GEOTECHNICAL ENGINEERING REPORT
TOWER VILLAGE DEVELOPMENT
LEBANON, MISSOURI

Prepared for:

O’REILLY DEVELOPMENT COMPANY, LLC
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Prepared by:

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PPI PROJECT NUMBER: 240652

January 26, 2017
January 26, 2017

O'Reilly Development Company, LLC
5051 South National Avenue, Suite 7B
Springfield, Missouri 65810

Attn: Ms. Denise Heintz
Email: denise@oreillydevelopment.com

RE: Geotechnical Engineering Report
Tower Village
Lebanon, Missouri
PPI Project Number: 240652

Dear Ms. Heintz:

Attached, please find the report summarizing the results of the geotechnical investigation conducted for the above referenced project. We appreciate this opportunity to be of service. If you have any questions, please don’t hesitate to contact this office.

PALMERTON & PARRISH, INC.
By:

Shane M. Rader, P.E.
Geotechnical Engineer

Submitted: One (1) Electronic .pdf Copy
SMR/BRP/BRP/jrh

cc: Mr. Brian Czerw, AIA
Stark Wilson Duncan Architects

PALMERTON & PARRISH, INC.
By:

Brandon R. Parrish, P.E.
Vice-President
# TABLE OF CONTENTS

EXECUTIVE SUMMARY ............................................................................................................. 1 & 2  
1.0 INTRODUCTION .................................................................................................................. 3  
2.0 PROJECT DESCRIPTION ...................................................................................................... 4  
3.0 SITE DESCRIPTION ............................................................................................................. 4  
4.0 SUBSURFACE INVESTIGATION ........................................................................................... 5  
   4.1 Subsurface Borings ........................................................................................................... 5  
   4.2 Laboratory Testing ........................................................................................................... 5  
5.0 SITE GEOLOGY .................................................................................................................... 6  
6.0 GENERAL SITE & SUBSURFACE CONDITIONS ................................................................ 6  
   6.1 Bedrock .......................................................................................................................... 7  
   6.2 Auger Refusal ................................................................................................................... 8  
   6.3 Groundwater .................................................................................................................... 9  
7.0 EARTHWORK .................................................................................................................... 9  
   7.1 Fill Material Types ........................................................................................................ 10  
   7.2 Compaction Requirements ............................................................................................ 11  
   7.3 Inclement Weather ........................................................................................................ 11  
   7.4 Site Drainage ................................................................................................................ 12  
   7.5 Earthwork Construction Considerations ..................................................................... 12  
   7.6 Excavations .................................................................................................................. 12  
8.0 FOUNDATIONS .................................................................................................................. 12  
   8.1 Uplift Capacity of Shallow Foundations ...................................................................... 13  
   8.2 Construction Considerations for Shallow Foundations .............................................. 14  
9.0 SEISMIC CONSIDERATIONS ............................................................................................ 14  
10.0 FLOOR SLABS ................................................................................................................ 14  
11.0 PAVEMENT ...................................................................................................................... 15  
   11.1 Flexible Pavement ......................................................................................................... 15  
   11.2 Rigid Pavement ............................................................................................................ 16  
   11.3 Pavement Thickness .................................................................................................... 16  
12.0 CONSTRUCTION OBSERVATION & TESTING ................................................................. 16  
13.0 REPORT LIMITATIONS .................................................................................................... 17

## FIGURES

**FIGURE 1** — BORING LOCATION PLAN

## APPENDICES

APPENDIX I — BORING LOGS & KEY TO SYMBOLS  
APPENDIX II — GENERAL NOTES  
APPENDIX III — IMPORTANT INFORMATION REGARDING YOUR GEOTECHNICAL REPORT
EXECUTIVE SUMMARY

A Geotechnical Investigation was performed at the site planned for construction of the new Tower Village located at 623 Tower Road in Lebanon, Missouri. It is understood that the proposed Tower Village Development will include constructing a Community Building, as well as nine (9) apartment structures. All structures are understood to be single-story in height, consist of wood framing and utilize slab-on-grade floor systems. Foundation and floor slab loadings are anticipated to be light. New pavement for entrance drives and parking is also planned. Minimal grade changes are anticipated to achieve finish subgrade elevations across the project site.

A total of fifteen (15) geotechnical borings were drilled across the subject property. All borings were discontinued in natural overburden soils, sandstone or dolomite at depths ranging from 5 to 11.3 ft. below the existing ground surface. Based upon the information obtained from the borings and subsequent laboratory testing, the site is suitable for construction of the proposed Tower Village Development. Important geotechnical considerations for the project are summarized below. However, users of the information contained in the report must review the entire report for specific details pertinent to geotechnical design considerations.

- The project site is currently a heavily wooded parcel with paths cleared to the planned boring locations which was performed by others prior to drill-rig mobilization;

- Topsoil was encountered across this site with typical thicknesses ranging from 0.3 to 0.8 ft. However, the upper clays at this site contain increased amounts of root matter due to this parcel being heavily wooded. Thicker topsoil or root impacted zones may be encountered during site development;

- Shallow natural soils encountered across the entire site contain little to no rock content and may undergo loss of shear strength properties upon an increase in soil moisture or when disturbed by heavier construction equipment. Additional undercutting or stabilization of these lean clays may be required to achieve stable subgrade prior to fill placement or pavement/slab construction;
EXECUTIVE SUMMARY (CONTINUED)

- Shallow to deeper CL-CH or CH clays were often encountered across the project site. Based upon the higher moisture content relative to the plastic limit, as well as the dilution effect caused by the increased chert content and past experience by this firm, it is anticipated that these clays will exhibit low shrink/swell potential;

- Shallow sandstone or cherty dolomite was encountered within several borings at depths ranging from 6.5 to 10.5 ft. below the existing ground surface;

- It is recommended that the planned new Tower Village Development structures be supported upon shallow foundations bearing upon natural foundation soils or controlled fill. These recommendations are further discussed in Section 8.0 of this report;

- Slab-on-grade or slab-on-fill floor systems and pavements may be constructed directly upon the proof-rolled/approved, and moisture conditioned natural subgrade or approved controlled fill material;

- The project site classifies as a Site Class C in accordance with Section 1613 of the 2012 International Building Code (IBC); and

- Palmerton & Parrish, Inc. should be retained for construction observation and construction materials testing. Close monitoring of subgrade preparation work is considered critical to achieve adequate foundation and subgrade performance.
GEOTECHNICAL ENGINEERING REPORT
TOWER VILLAGE DEVELOPMENT
LEBANON, MISSOURI

1.0 INTRODUCTION

This is the report of the Geotechnical Investigation performed at the site planned for construction of the new Tower Village Development located at 623 Tower Road in Lebanon, Missouri. This investigation was authorized by a letter proposal dated December 15, 2016, and signed by Ms. Denise Heintz, representing O'Reilly Development Company, LLC. The approximate site location is shown in the aerial photograph below for reference.
The purpose of the Geotechnical Investigation was to provide information for foundation design and construction planning, and to aid in site development. Palmerton & Parrish Inc.’s (PPI) scope of services included field and laboratory investigation of the subsurface conditions in the vicinity of the proposed project site, engineering analysis of the collected data, development of recommendations for foundation design and construction planning, and preparation of this engineering report.

2.0 PROJECT DESCRIPTION

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site Layout</td>
<td>See Figure 1: Boring Location Plan</td>
</tr>
</tbody>
</table>
| Tower Village Development   | • A Community Building;  
                               | • Nine (9) apartment buildings;  
                               | • All structures will be single-story in height;  
                               | • Utilize slab-on-grade floor systems; and  
                               | • Supported upon shallow foundations.                                                                                                     |
| Anticipated Foundation & Floor Slab Loadings | Light.                                                                                                                                     |
| New Pavement                | Pavement for access drives and/or parking is anticipated.                                                                                   |
| Anticipated Grading         | Minimal grade changes to achieve finish subgrade elevations across the project site.                                                        |

3.0 SITE DESCRIPTION

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Location</td>
<td>623 Tower Road, Lebanon, Missouri.</td>
</tr>
<tr>
<td>Township/Range/Section</td>
<td>34N/16W/12</td>
</tr>
<tr>
<td>Latitude/Longitude \ (± Center of Project Site)</td>
<td>37.679124° / -92.633346°</td>
</tr>
<tr>
<td>Historic Aerial Photography</td>
<td>Based upon readily available historic aerial photography, a single-story residential structure once resided within the east portion of the project site. Between 2012 and present, the structure was demolished with an existing gravel driveway remaining.</td>
</tr>
<tr>
<td>Current Ground Cover</td>
<td>With the exception of the gravel drive, the majority of the subject property is covered in relatively dense brush and trees with a few paths cleared by others to allow access with a drill-rig.</td>
</tr>
<tr>
<td>Existing Topography</td>
<td>Relatively flat lying.</td>
</tr>
<tr>
<td>Drainage Characteristics</td>
<td>Poor. Due to recent rain events, ponded water was noted within several structure footprints located along the south property line.</td>
</tr>
</tbody>
</table>
4.0 SUBSURFACE INVESTIGATION

Subsurface conditions were investigated through completion of fifteen (15) subsurface borings and subsequent laboratory testing.

