations for the pavement section and grading designs. The study was conducted in accordance with our proposal for geotechnical engineering services to City of Glenwood Springs/Downtown Development Authority dated November 15, 2016. Hepworth-Pawlak Geotechnical (now H-P/Kumar) previously conducted a subsoil study for pavement design along the south side of the project area and presented the findings in a report dated April 15, 2014, Job No. 114 070A.

A field exploration program consisting of exploratory borings was conducted to obtain information on the subsurface conditions. Samples of the subsoils obtained during the field exploration were tested in the laboratory to determine their classification and other engineering characteristics. The results of the field exploration and laboratory testing were analyzed to develop recommendations for pavement section thickness, foundation types, depths and allowable pressures for proposed site walls and subsurface drainage design. This report summarizes the data obtained during this study and presents our conclusions, design recommendations and other geotechnical engineering considerations based on the proposed construction and the subsurface conditions encountered.

PROPOSED CONSTRUCTION

The proposed improvements include replacing the existing streetscape along the north side, replacing the asphalt pavement between Blake Avenue and Cooper Avenue (east half), and replacing the asphalt pavement between Cooper Avenue and Grand Avenue (west half) with pervious granite pavers. The existing retaining walls between 7th Street and the railroad tracks will remain and could be modified with new walls as needed. Grading between 7th Street and the train station building (east half of project area) is not planned to be substantially changed and the overall grade changes are expected to be relatively minor. 7th Street will have normal traffic loading in the east half and will be restricted to pedestrians, delivery trucks and emergency

vehicles in the west half. Surface drainage design will include infiltration through pervious paver joints and possibly into drywells based in the underlying river gravel deposit.

If pavement traffic loadings, retaining wall locations or grading plans change significantly from those described above, we should be notified to re-evaluate the recommendations contained in this report.

SITE CONDITIONS

The existing street is asphalt paved and sidewalks are concrete in the east half and concrete pavers in the west half. A curb and gutter separates the street pavement from the sidewalks. Construction for the new Grand Avenue bridge has partly removed the street pavement and sidewalk in the west half. 7th Street slopes gently down to the west with about 5 feet of elevation difference across the project alignment. The grade change between 7th Street and down to the railroad tracks is about 10 to 12 feet and partly supported by retaining walls in the west half and the train station building in the east half. Based on experience with prior improvements to this part of 7th Street, old fill can be variable in type and be relatively deep on the north side of the street.

FIELD EXPLORATION

The field exploration for the project was conducted on January 6, 2017. Six exploratory borings were drilled at the locations shown on Figure 1 to evaluate the subsurface conditions. The borings were advanced with 4 inch diameter continuous flight augers powered by a truck-mounted CME-45B drill rig. The borings were logged by a representative of H-P/Kumar. The four exploratory borings drilled for the previous study on the south side of 7th Street are also shown on Figure 1. A percolation test was performed in Boring 4 following drilling and the boreholes were backfilled and patched.

Samples of the subsoils were taken with 1½ inch and 2 inch I.D. spoon samplers. The samplers were driven into the subsoils at various depths with blows from a 140 pound hammer falling 30 inches. This test is similar to the standard penetration test described by ASTM Method D-1586.

The penetration resistance values are an indication of the relative density or consistency of the subsoils. Depths at which the samples were taken and the penetration resistance values are shown on the Logs of Exploratory Borings, Figure 2. The samples were returned to our laboratory for review by the project engineer and testing.

SUBSURFACE CONDITIONS

Graphic logs of the subsurface conditions encountered at the site are shown on Figure 2. The subsoils, below about 2 to 4 inches of pavement surface and base course materials, consist of a variable fill depth up to about 7 feet overlying medium stiff to stiff silty sandy clay to depths between 4 to 9½ feet where dense, silty sandy gravel with cobbles and probable boulders was encountered to the boring depths of 10 to 11 feet. Drilling in the coarse granular soils with auger equipment was relatively difficult due to the cobbles and boulders. The fill soils are variable in type and condition and locally contain cinders.

Laboratory testing performed on samples obtained from the borings included natural moisture content and density, gradation analyses, liquid and plastic limits and unconfined compressive strength. Results of gradation analyses performed on small diameter drive samples (minus 1½ inch fraction) of the existing fill and natural granular soils are shown on Figures 4 and 5. The liquid and plastic limits testing show the clay soils to have low plasticity. The unconfined compressive strength tests indicate the clay soils have stiff consistency. The laboratory testing is summarized in Table 1.

No free water was encountered in the borings at the time of drilling and the subsoils were moist.