4.1 Subsurface Borings

Boring locations were selected by others and staked in the field by PPI. Approximate boring locations are shown on Figure 1: Boring Location Plan. The Missouri One-Call System was notified prior to the investigation to assist in locating buried public utilities.

All borings were discontinued in natural overburden soils, sandstone or dolomite at depths ranging from 5 to 11.3 ft. below the existing ground surface. Logs of the borings showing descriptions of soil and rock units encountered, as well as results of field and laboratory tests and a “Key to Symbols” are presented in Appendix I.

Borings were drilled December 30, 2016, and January 17 and 18, 2017 using either 4.5-inch O.D. continuous flight or 4.25-inch I.D. hollow stem augers powered by a balloon tired CME-1050 or 550X drill-rig. Soil samples were collected at 2.5 to 5-ft. centers during drilling. Soil sample types included split spoon samples collected while performing the Standard Penetration Test (SPT) in general accordance with ASTM D1586 and thin walled Shelby tubes pushed hydraulically in advance of drilling in accordance with ASTM D1587. Please refer to Appendix II for general notes regarding boring logs and additional soil sampling information.

4.2 Laboratory Testing

Collected samples were sealed and transported to the laboratory for further evaluation and visual examination. Laboratory soil testing included the following:

- Moisture Content (ASTM D2216);
- Unconfined Compressive Strength (ASTM D2166);
- Atterberg Limits (ASTM D4318); and
- Pocket Penetrometers.
Laboratory test results are shown on each boring log in Appendix I and are summarized in the following table.

<table>
<thead>
<tr>
<th>Boring</th>
<th>Depth (ft.)</th>
<th>Liquid Limit (LL)</th>
<th>Plastic Limit (PL)</th>
<th>Plasticity Index (PI)</th>
<th>Moisture Content (%)</th>
<th>USCS Symbol</th>
<th>Cohesion (psf)</th>
<th>Dry Unit Wt. (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>3.5 to 5</td>
<td>89</td>
<td>23</td>
<td>66</td>
<td>26.1</td>
<td>CH</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>0 to 1.5</td>
<td>46</td>
<td>20</td>
<td>26</td>
<td>23.6</td>
<td>CL-CH</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11</td>
<td>6 to 7.5</td>
<td>80</td>
<td>26</td>
<td>54</td>
<td>32.0</td>
<td>CH</td>
<td>5330</td>
<td>87.2</td>
</tr>
</tbody>
</table>

### 5.0 SITE GEOLOGY

The general site area is underlain at depth by Ordovician Age Bedrock of the Jefferson City-Cotter and/or Roubidoux Formations. These bedrock units characteristically consist of interbedded zones of light gray to brown, thin to medium bedded cherty dolomite and quartzose sandstone. The upper surface of the dolomite is often irregular due to the effects of differential vertical weathering and solution activity. Overburden soils at the site area typically consist of residual cherty sandy clays having developed through chemical and physical weathering of the underlying parent bedrock. The chert was once interbedded with the dolomite, but is much more resistant to weathering and has retained rock-like properties within overburden soils. The boundary between overburden soils and comparatively unweathered bedrock is usually abrupt.

### 6.0 GENERAL SITE & SUBSURFACE CONDITIONS

Based upon subsurface conditions encountered within the borings drilled at the project site, generalized subsurface conditions are summarized in the table below. Soil stratification lines on the boring logs indicate approximate boundary lines between different types of soil and rock units based upon observations made during drilling. In-situ transitions between soil and some rock types are typically gradual.
Stratum 2 consists of surficial lean clays. These shallow natural soils may undergo loss of shear strength properties upon an increase in soil moisture or when disturbed by heavier construction equipment. Additional undercutting or stabilization of these lean clays may be required to achieve a stable subgrade prior to fill placement or pavement/slab construction.

Stratum 3 consists of lean to fat or fat clays that are native to the Lebanon area. The in-situ clays exhibit primarily low shrink/swell potential due to the higher moisture content relative to the Plastic Limit and dilution effect caused by chert fragments unless allowed to dry, and then become saturated.

6.1 Bedrock

Dolomite or sandstone was encountered within Borings 1, 2, 3, 5, 9, 10 and 11 at depths ranging from 6 to 9.9 ft. below the existing ground surface. Refer to the following table for approximate depth to bedrock encountered in each boring. Shallow bedrock was not encountered in the remaining borings within the depths explored.
### Auger Refusal

Auger refusal is defined as the depth below the ground surface at which a boring can no longer be advanced with the soil drilling technique being used. Auger refusal is subjective and is based upon the type of drilling equipment and types of augers being used, as well as the effort exerted by the driller. Several different auger refusal conditions are possible in the general site area. These conditions are represented graphically in the adjacent figure: (A) on the upper surface of continuous bedrock, (B) on rock “pinnacles”, (C) in widened joints that may extend well below the...
surrounding bedrock surface, (D) slabs of unweathered rock suspended in the residual soil matrix, or “floaters”, or (E) on the upper surface of discontinuous bedrock.

6.3 Groundwater

Shallow groundwater was not observed within the borings on the date drilled. However, groundwater levels should be expected to fluctuate with changes in site grading, precipitation, and regional groundwater levels. Groundwater may be encountered at shallower depths during wetter periods.

7.0 EARTHWORK

Specific site grading plans for this project were not provided as of the date of this report. However, it is anticipated that minimal depths of cut and/or fill will be required to provide finish subgrade elevations across the site. The initial phase of site preparation should include:

- Site clearing shall be performed including tree and brush removal from the subject property;
- Removal of all organic matter. Site stripping and organic matter removal on the order of 0.5 to 1 ft. should be anticipated. Again, zones of increased roots are anticipated at this site. Thicker topsoil or root impacted zones may be encountered during site grading activities; and
- Topsoil and material containing organics should be stockpiled outside of areas to receive controlled fill and may be used in lawn or landscape areas only.

After these initial phases of site preparation are complete, it is recommended that all areas scheduled to receive controlled fill, building, or slab/pavement construction be proof-rolled to assure a stable subgrade. Proof-rolling consists essentially of rolling the ground surface with a loaded tandem axle dump truck or similar heavy rubber tired construction equipment and noting any areas which rut or deflect during rolling. All soft subgrade areas identified during proof-rolling should be undercut and replaced with compacted fill as outlined below. Proof-rolling, undercutting and replacement
should be monitored by a qualified representative of PPI. If construction is initiated during wetter months, the requirement for undercutting soft surficial soils below normal site stripping should be anticipated and reflected in contract documents.

After evaluation by proof-rolling and approval, the subgrade should be scarified to a depth of at least 8 inches in depth, adjusted to within the specified ranges of optimum moisture content and compacted to specified densities as outlined below (see Section 7.2). Placement of controlled fill may then proceed.

### 7.1 Fill Material Types

<table>
<thead>
<tr>
<th>Fill Type</th>
<th>USCS Classification</th>
<th>Acceptable Location for Placement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Volume Change Engineered Fill ²</td>
<td>CL, GC or SC (LL &lt; 50)</td>
<td>All locations and elevations</td>
</tr>
<tr>
<td>On-Site Soils</td>
<td>CL, CL-CH, GC or CH</td>
<td>All locations and elevations³</td>
</tr>
<tr>
<td>Potential Import Material</td>
<td>CL, GC, SC, CL-CH &amp; CH</td>
<td>All locations and elevations³</td>
</tr>
</tbody>
</table>

1. Controlled, compacted fill should consist of approved materials that are free of organic matter and debris and contain maximum rock size of 4 to 6 in. Frozen material should not be used and fill should not be placed on a frozen subgrade. A sample of each material type should be submitted to the Geotechnical Engineer for evaluation prior to its use.

2. Low plasticity cohesive soil or granular soil having at least 15% low plasticity fines.

3. CH Clays with Liquid Limit equal to or above 50 is considered suitable for use as controlled fill only if the percentage of rock fragments exceeds 35% or if placed 2 ft. below shallow foundations, slab or pavement areas.
### 7.2 Compaction Requirements

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subgrade Scarification Depth</td>
<td>At least 8 inches</td>
</tr>
<tr>
<td>Fill Lift Thickness</td>
<td>8-inches (loose)</td>
</tr>
</tbody>
</table>
| Compaction Requirements\(^1\) | • Structural Areas - 95% Standard Proctor Density (ASTM D-698); or  
                          | • Non-Structural Areas – 90% Standard Proctor Density (ASTM D-698) |
| Moisture Content\(^2\)     | • ± 2% optimum moisture for CL, GC or SC soil types; and  
                          | • 0 to 4% above optimum for CL-CH & CH soil types. |

1. We recommend that engineered fill (including scarified compacted subgrade) be tested for moisture content and compaction during placement. Should the results of the in-place density tests indicate the specified moisture or compaction limits have not been met, the area represented by the test should be reworked and retested as required until the specified moisture and compaction requirements are achieved. One (1) field density test for each 2500 and 5000 sq. ft. of fill lift, but no less than 3 tests per lift, is recommended in building and pavement areas, respectively.

2. Highly plastic natural clays containing little to no chert or sand, which may be exposed a finish subgrade elevations should be scarified to approximately 8-inches moisture conditioned as recommended above, and recompressed.

### 7.3 Inclement Weather

If construction is initiated during wetter months, the requirement for undercutting soft surficial soils below normal site stripping should be anticipated and reflected in contract documents. Undercut depths on the order of 2 or more ft. are considered possible within areas of site grading. Based upon past experience of this firm, the shallow lean clay subgrade at the site is known to significantly lose strength when saturated and disturbed by construction equipment. Further, material removed from undercuts may not be suitable for use as compacted fill due to high soil moisture if poor drying conditions (cool temperatures and/or frequent precipitation) occur during site grading. If the construction schedule will not permit delay for better drying conditions, the project budget should include an allowance for subgrade undercut and replacement soil material containing appreciable quantities of chert or sand and gravel from an off-site borrow area that meet the requirements above. As an alternate to select fill, rock fill subbase (4 to 8 inch top size stone) may be placed to improve subgrade stability.
7.4 Site Drainage

Discharge from roof downspouts should be collected and diverted well away from the building perimeter. Rapid, efficient runoff away from the building should also be provided. In addition, landscaping requiring frequent watering should be prohibited adjacent to building foundations.

7.5 Earthwork Construction Considerations

Once grading and filling operations have been completed, the moisture within the subgrade should be maintained and soils not be allowed to dry and desiccate prior to construction of floor slabs, pavements and footings. Grading of the site should be performed in such a manner so that ponding of surface water on prepared subgrade or in excavations is avoided. During construction, if the prepared subgrade should become frozen, desiccated, saturated, or disturbed, the affected material should be scarified or removed, moisture conditioned and recompacted prior to floor slab construction.

7.6 Excavations

Based upon the subsurface conditions encountered during this investigation, the on-site soils typically classify as Type B in accordance with OSHA regulations. Temporary excavations in soils classifying as Type B with a total height of less than 20 ft. should be cut no steeper than 1H:1V in accordance with OSHA guidelines. Confirmation of soil classification during construction, as well as construction safety (including shoring, if required), is the responsibility of the contractor.

8.0 FOUNDATIONS

As previously mentioned, medium stiff to very stiff natural clays were encountered across the project site. It is recommended that the planned new Tower Village Development be supported upon shallow foundations bearing in medium stiff to very stiff natural soils or controlled fill. Recommendations for shallow foundation design and construction are provided in the following table.
## Net allowable bearing pressure

1. The recommended net allowable bearing pressure is the pressure in excess of the minimum surrounding overburden pressure at the footing base elevation. The recommended pressure considers all unsuitable and/or soft or loose soils, if encountered, are undercut and replaced with tested and approved new engineered fill. Footing excavations should be free of loose and disturbed material, debris, and water when concrete is placed.

2. If minimal grade changes are expected within the building footprint, footings are recommended to be installed upon medium stiff to very stiff natural soils encountered at least 2.5 ft. (possibly deeper) below existing grade. PPI should be retained to observe footing excavations prior to placement of reinforcing steel.

3. For perimeter footings and footings beneath unheated areas.

4. Allowable passive pressure value considers a Factor of Safety of about 2. Passive pressure value applies to undisturbed native clay or properly compacted fill. If formed footings are constructed, the space between the formed side of a footing and excavation sidewall should be cleaned of all loose material, debris, and water and backfilled with tested and approved fill compacted to at least 95% of the material’s Standard Proctor dry density. Passive resistance should be neglected for the upper 2.5 ft. of the soil below the final adjacent grade due to strength loss from freeze/thaw and shrink/swell.

5. Coefficient of friction value is an ultimate value and does not contain a Factor of Safety.

### 8.1 Uplift Capacity of Shallow Foundations

Resistance of shallow spread footings to uplift ($U_p$) may be based upon the dead weight of the concrete footing structure ($W_C$) and the weight of soil backfill contained in an inverted cone or pyramid directly above the footings ($W_S$). The following parameters may be used in design:

<table>
<thead>
<tr>
<th>Description</th>
<th>Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of Concrete ($W_C$)</td>
<td>150 pcf</td>
</tr>
<tr>
<td>Weight of Soil Resistance ($W_S$)</td>
<td>100 pcf</td>
</tr>
</tbody>
</table>
The base of the cone or pyramid should be the top of the footing and the pyramid or cone sides should form an angle of 30 degrees with the vertical. Allowable uplift capacity ($U_p$) should be computed as the lesser of the two (2) equations listed below:

$$U_p = \left(\frac{W_S}{2.0}\right) + \left(\frac{W_C}{1.25}\right)$$

$$U_p = \left(\frac{W_S + W_C}{1.5}\right)$$

### 8.2 Construction Considerations for Shallow Foundations

It is essential that footing bottoms (individual or continuous) should not be allowed to become dry and desiccate prior to concrete placement to help reduce the potential for shrink/swell behavior. Footings should be clean and free of standing water, debris, and loose soil at the time of concrete placement. Footing excavations should be observed by a representative of PPI prior to placement of reinforcing steel and concrete placement.

### 9.0 SEISMIC CONSIDERATIONS

<table>
<thead>
<tr>
<th>Code Used</th>
<th>Site Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012 International Building Code (IBC)(^1)</td>
<td>C</td>
</tr>
</tbody>
</table>

1. In general accordance with the *2012 International Building Code*, Section 1613

### 10.0 FLOOR SLABS

A slab-on-grade or slab-on-fill floor system is considered appropriate at the site based upon subsurface conditions encountered and future site grading. Listed below are key considerations for design purposes of the floor slab.

- Prior to placement of controlled fill, if any, natural soils should be scarified, moisture content adjusted and re-compacted in accordance with Sections 7.0 of this report: and

- Prior to slab placement, soil moisture should be adjusted and maintained within the parameters specified in Section 7.0 of this report.

Placement of 4 or more inches of compacted free-draining granular base course below slabs that are not below grade is recommended to limit moisture rise through slabs and to improve slab support, particularly at joints. An impervious moisture barrier consisting of 6-mil plastic sheeting or equivalent should be provided in accordance with the 2012...
IBC. Use of a 10-mil vapor barrier is recommended below all slab areas with an intended use sensitive to slab moisture.

11.0 PAVEMENT

It is anticipated that any new pavements associated with this project will be constructed of either an asphaltic concrete wearing surface placed over a base or a rigid Portland Cement Concrete pavement over a granular base. It is considered essential that subgrades be prepared and approved in accordance with Section 7.0 of this report, in order for satisfactory pavement performance to be achieved.

11.1 Flexible Pavement

If asphaltic paving is selected, the aggregate base may be a granular compacted crushed limestone with a gradation and quality conforming to the requirements of the Missouri Department of Transportation, Standard Specification 1007 for either Type 1 or Type 5 aggregates. The maximum lift thickness for the granular base is 4 inches. Granular base thicknesses in excess of 4 inches should be placed in multiple lifts with each lift being of approximate equal thickness. The granular base should be compacted to at least 100% of Standard Proctor Compaction (ASTM D698). The base may also be a bituminous base.

Asphaltic concrete, both base and surface, should conform to the applicable volumetric and gradational requirements of MoDOT Standard Specification 401 except that sampling for testing compliance during laydown should be from hot mix samples taken behind the paver. Asphaltic concrete should be compacted to 92 to 96% of Maximum Theoretical Specific Gravity (ASTM D2041). 95% of 50-Blow Marshall compaction is also accepted as a minimum compaction if the void content (Va) is within the specification value range. Substitution of an appropriate Superpave Mix Design (MoDOT Section 403) is permitted. SP 190C or SP 250C can be used in place of the bituminous base. SP 190C or SP 125C may be used for the surface. All bituminous mix designs should have been prepared or verified within six (6) months of the date of placement on this project and should recognize the tendency of the mineral aggregate to “fine up” in the mixer.
11.2 Rigid Pavement

If rigid concrete paving is selected a minimum 4-inch thick granular base compacted to 100% of Standard Proctor should be placed on the prepared subgrade. The Portland Cement Concrete mix should have a minimum 28-day compressive strength of 4000 pounds per square inch (psi). Concrete should be placed at a low slump (1 to 3 inches) and have an entrained air content of 5 to 7%. If an increased slump is desired, use of Super Plasticizer is recommended. The use of 6x6-inch welded wire mesh is also recommended for reinforcement.

11.3 Pavement Thickness

A pavement thickness would best be computed if traffic frequencies and wheel loadings were provided to us, but a typical pavement design for this type of facility would generally generate a Structural Number of 3.0 to 3.5 within heavy duty areas and 2.4 to 2.6 within light duty areas, depending on the subgrade conditions. These thicknesses are based upon a CBR value of 4.0. The following table presents corresponding typical flexible and rigid pavement thicknesses which are conservative using the general Structural Numbers. This table can be modified after PPI receives grading plans, traffic frequencies and wheel loadings, if desired.