BEARING CONDITIONS

The soils encountered at existing pavement subgrade level are variable and generally consist of loose to medium dense, clayey fill soils to medium stiff to stiff, silty sandy clay of mainly low plasticity. Unsuitable soils for support of pavement sections and retaining wall foundations may be encountered and need treatment such as removal or stabilization. Infiltration of surface water through pervious pavers or from detention areas could adversely impact support of the variable bearing soils. The clayey fill and natural clay soils will also tend to restrict downward flow of

surface water infiltration possibly causing a temporary perched condition. Adequate subsurface drainage will be needed to prevent or mitigate these potential adverse conditions such as by providing a drainage blanket below pervious paver areas and drywells which extend down into the underlying natural coarse granular soils.

DESIGN RECOMMENDATIONS

FOUNDATIONS

Considering the subsurface conditions encountered in the exploratory borings and the nature of the proposed construction, we recommend new retaining walls be founded with spread footings bearing on the natural granular soils or compacted structural fill.

The design and construction criteria presented below should be observed for a spread footing foundation system.

- 1) Footings placed on the undisturbed natural granular soils or compacted structural fill should be designed for an allowable bearing pressure of 3,000 psf. A one-third increase in the maximum allowable bearing pressure can be taken for eccentrically loaded (retaining wall) footings with the resultant of all forces in the central third of the footing section. Based on experience, we expect settlement of footings designed and constructed as discussed in this section will be about 1 inch or less.
- 2) The footings should have a minimum width of 16 inches for continuous walls and 2 feet for isolated pads.
- 3) 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 exterior grade is typically used in this area.
- 4) Continuous foundation walls should be reinforced top and bottom to span local anomalies such as by assuming an unsupported length of at least 10 feet. Walls acting as retaining structures should also be designed to resist lateral earth pressures as discussed in the "Retaining Walls" section of this report.

- 5) All existing fill, topsoil and any loose or disturbed soils should be removed and the footing bearing level extended down to the relatively dense natural granular soils. The exposed soils in footing area should then be moistened and compacted. Structural fill placed to reestablish design bearing level should consist of granular soil compacted to at least 100% of standard Proctor density at near optimum moisture content. The structural fill should extend laterally beyond the footing edge a distance at least equal to the fill depth below the bearing level.
- 6) A representative of the geotechnical engineer should evaluate bearing conditions and fill compaction for project specification compliance and observe all footing excavations prior to concrete placement.

RETAINING STRUCTURES

Retaining structures which are laterally supported and can be expected to undergo only a slight amount of deflection should be designed for a lateral earth pressure computed on the basis of an equivalent fluid unit weight of at least 50 pcf for backfill consisting of the on-site predominantly granular soils free of organics, debris and rock larger than about 6 inches. Cantilevered retaining structures which are separate from other structures and can be expected to deflect sufficiently to mobilize the full active earth pressure condition should be designed for a lateral earth pressure computed on the basis of an equivalent fluid unit weight of at least 40 pcf for backfill consisting of the on-site predominantly granular soils free of organics, debris and rock larger than about 6 inches.

All retaining structures should be designed for appropriate hydrostatic and surcharge pressures such as adjacent footings, traffic, construction materials and equipment. The pressures recommended above assume drained conditions behind the walls and a horizontal backfill surface. The buildup of water behind a wall or an upward sloping backfill surface will increase the lateral pressure imposed on a retaining structure. An underdrain should be provided to prevent hydrostatic pressure buildup behind walls.

Backfill should be placed in uniform lifts and compacted to at least 95% of the maximum standard Proctor density at near optimum moisture content. Care should be taken not to overcompact the backfill or use large equipment near the wall, since this could cause excessive

lateral pressure on the wall. Some settlement of deep wall backfill should be expected, even if the material is placed correctly, and could result in distress to facilities constructed on the backfill.

We recommend predominantly granular soils for backfilling retaining structures because their use results in lower lateral earth pressures and the backfill will help facilitate subsurface drainage. Granular wall backfill should contain less than 25% passing the No. 200 sieve and have a maximum size of 6 inches.

The lateral resistance of foundation or retaining wall footings 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 0.45. Passive pressure of compacted backfill against the sides of the footings can be calculated using an equivalent fluid unit weight of 350 pcf. The coefficient of friction and passive pressure values recommended above assume ultimate soil strength. Suitable factors of safety should be included in the design to limit the strain which will occur at the ultimate strength, particularly in the case of passive resistance. Fill placed against the sides of the footings to resist lateral loads should be a predominantly granular material compacted to at least 95% of the maximum standard Proctor density at a moisture content near optimum.