<table>
<thead>
<tr>
<th>Pavement Type</th>
<th>Anticipated Traffic Frequency</th>
<th>Asphaltic* Surface (in.)</th>
<th>Asphaltic* Base (in.)</th>
<th>Concrete* Thickness (in.)</th>
<th>Aggregate* Base (in.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexible Pavement</td>
<td>Heavy Duty</td>
<td>3.0</td>
<td>4.0</td>
<td>-</td>
<td>6.0</td>
</tr>
<tr>
<td></td>
<td>Light Duty</td>
<td>2.0</td>
<td>2.0</td>
<td>-</td>
<td>6.0</td>
</tr>
<tr>
<td>Rigid Pavement</td>
<td>Heavy Duty</td>
<td>-</td>
<td>-</td>
<td>7.0</td>
<td>4.0</td>
</tr>
<tr>
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<td>Light Duty</td>
<td>-</td>
<td>-</td>
<td>5.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

12.0 CONSTRUCTION OBSERVATION & TESTING

The construction process is an integral design component with respect to the geotechnical aspects of a project. Since geotechnical engineering is influenced by variable depositional and weathering processes and because we sample only a small portion of the soils affecting the performance of the proposed structures, unanticipated or changed conditions can be disclosed during grading. Proper geotechnical
observation and testing during construction is imperative to allow the Geotechnical Engineer the opportunity to evaluate assumptions made during the design process. Therefore, we recommend that PPI be kept apprised of design modifications and construction schedule of the proposed project to observe compliance with the design concepts and geotechnical recommendations, and to allow design changes in the event that subsurface conditions or methods of construction differ from those assumed while completing this study. We recommend that during construction all earthwork be monitored by a representative of PPI, including site preparation, placement of all engineered fill and trench backfill, and all foundation excavations as outlined below.

- An experienced Geotechnical Engineer or Engineering Technician of PPI should observe the subgrade throughout the proposed project site immediately following stripping to evaluate the native clay, identify areas requiring additional undercutting, and evaluate the suitability of the exposed surface for fill placement;

- An experienced Engineering Technician of PPI should monitor and test all fill placed within the building and pavement areas to determine whether the type of material, moisture content, and degree of compaction are within recommended limits;

- An experienced Technician or Engineer of PPI should observe and test all footing excavations. Where unsuitable bearing conditions are observed, remedial procedures can be established in the field to avoid construction delays; and

- The condition of the subgrade should be evaluated immediately prior to construction of the building floor slabs to determine whether the moisture content and relative density of the subgrade soils are as recommended.

13.0 REPORT LIMITATIONS

This report has been prepared in accordance with generally accepted practices of other consultants undertaking similar studies at the same time and in the same geographical area. Palmerton & Parrish, Inc. observed that degree of care and skill generally exercised by other consultants under similar circumstances and conditions. Palmerton &
Parrish’s findings and conclusions must be considered not as scientific certainties, but as opinions based on our professional judgment concerning the significance of the data gathered during the course of this investigation. Other than this, no warranty is implied or intended.
APPENDIX I

BORING LOGS & KEY TO SYMBOLS
**GEOTECHNICAL BORING LOG**

**CLIENT**  
O'Reilly Development Co., LLC.

**PROJECT NO.**  
240652

**DATE STARTED**  
12/30/16

**DATE COMPLETED**  
12/30/16

**DRILLER**  
MR

**DRILL RIG**  
2015 CME-55

**HAMMER TYPE**  
Auto

**LOGGED BY**  
BC

**CHECKED BY**  
SR

**SURFACE ELEVATION**  

**BENCHMARK EL.**  

**GROUND WATER LEVELS**  
None

**AT TIME OF DRILLING**  
None

**AT END OF DRILLING**  
Refusal at 8.5 feet.
Bottom of borehole at 8.5 feet.

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>DRILLING METHOD</th>
<th>STRATA SYMBOL</th>
<th>MATERIAL DESCRIPTION</th>
<th>UNIFIED SOIL CLASSIFICATION SYSTEM</th>
<th>SAMPLE TYPE NUMBER</th>
<th>RECOVERY % (ROD %)</th>
<th>CORRECTED BLOW COUNTS (N VALUE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td></td>
<td>TOPSOIL, Grass &amp; Leaf Covered 0.3 ft</td>
<td>LEAN CLAY, Trace Chert, Brown, Soft to Medium Stiff, Moist (CL)</td>
<td>SPT 1</td>
<td>1-4-8</td>
<td>1.5</td>
</tr>
<tr>
<td>0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
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<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SPT 2</td>
<td>32-55-63</td>
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<tr>
<td>3.0</td>
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<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SPT 3</td>
<td>28-69/4&quot;</td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BORING NUMBER**  
1

**PROJECT LOCATION**  
Lebanon, Missouri

**PROJECT NAME**  
New Tower Village

**CLIENT**  
O'Reilly Development Co., LLC.

**PROJECT NO.**  
240652

**TOPSOIL, Grass & Leaf Covered**

**LEAN CLAY, Trace Chert, Brown, Soft to Medium Stiff, Moist (CL)**
- Stiff Below 1.3'

**LEAN CLAY, Scattered Chert & Sand, Brown Tan Red, Stiff, Moist (CL)**

**FAT CLAY, Scattered Chert & Sand, Tan Gray, Stiff, Moist (CH)**
- Occasional Cobble Below 4.0'

**DOLOMITE, Cherty, Weathered**

**NOTES**

**DRY UNIT WT (pcf)**

**N VALUE**

**SHEAR STRENGTH (ksf)**

- Refusal at 8.5 feet.
- Bottom of borehole at 8.5 feet.
### Geotechnical Boring Log

**Boring Number:** 2

**Project Name:** New Tower Village

**Client:** O'Reilly Development Co., LLC.

**Project No.:** 240652

**Date Started:** 12/30/16

**Completed:** 12/30/16

**Surface Elevation:**

**Benchmark El.:**

**Driller:** MR

**Drill Rig:** 2015 CME-55

**Hammer Type:** Auto

**Logged By:** BC

**Checked By:** SR

**Notes:**

**Drilling Method:** CFA - 4.5" O.D.

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Material Description</th>
<th>Unified Soil Classification System</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>TOPSOIL, Wet</td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td>LEAN CLAY, Scattered Roots, Brown Gray, Medium Stiff, Moist (CL)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Stiff Below 1.5'</td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td>CLAYEY GRAVEL, Scattered Sand, Red Brown, Very Dense, Moist (GC)</td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td>FAT CLAY, Brown Tan, Medium Stiff, Moist (CH)</td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td>QUARTZOSE SANDSTONE</td>
<td></td>
</tr>
<tr>
<td>6.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Refusal at 8.5 feet.**

**Bottom of borehole at 6.8 feet.**

**Dry Unit WT (pcf):**

- 20
- 40
- 60
- 80
- 100

**N Value:**

- 20
- 40
- 60
- 80

**Shear Strength (ksf):**

- 1
- 2
- 3
- 4

**Recovery % (RQD %):**

- 69/4% 4.5
## Geotechnical Boring Log

**Boring Number**: 3

### Project Details
- **Client**: O'Reilly Development Co., LLC.
- **Project Name**: New Tower Village
- **Project No.**: 240652
- **Project Location**: Lebanon, Missouri
- **Date Started**: 1/18/17
- **Completed**: 1/18/17
- **Surficial Elevation**: __________
- **Ground Water Levels**: None
- **Drill Rig**: 2000 CME-1050
- **Hammer Type**: Auto
- **Logged By**: BS
- **Checked By**: SR
- **Driller**: MR
- **Ground Water Levels at Time of Drilling**: None
- **Notes**: Ground Water Levels at Time of Drilling: None

### Material Description

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Drilling Method</th>
<th>Stratification</th>
<th>Unified Soil Classification System</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td></td>
<td>TOPSOIL, Wet</td>
</tr>
<tr>
<td>0.7</td>
<td>SPT 1</td>
<td>SPT 1</td>
<td>0-4-5 (9)</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td>LEAN CLAY, Trace Chert, Tan Brown, Medium Stiff to Stiff, Moist (CL)</td>
</tr>
<tr>
<td>3.5</td>
<td></td>
<td></td>
<td>FAT CLAY, Scattered Chert, Tan Gray, Medium Stiff, Moist (CH)</td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td></td>
<td>CLAYEY GRAVEL, Sandy, Red Tan Gray, Dense, Moist (GC)</td>
</tr>
<tr>
<td>6.5</td>
<td></td>
<td></td>
<td>DOLOMITE, Sandy</td>
</tr>
<tr>
<td>6.5</td>
<td></td>
<td></td>
<td>Refusal at 6.5 feet. Bottom of borehole at 6.5 feet.</td>
</tr>
</tbody>
</table>

### Sample Type
- **Sample Type Number**: SPT 1, SPT 2
- **Recovery %**:
  - 0-4-5 (9)
  - 39-23-16 (39)
- **Corrected Blow Counts (N Value)**:
  - 2.5
  - 4.5

### Shear Strength (ksf)
- **PL**: 1
- **MC**: 2
- **LL**: 3

### Dry Unit WT (pcf)
- 20
- 40
- 60
- 80
- 100

**Boring Log - PPI - PPI STD TEMPLATE.GDT - 1/26/17 11:15 - S:\_MASTER PROJECT FILE\2016\MO\O\O'REILLY DEV CO-240652-TOWER VILLAGE-SUB\BORING LOGS\BORING LOGS.GPJ**