PAVEMENT SECTION

The subgrade soils encountered at the site are variable in type, condition and depth and contain considerable silt and clay fines with limit drainage capacity. Certain soils such as the finer graded fill and natural soils at the site are frost susceptible and could impact pavement performance. If those soils are wetted, the resulting frost heave movements can be large and erratic. Therefore, pavement design procedures assume dry subgrade conditions by providing proper surface and subsurface drainage. At this project, the risk of frost heave may be higher than normal due to the proposed use of pervious granite pavers.

Subgrade Materials: The upper soils encountered at the site are mainly low plasticity clayey sand to sandy clay with AASHTO classifications of A-4 and A-6 which are considered poor

support for pavement materials. The soil classification tests indicate a Hveem stabilometer "R" value in the range of 5 to 10. For design purposes, the soil support value of the subgrade was selected based on a Hveem "R" value of 8 for asphalt/flexible pavement and a modulus of subgrade reaction of 50 pci was selected for portland cement concrete pavement.

Pavement Sections: Since estimated traffic loading information was not available at the time of report preparation, an 18 kip equivalent daily load application (EDLA) of 30 was assumed for combined automobile and truck traffic in the east half of the project and 20 was assumed in the west half of the project which will have restricted truck traffic. This loading is typical of local commercial streets and should be checked by the project civil engineer. A Regional Factor of 2.0 was assumed for this area of Garfield County based on the site terrain, drainage and climatic conditions.

Based on assumed parameters, and using CDOT design procedures with an "R" value of 8, an 18 kip EDLA of 30, a Regional Factor of 2.0 and a serviceability index of 2.0, we recommend the minimum pavement section thickness in the east half of the project consist of 5 inches of asphalt on 8 inches of base course. Concrete sections subjected to truck traffic should consist of a minimum 7 inches of portland cement concrete on 4 inches of base course. In pedestrian only sidewalk areas, 4 inches of portland cement concrete on 4 inches of base course can be used.

In the west half of the project where pervious granite pavers will be used in truck traffic areas, the support materials below the pavers have not been specified. We expect that coarse sand will be placed directly below the pavers and some depth of ¾-inch screened rock will be placed below the coarse sand. The gradation of these materials should be evaluated for compatibility and filter criteria. For stability of the subgrade under traffic loading, we recommend a minimum 8 inches of base course below 8 inches of open-graded ¾-inch aggregate. A subgrade stabilization geogrid such as Tensar TX140 should be placed between the base course and open-graded aggregate. In pedestrian only walkway areas, the base course thickness can be reduced to a minimum of 4 inches.

The base course should meet CDOT Class 6 specifications. The open-graded aggregate should consist of predominantly crushed rock with a maximum size of ¾ inch with less than 2% passing the No. 200 sieve. All base course and required subgrade fill should be compacted to at least

95% of the maximum standard Proctor density at a moisture content within about 2% of optimum. Concrete should have a minimum 28 day compressive strength of 4,500 psi and be air entrained. The pavement design sections are based on strength coefficients of 0.44 for asphalt, 0.25 for pavers, 0.14 for Class 6 base course and 0.10 for open-graded crushed rock subbase.

Subgrade Preparation: Required fill to establish design subgrade level can consist of the on-site predominantly granular soils or suitable imported granular soils meeting the project specifications. Prior to fill placement, any organics, debris and unsuitable fill soils should be removed, the subgrade scarified to a depth of 8 inches, adjusted to near optimum moisture content and compacted. In soft or wet areas, the subgrade may require drying or stabilization prior to fill placement. A geogrid and/or subexcavation and replacement with aggregate base soils may be needed for the stabilization. The subgrade should be proofrolled. Areas that deflect excessively should be corrected before placing pavement materials. The subgrade improvements and placement and compaction of base materials should be monitored on a regular basis by a representative of the geotechnical engineer. Once traffic loadings are better known, we can review our pavement section recommendations when requested.

Surface Drainage: The collection and diversion of surface drainage away from paved areas is extremely important to the satisfactory performance of the pavement. Drainage design should provide for the removal of water from paved areas and prevent excessive wetting of the subgrade soils. The pervious granite pavers are designed to accept a certain amount of surface runoff which would likely cause wetting of the pavement subgrade. As a mitigation measure, placing an impervious membrane on the subgrade, such as 30 mil PVC, could be used to help prevent subgrade wetting. The open-graded gravel layer should have positive gravity outlet for drainage.

SUBDRAIN SYSTEM

Although free water was not encountered during our exploration, it has been our experience in the area that local perched groundwater can develop during times of heavy precipitation or seasonal runoff. Frozen ground during spring runoff can create a perched condition. We recommend below-grade construction such as retaining walls be protected from wetting and hydrostatic pressure buildup by an underdrain system.