---

4168 W Kearney Street
Springfield, MO 65803
Telephone: 417-864-6000
Fax: 417-864-6004
CLIENT: O'Reilly Development Co., LLC.
PROJECT NO: 240652
PROJECT NAME: New Tower Village
PROJECT LOCATION: Lebanon, Missouri
DATE STARTED: 1/18/17
COMPLETED: 1/18/17
DRILLER: MR
DRILL RIG: 2000 CME-1050
HAMMER TYPE: Auto
LOGGED BY: BS
CHECKED BY: SR

SURFACE ELEVATION

GROUND WATER LEVELS
AT TIME OF DRILLING: None
AT END OF DRILLING

NOTES

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>MATERIAL DESCRIPTION</th>
<th>SAMPLE TYPE</th>
<th>RECOVERY % (RQD%)</th>
<th>CORRECTED BLOW COUNTS (N VALUE)</th>
<th>SHEAR STRENGTH (ksf)</th>
<th>DRY UNIT WT (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>TOPSOIL, Wet</td>
<td>SPT 1</td>
<td>0-1-4 (5)</td>
<td>0</td>
<td>▲ N VALUE ▲ 20 40 60 80</td>
<td>20 40 60 80 100</td>
</tr>
<tr>
<td>2.5</td>
<td>LEAN CLAY, Trace Chert, Tan Brown Red, Medium Stiff, Moist (CL)</td>
<td>SPT 2</td>
<td>16-20-31 (51)</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5</td>
<td>CLAYEY GRAVEL, Sandy, Tan Brown, Very Dense, Moist (GC)</td>
<td>SPT 3</td>
<td>14-13-7 (20)</td>
<td>4.5</td>
<td></td>
<td></td>
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<tr>
<td>10.0</td>
<td>FAT CLAY, Sandy, With Gravel, Tan Brown, Very Stiff, Moist (CH)</td>
<td>SPT 4</td>
<td>5-7-9 (16)</td>
<td>3.5</td>
<td></td>
<td></td>
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</table>

Bottom of borehole at 10.0 feet.
**Geotechnical Boring Log**

<table>
<thead>
<tr>
<th>BORING NUMBER</th>
<th>5</th>
</tr>
</thead>
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**Client**
O'Reilly Development Co., LLC.

**Project Name**
New Tower Village

**Project No.**
240652

**Date Started**
1/18/17

**Completed**
1/18/17

**Surface Elevation**

**Benchmark EL**

**Ground Water Levels**

**Drill Rig**
2000 CME-1050

**Driller**
MR

**Hammer Type**
Auto

**Logged By**
BS

**Checked By**
SR

**Notes**

---

**Drilling Method**

**Strata Symbol**

**Material Description**
Unified Soil Classification System

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Drilling Method</th>
<th>Strata Symbol</th>
<th>Material Description</th>
<th>Sample Type Number</th>
<th>Recovery % (RQD%)</th>
<th>Corrected Blow Counts (N Value)</th>
<th>Pocket Pen. (tsf)</th>
<th>Shear Strength (ksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td></td>
<td>TOPSOIL, Wet</td>
<td>SPT 1</td>
<td>3-7-10 (17)</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0</td>
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<td>LEAN CLAY, Trace Chert, Tan Brown Red, Stiff, Moist (CL)</td>
<td>SPT 2</td>
<td>30-29-25 (54)</td>
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</tr>
<tr>
<td>3.0</td>
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<td></td>
<td>FAT CLAY, Sandy, Scattered Chert, Tan Brown, Medium Stiff, Moist (CH)</td>
<td>SPT 3</td>
<td>29-65/4*</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td></td>
<td>CLAYEY GRAVEL, Scattered Sand, Tan Brown, Very Dense, Moist (GC)</td>
<td></td>
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</tbody>
</table>

---

**Refusal at 9.3 feet.**
Bottom of borehole at 9.3 feet.

**Boring Log - PPI - PPI STD TEMPLATE.GDT - 1/26/17 11:15 - S:\_MASTER PROJECT FILE\2016\MO\O\O'REILLY DEV CO-240652-TOWER VILLAGE-SUB\BORING LOGS\BORING LOGS.GPJ**

---

**Project Location**
Lebanon, Missouri

**Project Name**
New Tower Village

**Client**
O'Reilly Development Co., LLC.

**Project No.**
240652

**Address**
4168 W Kearney Street
Springfield, MO 65803
Telephone: 417-864-6000
Fax: 417-864-6004

---

**Topsoil, Wet**

**Lean Clay, Trace Chert, Tan Brown Red, Stiff, Moist (CL)**

**Fat Clay, Sandy, Scattered Chert, Tan Brown, Stiff, Moist (CH)**

**Clayey Gravel, Scattered Sand, Tan Brown, Very Dense, Moist (GC)**

**Dolomite, Cherty**
**GEOTECHNICAL BORING LOG**

**CLIENT**  O'Reilly Development Co., LLC.  
**PROJECT NO.**  240652  
**DATE STARTED**  1/18/17  
**COMPLETED**  1/18/17  
**DRILLER**  MR  
**DRILL RIG**  2000 CME-1050  
**PROJECT NAME**  New Tower Village  
**PROJECT LOCATION**  Lebanon, Missouri  
**LOGGED BY**  BS  
**CHECKED BY**  SR  

**SURFACE ELEVATION**  
**GROUND WATER LEVELS**  
**AT TIME OF DRILLING**  None  
**AT END OF DRILLING**  

**GROUND WATER LEVELS AT TIME OF DRILLING**  None

**MATERIAL DESCRIPTION**

- **TOPSOIL, Grass & Leaf Covered**
- **LEAN CLAY, Trace Gravel, Tan Brown Gray, Stiff, Moist (CL)**
- **GRAVELLY FAT CLAY, Tan Brown, Stiff, Moist (CH)**
- **FAT CLAY, Sandy, Scattered Chert, Tan Red, Stiff, Moist (CH)**

- With Chert Below 8.0'

**DRY UNIT WT (pcf)**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>0.7</th>
<th>2.0</th>
<th>3.5</th>
<th>10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pocket Pen. (tsf)</td>
<td>2.75</td>
<td>4.5</td>
<td>4.5</td>
<td>4.5</td>
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**RECOVERY % (RQD %)**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>0.7</th>
<th>2.0</th>
<th>3.5</th>
<th>10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPT 1</td>
<td>(13)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT 2</td>
<td>(14)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT 3</td>
<td>(20)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT 4</td>
<td>(31)</td>
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**N VALUE**

<table>
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<tr>
<th>Depth (ft)</th>
<th>0.7</th>
<th>2.0</th>
<th>3.5</th>
<th>10.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Blow Counts (N Value)</td>
<td></td>
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</table>

**SHEAR STRENGTH (ksf)**

<table>
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<th>Depth (ft)</th>
<th>0.7</th>
<th>2.0</th>
<th>3.5</th>
<th>10.0</th>
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</thead>
<tbody>
<tr>
<td>Drilled Pl</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field MC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**BENCHMARK EL.**  

**NOTES**

- Bottom of borehole at 10.0 feet.
## Boring Log - New Tower Village

### General Information
- **Client:** O'Reilly Development Co., LLC.
- **Project Name:** New Tower Village
- **Project Location:** Lebanon, Missouri
- **Project No.:** 240652
- **Date Started:** 1/18/17
- **Completed:** 1/18/17
- **Drill Rig:** 2000 CME-1050
- **Hammer Type:** Auto
- **Logged By:** BS
- **Checked By:** SR

### Drilling Method
- **Topsoil, Wet**
- **Lean Clay, Trace Chert, Tan Brown Gray, Stiff, Moist (CL)**
- **Lean Clay, Trace Chert, Red Brown, Medium Stiff, Moist (CL)**
- **Clayey Gravel, Scattered Sand, Tan Brown, Very Dense, Moist (GC)**
- **Fat Clay, Sandy, With Chert, Tan Red, Medium Stiff, Moist (CH)**
- **Clayey Gravel, Scattered Sand, Tan Brown, Very Dense, Moist (GC)**

### Ground Water Levels
- AT TIME OF DRILLING: None

### Geotechnical Boring Log

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Strat a Symbol</th>
<th>Material Description</th>
<th>Sample Type Number</th>
<th>Recovery % (RQD %)</th>
<th>Corrected Blow Counts (N Value)</th>
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</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td>Topsoil, Wet</td>
<td>SPT 1</td>
<td>3-3-7 (10)</td>
<td>1.5</td>
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<tr>
<td>0.7</td>
<td></td>
<td>Lean Clay, Trace Chert, Tan Brown Gray, Stiff, Moist (CL)</td>
<td>SPT 2</td>
<td>52-52-52 (104)</td>
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</tr>
<tr>
<td>1.5</td>
<td></td>
<td>Lean Clay, Trace Chert, Red Brown, Medium Stiff, Moist (CL)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td>Clayey Gravel, Scattered Sand, Tan Brown, Very Dense, Moist (GC)</td>
<td>SPT 3</td>
<td>7-7-16 (23)</td>
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</tr>
<tr>
<td>5.0</td>
<td></td>
<td>Clayey Gravel, Scattered Sand, Tan Brown, Very Dense, Moist (GC)</td>
<td>SPT 4</td>
<td>13-13-12 (25)</td>
<td></td>
</tr>
</tbody>
</table>

### Surface Elevation
- Surface Elevation: Le 4.25" I.D.

### Notes
- Bottom of borehole at 10.0 feet.
- *DRY UNIT WT (pcf)*
- *N VALUE* for PL, MC, LL
- *Recovery % (RQD %)*
- *Shear Strength (ksf)*
- *Recovery % (RQD %)*
<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>MATERIAL DESCRIPTION</th>
<th>DRILLING METHOD</th>
<th>STRATA SYMBOL</th>
<th>SAMPLE TYPE NUMBER</th>
<th>RECOVERY % (ROD %)</th>
<th>CORRECTED BLOW COUNTS (N VALUE)</th>
<th>POCKET PEN. (ft2)</th>
<th>DRY UNIT WT (pcf)</th>
<th>N VALUE</th>
<th>SHEAR STRENGTH (ksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>TOPSOIL, Grass &amp; Leaf Covered</td>
<td></td>
<td></td>
<td>SPT 1</td>
<td>1-5-9 (14)</td>
<td>1.5</td>
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<td></td>
<td>20</td>
<td>PL MC LL</td>
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<tr>
<td>0.5 ft</td>
<td>LEAN CLAY, Trace Chert, Brown, Medium Stiff, Moist (CL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>1.0 ft</td>
<td>LEAN TO FAT CLAY, Trace Chert, Red Brown, Stiff, Moist (CL-CH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>2.0 ft</td>
<td>FAT CLAY, With Chert, Tan Brown, Stiff, Moist (CH)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>3.5 ft</td>
<td>CLAYEY GRAVEL, Scattered Sand, Red Tan, Very Dense, Moist (GC)</td>
<td></td>
<td></td>
<td>SPT 2</td>
<td>36-36-36 (72)</td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>7.5 ft</td>
<td>Topsoil, Grass &amp; Leaf Covered</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>10.0 ft</td>
<td>Bottom of borehole at 10.0 feet.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td></td>
</tr>
</tbody>
</table>

- Dense Below 8.0'
<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>DRILLING METHOD</th>
<th>STRATA SYMBOL</th>
<th>MATERIAL DESCRIPTION</th>
<th>UNIFIED SOIL CLASSIFICATION SYSTEM</th>
<th>SAMPLE TYPE NUMBER</th>
<th>RECOVERY % (ROD %)</th>
<th>CORRECTED BLOW COUNTS (N VALUE)</th>
<th>DRY UNIT WT (pcf)</th>
<th>SHEAR STRENGTH (ksf)</th>
<th>RECOVERY %</th>
<th>N VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>TOPSOIL, Wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.8 ft</td>
<td>SPT 1</td>
<td></td>
<td>LEAN CLAY, Trace Gravel &amp; Roots, Tan Brown w/ Red Mottling, Stiff, Moist (CL)</td>
<td></td>
<td>1-3-5 (8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0 ft</td>
<td>SPT 2</td>
<td></td>
<td>FAT CLAY, With Chert, Tan Brown, Stiff, Moist (CH)</td>
<td></td>
<td>5-13-8 (21)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>5.0 ft</td>
<td>SPT 3</td>
<td></td>
<td>FAT CLAY, Sandy, Scattered Chert, Tan Red, Stiff, Moist (CH)</td>
<td>- With Chert Below 6.5’</td>
<td>5-8-13 (21)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.0 ft</td>
<td>SPT 4</td>
<td></td>
<td>CLAYEY GRAVEL, Scattered Sand, Tan Red, Medium Dense, Moist (GC)</td>
<td></td>
<td>5-7-65/5’</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.7 ft</td>
<td></td>
<td></td>
<td>DOLOMITE, Sandy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.9 ft</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Refusal at 9.8 feet.
Bottom of borehole at 9.9 feet.
## GEOTECHNICAL BORING LOG

**CLIENT**  
O'Reilly Development Co., LLC.

**PROJECT NO.**  
240652

**DATE STARTED**  
1/17/17

**COMPLETED**  
1/17/17

**PROJECT NAME**  
New Tower Village

**PROJECT LOCATION**  
Lebanon, Missouri

**DRILLER**  
MR

**DRILL RIG**  
2000 CME-1050

**HAMMER TYPE**  
Auto

**LOGGED BY**  
BS

**CHECKED BY**  
SR

**SURFACE ELEVATION**  
0.0 ft

**BENCHMARK EL.**  
0.0 ft

**GROUND WATER LEVELS**  
None

**AT TIME OF DRILLING**  
None

**AT END OF DRILLING**  
None

### NOTES

**GROUND WATER LEVELS**

- None

**RECOVERY %**

- 100%

**CORRECTED BLOW COUNTS (N VALUE)**

- 1-8 (14) = 3
- 3-8 (14) = 3.25
- 7-21-10 (31) =
- 6-3-6 (9) = 2

**RECOV. %**

- 100%

**SHEAR STRENGTH (ksf)**

- 1
- 2
- 3
- 4

**DRY UNIT WT (pcf)**

- 20
- 40
- 60
- 80

**N VALUE**

- 20
- 40
- 60
- 80

**PL**

- 1
- 2
- 3
- 4

**MC**

- 1
- 2
- 3
- 4

**LL**

- 1
- 2
- 3
- 4

**DRY UNIT WT (pcf)**

- 20
- 40
- 60
- 80

**N VALUE**

- 20
- 40
- 60
- 80

**PL**

- 1
- 2
- 3
- 4

**MC**

- 1
- 2
- 3
- 4

**LL**

- 1
- 2
- 3
- 4

### MATERIAL DESCRIPTION

- **TOPSOIL, Wet**
- **LEAN CLAY, Scattered Chert, Tan Brown, Medium Stiff to Stiff, Moist (CL)**
- **FAT CLAY, Trace Chert, Tan Brown, Stiff, Moist (CH)**
- **CLAYEY GRAVEL, Scattered Sand, Tan Red, Dense, Moist (GC)**
- **DOLOMITE, Cherty**

### BORING LOG

- **BORING NUMBER**  
10

- **PROJECT LOCATION**  
Lebanon, Missouri

- **PROJECT NAME**  
New Tower Village

- **CLIENT**  
O'Reilly Development Co., LLC.

- **PROJECT NO.**  
240652

- **DATE STARTED**  
1/17/17

- **COMPLETED**  
1/17/17

- **DRILLER**  
MR

- **DRILL RIG**  
2000 CME-1050

- **HAMMER TYPE**  
Auto

- **LOGGED BY**  
BS

- **CHECKED BY**  
SR

### MATERIAL DESCRIPTION

- **Unified Soil Classification System**

- **TOPSOIL, Wet**  
0.5 ft

- **LEAN CLAY, Scattered Chert, Tan Brown, Medium Stiff to Stiff, Moist (CL)**  
6.0 ft

- **FAT CLAY, Trace Chert, Tan Brown, Stiff, Moist (CH)**  
3.0 ft

- **CLAYEY GRAVEL, Scattered Sand, Tan Red, Dense, Moist (GC)**  
7.5 ft

- **FAT CLAY, Scattered Chert & Sand, Tan Brown, Stiff, Moist (CH)**  
8.0 ft

- **DOLOMITE, Cherty**  
10.0 ft

Bottom of borehole at 10.0 feet.
**Geotechnical Boring Log**

**Boring Number:** 11

**Client:** O'Reilly Development Co., LLC.

**Project Name:** New Tower Village

**Project No.:** 240652

**Date Started:** 12/30/16  
**Completed:** 12/30/16

**Driller:** MR  
**Drill Rig:** 2015 CME-55

**Hammer Type:** Auto

**Logged by:** BC  
**Checked by:** SR

**Surface Elevation:** 

**Benchmark El.:**

**Ground Water Levels:** None

**At Time of Drilling:**

**At End of Drilling:**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Drilling Method</th>
<th>Stratigraphic Symbol</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td>SPT 1</td>
<td>Topsoil, Wet</td>
</tr>
<tr>
<td>0.3</td>
<td></td>
<td>SPT 1</td>
<td>Lean Clay, Trace Gravel, Brown Gray, Medium Stiff to Stiff, Moist (CL)</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td>SPT 2</td>
<td>Fat Clay, Trace Chert, Tan Gray, Stiff, Moist (CH)</td>
</tr>
<tr>
<td>6.0</td>
<td></td>
<td>ST 3</td>
<td>Fat Clay, Sandy, Trace Chert, Tan Red Gray, Very Stiff, Moist (CH)</td>
</tr>
<tr>
<td>10.5</td>
<td></td>
<td>SPT 4</td>
<td>Dolomite, Sandy, Weathered</td>
</tr>
</tbody>
</table>

**Elevation (ft):**

- Refusal at 11.3 feet.