The drains should consist of drainpipe placed in the bottom of the wall backfill surrounded above the invert level with free-draining granular material. The drain should be placed behind each wall at least 1 foot below lowest adjacent finish grade and sloped at a minimum 1% to a suitable gravity outlet or drywell. Free-draining granular material used in the underdrain system should contain less than 2% passing the No. 200 sieve, less than 50% passing the No. 4 sieve and have a maximum size of 2 inches. The drain gravel backfill should be at least 1½ feet deep.

SURFACE DRAINAGE

The following drainage precautions should be observed during construction and maintained at all times after the improvements have been completed:

- 1) Inundation of the foundation excavations and underslab areas should be avoided during construction.
- 2) Backfill should be adjusted to near optimum moisture and compacted to at least 95% of the maximum standard Proctor density in pavement and walkway areas and to at least 90% of the maximum standard Proctor density in landscape areas.
- 3) The ground surface should be adequately sloped to drain and prevent ponding. Free-draining wall backfill should be capped with at least 2 feet of the on-site finer graded soils to reduce surface water infiltration.
- 4) Regular heavy landscape irrigation should be minimized. Consideration should be given to use of xeriscape to reduce the potential for wetting of bearing soils caused by irrigation.

LIMITATIONS

This study has been conducted in accordance with generally accepted geotechnical engineering principles and practices in this area at this time. We make no warranty either express or implied. The conclusions and recommendations submitted in this report are based upon the data obtained from the exploratory borings drilled at the locations indicated on Figure 1, the proposed type of construction and our experience in the area. Our findings include interpolation and extrapolation of the subsurface conditions identified at the exploratory borings and variations in the subsurface conditions may not become evident until excavation is performed. If conditions encountered

during construction appear different from those described in this report, we should be notified so that re-evaluation of the recommendations may be made.

This report has been prepared for the exclusive use by our client for design purposes. We are not responsible for technical interpretations by others of our information. As the project evolves, we should provide continued consultation and field services during construction to review and monitor the implementation of our recommendations, and to verify that the recommendations have been appropriately interpreted. Significant design changes may require additional analysis or modifications to the recommendations presented herein. We recommend on-site observation of excavations and bearing soils and testing of structural fill by a representative of the geotechnical engineer.

Respectfully Submitted,

H-P # KUMAR

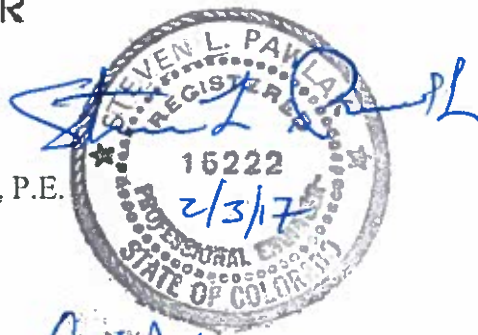
Steven L. Pawlak, P.E.

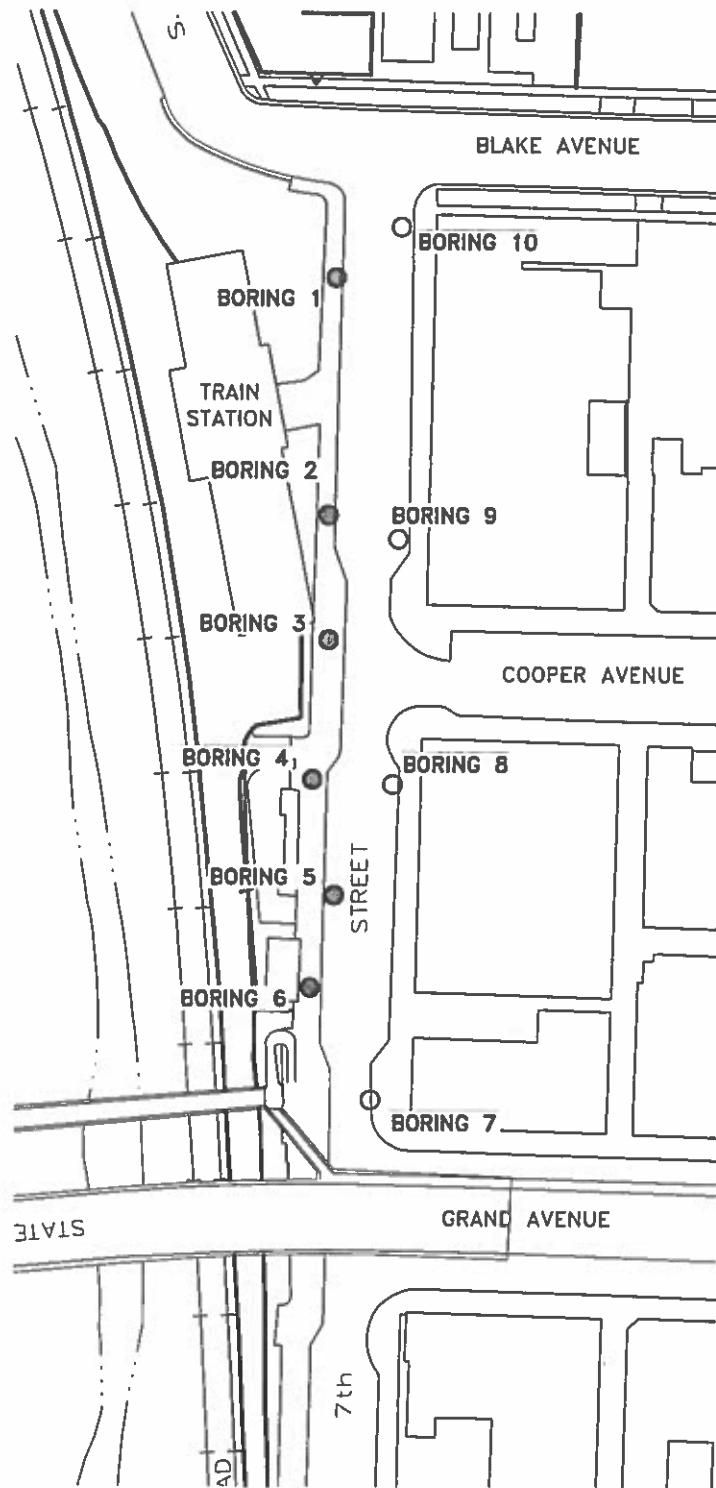
Reviewed by:

Daniel E. Hardin, P.E.

SLP/kac

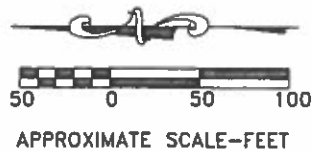
cc: Boundaries Unlimited – Deric Walter (deric@bu-inc.com)





LEGEND

- BORINGS DRILLED FOR THIS STUDY (B-1 TO 6)
- BORINGS DRILLED FOR PREVIOUS STUDY (B-7 TO 10)



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16-7-637

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LOCATION OF EXPLORATORY BORINGS

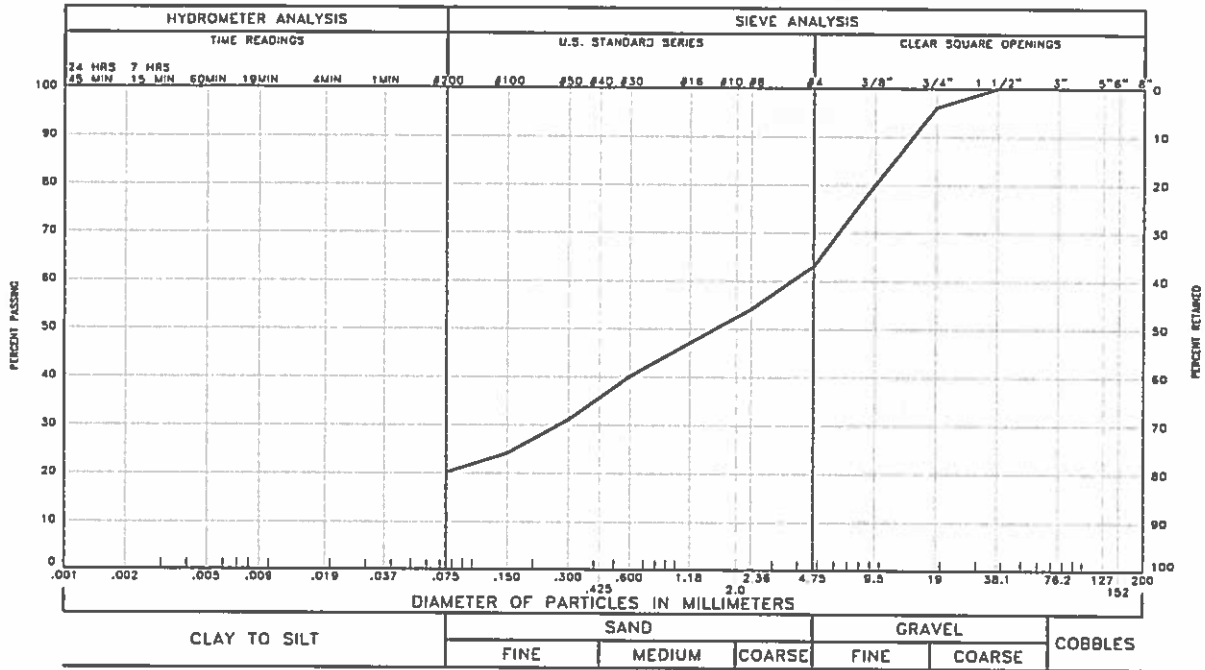
Fig. 1

LEGEND

- (4)  ASPHALT, THICKNESS IN INCHES SHOWN IN PARENTHESES TO LEFT OF THE LOG.
- (8)  BASE COURSE, THICKNESS IN INCHES SHOWN IN PARENTHESES TO LEFT OF THE LOG.
- (4)  CONCRETE SIDEWALK AT BORING 1, CONCRETE PAVERS AT BORINGS 2 AND 3, THICKNESS IN INCHES SHOWN IN PARENTHESES TO LEFT OF THE LOG.
-  FILL: MIXED SILTY, CLAYEY SAND WITH GRAVEL, MEDIUM DENSE, MOIST, MIXED BROWN.
-  FILL: CINDERS, SOME CONCRETE, LOOSE TO MEDIUM DENSE, MOIST, BLACK.
-  CLAY (CL); SILTY, SLIGHTLY SANDY TO SANDY, MEDIUM STIFF TO STIFF, MOIST, BROWN, SLIGHTLY CALCAREOUS, LOW PLASTICITY.
-  GRAVEL (GM-GP); SLIGHTLY SILTY TO SILTY, SANDY, COBBLES, PROBABLE BOULDERS, DENSE, MOIST, BROWN, ROUNDED ROCK.
-  DRIVE SAMPLE, 2-INCH I.D. CALIFORNIA LINER SAMPLE.
-  DRIVE SAMPLE, 1 3/8-INCH I.D. SPLIT SPOON STANDARD PENETRATION TEST.
- 13/12 DRIVE SAMPLE BLOW COUNT. INDICATES THAT 13 BLOWS OF A 140-POUND HAMMER FALLING 30 INCHES WERE REQUIRED TO DRIVE THE SAMPLER 12 INCHES.

NOTES

1. THE EXPLORATORY BORINGS WERE DRILLED ON JANUARY 6, 2016 WITH A 4-INCH DIAMETER CONTINUOUS FLIGHT POWER AUGER.
2. THE LOCATIONS OF THE EXPLORATORY BORINGS WERE MEASURED APPROXIMATELY BY PACING FROM FEATURES SHOWN ON THE SITE PLAN PROVIDED.
3. THE ELEVATIONS OF THE EXPLORATORY BORINGS WERE OBTAINED BY INTERPOLATION BETWEEN CONTOURS ON THE CITY TOPOGRAPHIC MAP.
4. THE EXPLORATORY BORING LOCATIONS AND ELEVATIONS 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 WAS NOT ENCOUNTERED IN THE BORINGS AT THE TIME OF DRILLING.
7. LABORATORY TEST RESULTS:
WC = WATER CONTENT (%) (ASTM D 2216);
DD = DRY DENSITY (pcf) (ASTM D 2216);
+4 = PERCENTAGE RETAINED ON NO. 4 SIEVE (ASTM D 422);
-200 = PERCENTAGE PASSING NO. 200 SIEVE (ASTM D 1140);
LL = LIQUID LIMIT (ASTM D 4318);
PI = PLASTICITY INDEX (ASTM D 4318);
A-4 (6) = AASHTO CLASSIFICATION (GROUP INDEX) (AASHTO M 145);
UC = UNCONFINED COMPRESSIVE STRENGTH (psi) (ASTM D 2166).

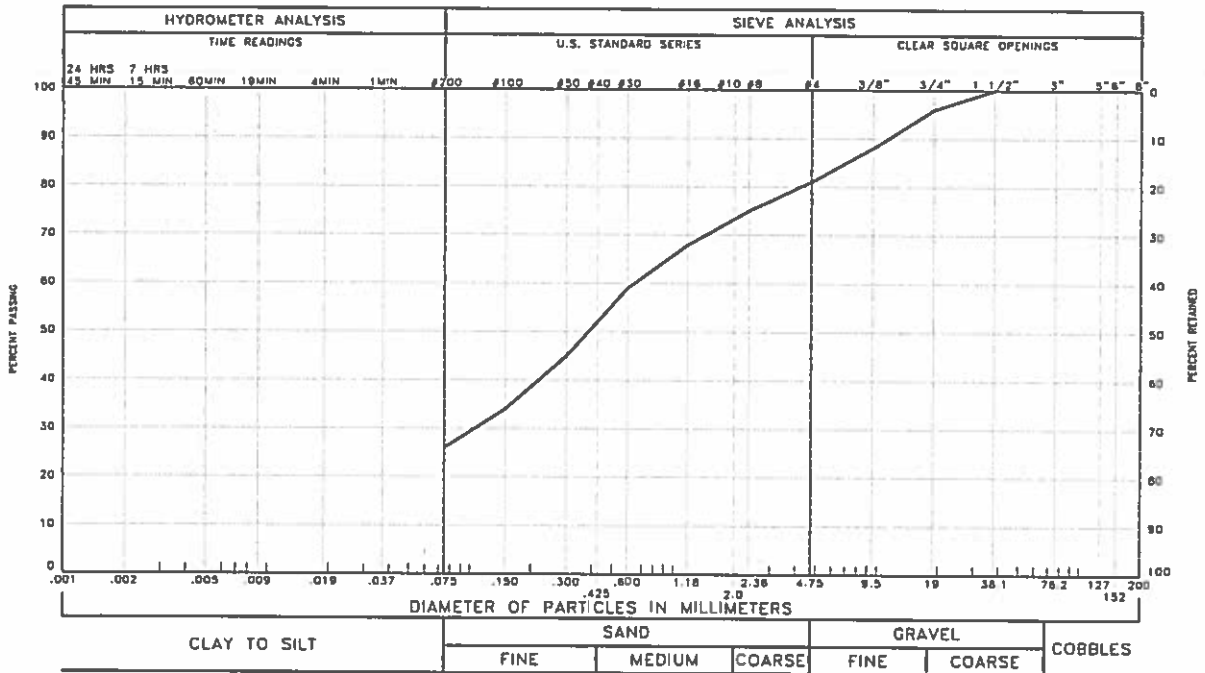


GRAVEL 37 % SAND 43 % SILT AND CLAY 20 %

LIQUID LIMIT PLASTICITY INDEX

SAMPLE OF: Clayey Sand and Gravel (Fill)

FROM: Boring 2 @ 5'



GRAVEL 19 % SAND 55 % SILT AND CLAY 26 %

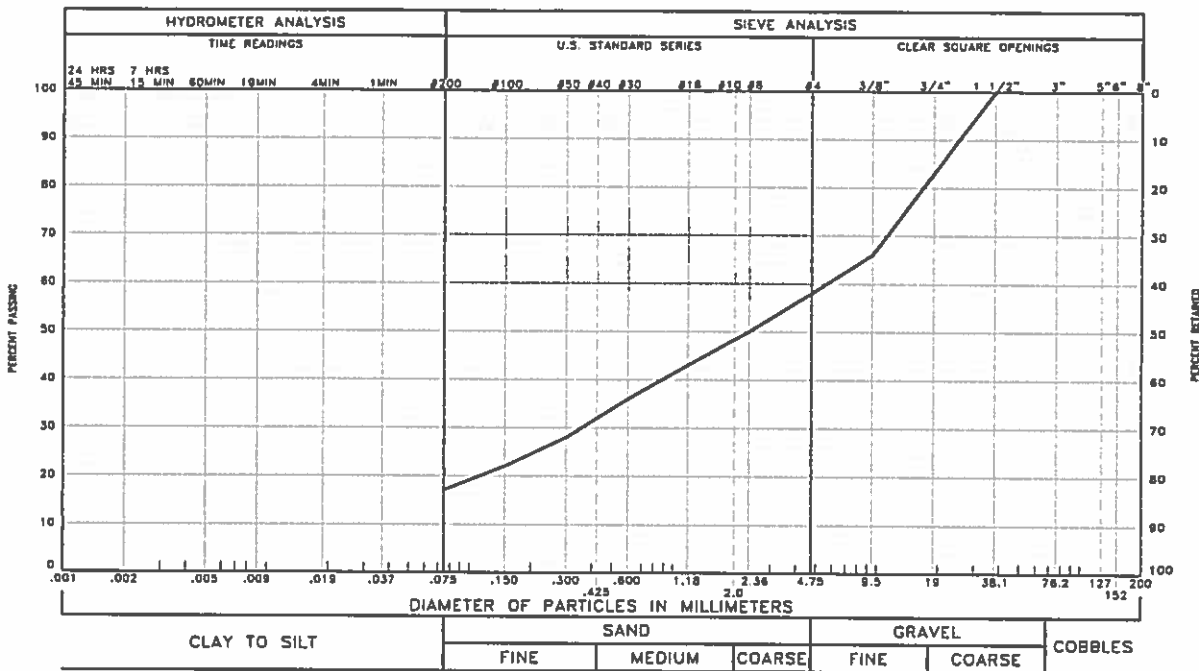
LIQUID LIMIT PLASTICITY INDEX

SAMPLE OF: Silty Sand with Gravel

FROM: Boring 3 @ 8' & 10' Combined

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 D422, ASTM C136 and/or ASTM D1140.

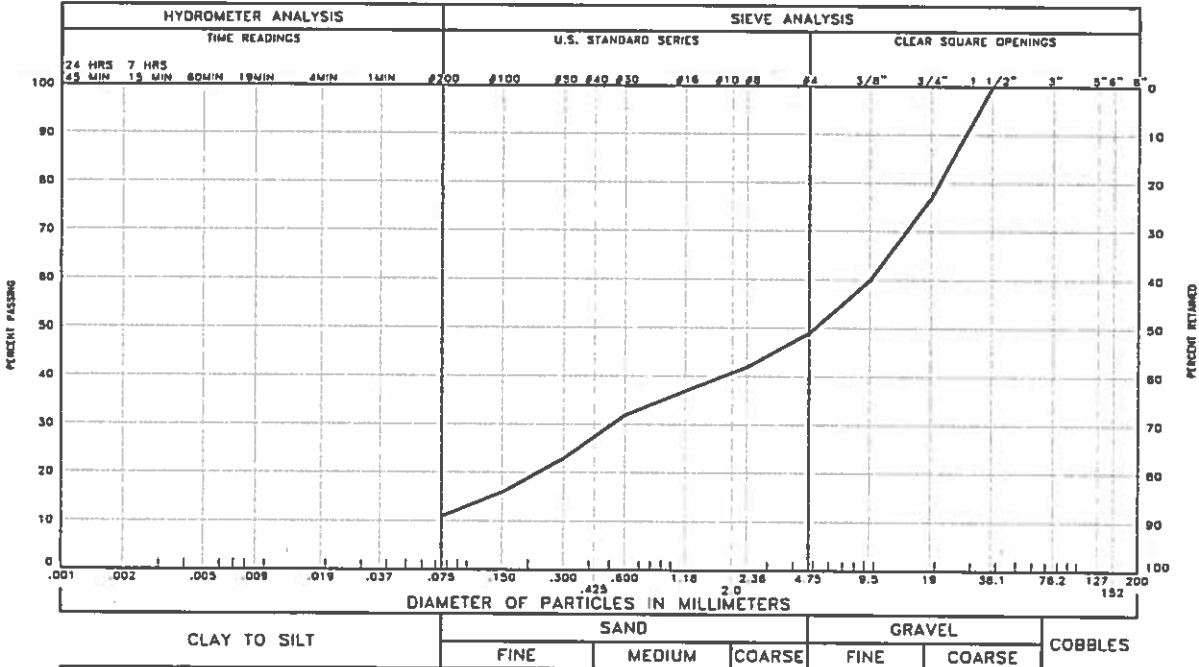
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GRAVEL 42 % SAND 41 % SILT AND CLAY 17 %

LIQUID LIMIT PLASTICITY INDEX

SAMPLE OF: Silty Sand and Gravel FROM: Boring 4 @ 4' & 6' Combined



GRAVEL 51 % SAND 38 % SILT AND CLAY 11 %

LIQUID LIMIT PLASTICITY INDEX

SAMPLE OF: Silty Sandy Gravel FROM: Boring 6 @ 7'

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 D422, ASTM C136 and/or ASTM D1140.

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**TABLE 2
PERCOLATION TEST RESULTS**

PROJECT NO. 16-7-637

HOLE NO.	HOLE DEPTH (INCHES)	LENGTH OF INTERVAL (MIN)	WATER DEPTH AT START OF INTERVAL (INCHES)	WATER DEPTH AT END OF INTERVAL (INCHES)	DROP IN WATER LEVEL (INCHES)	AVERAGE PERCOLATION RATE (MIN./INCH)
B-4	97	5	39½	35½	4	1.25
			35½	31¾	3¾	1.3
		2	31¾	30¾	1	2
			30¾	30	¾	2.7
			30	29	1	2
			29	28¾	¾	2.7
			28¾	27½	¾	2.7

Note: Percolation test was conducted in the borehole on January 9, 2017.