- Bottom of borehole at 11.3 feet.
CLIENT: O'Reilly Development Co., LLC.
PROJECT NAME: New Tower Village
PROJECT NO.: 240652
DATE STARTED: 1/17/17
COMPLETED: 1/17/17
SURFACE ELEVATION:  
BENCHMARK EL:  
GROUND WATER LEVELS:
AT TIME OF DRILLING: None
AT END OF DRILLING:  

LOGGED BY: BS
CHECKED BY: SR

DRILL RIG: 2000 CME-1050
HAMMER TYPE: Auto

DRILLER: MR

NOTES:

**MATERIAL DESCRIPTION**

Unified Soil Classification System

**DETAILED MATERIALS REPORT**

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>DRILLING METHOD</th>
<th>STRATA SYMBOL</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td></td>
<td>TOPSOIL, Wet</td>
</tr>
<tr>
<td>0.5 ft</td>
<td></td>
<td>SPT 1</td>
<td>LEAN CLAY, Trace Chert, Tan Brown, Soft, Moist (CL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- w/ Red Mottling, Medium Stiff Below 1.0'</td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
<td>FAT CLAY, Scattered Chert, Tan Brown, Stiff, Moist (CH)</td>
</tr>
<tr>
<td>3.0 ft</td>
<td></td>
<td>SPT 2</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.0 ft</td>
<td></td>
<td>SPT 3</td>
<td>FAT CLAY, Sandy, With Chert, Tan Red, Very Stiff, Moist (CH)</td>
</tr>
<tr>
<td>10.0 ft</td>
<td></td>
<td></td>
<td>Bottom of borehole at 10.0 feet.</td>
</tr>
</tbody>
</table>

**SURFACE ELEVATION**

**DATE STARTED**

**COMPLETED**

**DRILL RIG**

**HAMILER TYPE**

**LOGGED BY**

**CHECKED BY**

**DRILLER**

**NOTES**

**GROUND WATER LEVELS**

**AT TIME OF DRILLING**

**AT END OF DRILLING**

**SURFACE ELEVATION**

**BENCHMARK EL**

**GROUND WATER LEVELS**

**AT TIME OF DRILLING**

**AT END OF DRILLING**

**NOTES**

**MATERIAL DESCRIPTION**

Unified Soil Classification System

**DRILLING METHOD**

**STRATA SYMBOL**

**MATERIAL DESCRIPTION**

Unified Soil Classification System

**DETAILED MATERIALS REPORT**

<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>DRILLING METHOD</th>
<th>STRATA SYMBOL</th>
<th>MATERIAL DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td></td>
<td></td>
<td>TOPSOIL, Wet</td>
</tr>
<tr>
<td>0.5 ft</td>
<td></td>
<td>SPT 1</td>
<td>LEAN CLAY, Trace Chert, Tan Brown, Soft, Moist (CL)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>- w/ Red Mottling, Medium Stiff Below 1.0'</td>
</tr>
<tr>
<td>2.5</td>
<td></td>
<td></td>
<td>FAT CLAY, Scattered Chert, Tan Brown, Stiff, Moist (CH)</td>
</tr>
<tr>
<td>3.0 ft</td>
<td></td>
<td>SPT 2</td>
<td></td>
</tr>
<tr>
<td>5.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.0 ft</td>
<td></td>
<td>SPT 3</td>
<td>FAT CLAY, Sandy, With Chert, Tan Red, Very Stiff, Moist (CH)</td>
</tr>
<tr>
<td>10.0 ft</td>
<td></td>
<td></td>
<td>Bottom of borehole at 10.0 feet.</td>
</tr>
</tbody>
</table>
**Geotechnical Boring Log**

**Client:** O'Reilly Development Co., LLC.  
**Project No.:** 240652  
**Project Name:** New Tower Village  
**Project Location:** Lebanon, Missouri  
**Date Started:** 12/30/16  
**Completed:** 12/30/16  
**Driller:** MR  
**Drill Rig:** 2015 CME-55  
**Hammer Type:** Auto  
**Logged By:** BC  
**Checked By:** SR  
**Drill Rig:** 2015 CME-55  
**Ground Water Levels:** None  
**At Time of Drilling:** None  
**At End of Drilling:** None  
**Notes:**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Drilling Method</th>
<th>Strat Symbol</th>
<th>Material Description</th>
<th>Unified Soil Classification System</th>
<th>Sample Type Number</th>
<th>Recovery % (RoD %)</th>
<th>Corrected Blow Counts (N Value)</th>
<th>Pocket Pen. (lbs)</th>
<th>Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>Topsoil, Wet</td>
<td>Unified Soil Classification System</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td>SPT 1</td>
<td>Lean clay, Trace Chert, Brown, Stiff, Moist (CL)</td>
<td>Unified Soil Classification System</td>
<td>SPT 1</td>
<td>3-8-8</td>
<td>3.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.0</td>
<td></td>
<td></td>
<td>Lean clay, Scattered Chert, Brown Tan, Stiff, Moist (CL)</td>
<td>Unified Soil Classification System</td>
<td>SPT 1</td>
<td>3-8-8</td>
<td>3.25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0</td>
<td></td>
<td></td>
<td>Fat clay, Scattered Chert, Tan Brown Gray, Stiff, Moist (CH)</td>
<td>Unified Soil Classification System</td>
<td>SPT 2</td>
<td>4-7-7</td>
<td>4.5</td>
<td></td>
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</tr>
</tbody>
</table>

Bottom of borehole at 5.0 feet.
GEOTECHNICAL BORING LOG

BORING LOG - PPI - PPI STD TEMPLATE.GDT - 1/26/17 11:15 - S:\_MASTER PROJECT FILE\2016\MO\O\O'REILLY DEV CO-240652-TOWER VILLAGE-SUB\BORING LOGS\BORING LOGS.GPJ

CLIENT  O'Reilly Development Co., LLC.  PROJECT NAME  New Tower Village
PROJECT NO.  240652  PROJECT LOCATION  Lebanon, Missouri
DATE STARTED  1/18/17  COMPLETED  1/18/17  SURFACE ELEVATION  
GROUND WATER LEVELS  AT TIME OF DRILLING  None
HAMMER TYPE  Auto  DRILL RIG  2000 CME-1050
LOGGED BY  BS  CHECKED BY  SR

DRILLING METHOD  
TOPSOIL, Wet 
LEAN CLAY, Trace Chert, Tan Brown Gray, Medium Stiff, Moist (CL)  0.5 ft  SPT 1  1-3-4 (7)  1.5
LEAN CLAY, Trace Chert, Red Tan, Medium Stiff, Moist (CL)  1.0 ft
LEAN CLAY, Trace Chert, Red Tan, Medium Stiff, Moist (CL)  2.0 ft
FAT CLAY, Scattered Chert, Red Tan, Medium Stiff, Moist (CH)  3.5 ft
CLAYEY GRAVEL, Red Tan, Very Dense, Moist (GC)  5.0 ft

Bottom of borehole at 5.0 feet.

BENCHMARK EL.  
N VALUE  
DRY UNIT WT (pcf)  
SHEAR STRENGTH (ksf)  
RECOVERY % (RQD %)  
CORRECTED BLOW COUNTS (N VALUE)  
POCKET PEN. (tsf)  

GEOLOGY

- Topsoil, wet
- Lean clay, trace chert, tan brown gray, medium stiff, moist (CL)
- Lean clay, trace chert, red tan, medium stiff, moist (CL)
- Fat clay, scattered chert, red tan, medium stiff, moist (CH)
- Clayey gravel, red tan, very dense, moist (GC)

Bottom of borehole at 5.0 feet.
<table>
<thead>
<tr>
<th>DEPTH (ft)</th>
<th>DRILLING METHOD</th>
<th>STRATA SYMBOL</th>
<th>MATERIAL DESCRIPTION</th>
<th>SAMPLE TYPE NUMBER</th>
<th>RECOVERY % (ROD %)</th>
<th>CORRECTED BLOW COUNTS (N VALUE)</th>
<th>POCKET PEN. (tsf)</th>
<th>SHEAR STRENGTH (ksf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>TOPSOIL, Wet</td>
<td></td>
<td></td>
<td></td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td></td>
<td>LEAN CLAY, Trace Chert, Red Tan Brown, Medium Stiff to Stiff, Moist (CL)</td>
<td>SPT 1</td>
<td>0-3-8</td>
<td>(11)</td>
<td>4.5</td>
<td>n/a</td>
</tr>
<tr>
<td>2.0</td>
<td></td>
<td></td>
<td>CLAYEY GRAVEL, Scattered Sand, Brown Tan, Very Dense, Moist (GC)</td>
<td></td>
<td></td>
<td></td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Bottom of borehole at 5.0 feet.
### LITHOLOGIC SYMBOLS
(Unified Soil Classification System)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>CH</td>
<td>USCS High Plasticity Clay</td>
</tr>
<tr>
<td>Gravelly Fat Clay</td>
<td>USCS High Plasticity Clay</td>
</tr>
<tr>
<td>CL</td>
<td>USCS Low Plasticity Clay</td>
</tr>
<tr>
<td>CL-CH</td>
<td>USCS Low to High Plasticity Clay</td>
</tr>
<tr>
<td>DOLOMITE</td>
<td></td>
</tr>
<tr>
<td>GC</td>
<td>USCS Clayey Gravel</td>
</tr>
<tr>
<td>SANDSTONE</td>
<td>Sandstone</td>
</tr>
<tr>
<td>TOPSOIL</td>
<td>Topsoil</td>
</tr>
</tbody>
</table>

### Sampler Symbols

- Standard Penetration Test
- Shelby Tube

### Well Construction Symbols

- Water Level at Time Drilling, or as Shown
- Water Level at End of Drilling, or as Shown
- Water Level After 24 Hours, or as Shown

### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>LL</td>
<td>LIQUID LIMIT (%)</td>
</tr>
<tr>
<td>PI</td>
<td>PLASTIC INDEX (%)</td>
</tr>
<tr>
<td>W</td>
<td>MOISTURE CONTENT (%)</td>
</tr>
<tr>
<td>DD</td>
<td>DRY DENSITY (PCF)</td>
</tr>
<tr>
<td>NP</td>
<td>NON PLASTIC</td>
</tr>
<tr>
<td>-200</td>
<td>PERCENT PASSING NO. 200 SIEVE</td>
</tr>
<tr>
<td>PP</td>
<td>POCKET PENETROMETER (TSF)</td>
</tr>
<tr>
<td>TV</td>
<td>TORVANE</td>
</tr>
<tr>
<td>PID</td>
<td>PHOTOIONIZATION DETECTOR</td>
</tr>
<tr>
<td>UC</td>
<td>UNCONFINED COMPRESSION</td>
</tr>
<tr>
<td>ppm</td>
<td>PARTS PER MILLION</td>
</tr>
</tbody>
</table>

**Project Information**

- **Client**: O'Reilly Development Co., LLC.
- **Project Name**: New Tower Village
- **Project No.**: 240652
- **Project Location**: Lebanon, Missouri

**Address**

4168 W Kearney Street
Springfield, MO 65803
Telephone: 417-864-6000
Fax: 417-864-6004
SOIL PROPERTIES & DESCRIPTIONS

COHESIVE SOILS

<table>
<thead>
<tr>
<th>Consistency</th>
<th>Unconfined Compressive Strength (Qu) (psf)</th>
<th>Pocket Penetrometer Strength (tsf)</th>
<th>N-Value (blows/ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Soft</td>
<td>&lt;500</td>
<td>&lt;0.25</td>
<td>0-1</td>
</tr>
<tr>
<td>Soft</td>
<td>500-1000</td>
<td>0.25-0.50</td>
<td>2-4</td>
</tr>
<tr>
<td>Medium Stiff</td>
<td>1001-2000</td>
<td>0.50-1.00</td>
<td>5-8</td>
</tr>
<tr>
<td>Stiff</td>
<td>2001-4000</td>
<td>1.00-2.00</td>
<td>9-15</td>
</tr>
<tr>
<td>Very Stiff</td>
<td>4001-8000</td>
<td>2.00-4.00</td>
<td>16-30</td>
</tr>
<tr>
<td>Hard</td>
<td>&gt;8000</td>
<td>&gt;4.00</td>
<td>31-60</td>
</tr>
<tr>
<td>Very Hard</td>
<td></td>
<td></td>
<td>&gt;60</td>
</tr>
</tbody>
</table>

**Group Symbol**

**Group Name**

- CL – Lean Clay
- ML – Silt
- OL – Organic Clay or Silt
- CH – Fat Clay
- MH – Elastic Silt
- OH – Organic Clay or Silt
- PT – Peat
- CL-CH – Lean to Fat Clay

**Plasticity**

- Lean
- Lean to Fat
- Fat

**Moisture**

- Liquid Limit (LL)
- Descriptive Term
- Guide

<table>
<thead>
<tr>
<th>Plasticity</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lean</td>
<td>&lt;45%</td>
</tr>
<tr>
<td>Lean to Fat</td>
<td>45-49%</td>
</tr>
<tr>
<td>Fat</td>
<td>≥50%</td>
</tr>
</tbody>
</table>

Fine Grained Soil Subclassification

Terms: SILT, LEAN CLAY, FAT CLAY, ELASTIC SILT

Sandy, gravelly, abundant cobbles, abundant boulders
with sand, with gravel, with cobbles, with boulders
scattered sand, scattered gravel, scattered cobbles, scattered boulders
a trace sand, a trace gravel, a few cobbles, a few boulders

Primary Constituent

- >30-50 [Secondary coarse grained constituents]
- >15-30 [%]
- 5-15 [%]
- <5 [%]

Silty (MH & ML)*, clayey (CL & CH)*
(with silt, with clay)*
(trace silt, trace clay)*

The relationship of clay and silt constituents is based on plasticity and normally determined by performing index tests. Refined classifications are based on Atterberg Limits tests and the Plasticity Chart.

NON-COHESIVE (GRANULAR) SOILS

**Grain Size Identification**

<table>
<thead>
<tr>
<th>Name</th>
<th>Size Limits</th>
<th>Familiar Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>12 in. or more</td>
<td>Larger than basketball</td>
</tr>
<tr>
<td>Coarse Gravel</td>
<td>3 in. to 12 in.</td>
<td>Grapefruit</td>
</tr>
<tr>
<td>Fine Gravel</td>
<td>¾-in. to 3 in.</td>
<td>Orange or lemon</td>
</tr>
<tr>
<td>Coarse Sand</td>
<td>No. 4 sieve to ¾-in.</td>
<td>Grape or pea</td>
</tr>
<tr>
<td>Medium Sand</td>
<td>No. 10 sieve to No. 6</td>
<td>Rock salt</td>
</tr>
<tr>
<td>Fine Sand*</td>
<td>No. 200 sieve to No. 40</td>
<td>Sugar, table salt</td>
</tr>
<tr>
<td>Fines</td>
<td>Less than No. 200</td>
<td>Powdered sugar</td>
</tr>
</tbody>
</table>

Terms: GRAVEL, SAND, COBBLES, BOULDERS

Sandy, gravelly, abundant cobbles, abundant boulders
with gravel, with sand, with cobbles, with boulders
scattered gravel, scattered sand, scattered cobbles, scattered boulders
a trace gravel, a trace sand, a few cobbles, a few boulders

Primary Constituent

- >30-50 [%]
- >15-30 [%]
- 5-15 [%]
- <5 [%]

Particles finer than fine sand cannot be discerned with the naked eye at a distance of 8 in.

*Index tests and/or plasticity tests are performed to determine whether the term “silt” or “clay” is used.

**Modified after Ref. ASTM D2487-93 & D2488-93

**Modified after Ref. Oregon DOT 1987 & FHWA 1997

***Modified after Ref. AASHTO 1988, DM 7.1 1982, and Oregon DOT 1987
GENERAL NOTES

BEDROCK PROPERTIES & DESCRIPTIONS

ROCK QUALITY DESIGNATION (RQD)

<table>
<thead>
<tr>
<th>Description of Rock Quality</th>
<th>RQD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Poor</td>
<td>&lt; 25</td>
</tr>
<tr>
<td>Poor</td>
<td>25-50</td>
</tr>
<tr>
<td>Fair</td>
<td>50-75</td>
</tr>
<tr>
<td>Good</td>
<td>75-90</td>
</tr>
<tr>
<td>Excellent</td>
<td>90-100</td>
</tr>
</tbody>
</table>

*RQD is defined as the total length of sound core pieces 4 in. or greater in length, expressed as a percentage of the total length cored. RQD provides an indication of the integrity of the rock mass and relative extent of seams and bedding planes.

SCALE OF RELATIVE ROCK HARDNESS

<table>
<thead>
<tr>
<th>Term</th>
<th>Field Identification</th>
<th>Approx. Unconfined Compressive Strength (tsf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Soft</td>
<td>Can be indented by thumbnail</td>
<td>2-6-10</td>
</tr>
<tr>
<td>Very Soft</td>
<td>Can be peeled by pocket knife</td>
<td>10-50</td>
</tr>
<tr>
<td>Soft</td>
<td>Can be peeled with difficulty by pocket knife</td>
<td>50-260</td>
</tr>
<tr>
<td>Medium Hard</td>
<td>Can be grooved 2 mm deep by firm pressure of knife</td>
<td>260-520</td>
</tr>
<tr>
<td>Moderately Hard</td>
<td>Requires one hammer blow to fracture</td>
<td>520-1040</td>
</tr>
<tr>
<td>Hard</td>
<td>Can be scratched with knife or pick only with difficulty</td>
<td>1040-2610</td>
</tr>
<tr>
<td>Very Hard</td>
<td>Cannot be scratched by knife or sharp pick</td>
<td>&gt;2610</td>
</tr>
</tbody>
</table>

DEGREE OF WEATHERING

<table>
<thead>
<tr>
<th>Degree of Weathering</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly Weathered</td>
<td>Rock generally fresh, joints stained and discoloration extends into rock up to 25 mm (1 in.), open joints may contain clay, core rings under hammer impact.</td>
</tr>
<tr>
<td>Weathered</td>
<td>Rock mass is decomposed 50% or less, significant portions of rock show discoloration and weathering effects, cores cannot be broken by hand or scraped by knife.</td>
</tr>
<tr>
<td>Highly Weathered</td>
<td>Rock mass is more than 50% decomposed, complete discoloration of rock fabric, core may be extremely broken and gives clunk sound when struck by hammer, may be shaved with a knife.</td>
</tr>
</tbody>
</table>

GRAIN SIZE (TYPICALLY FOR SEDIMENTARY ROCKS)

<table>
<thead>
<tr>
<th>Description</th>
<th>Diameter (mm)</th>
<th>Field Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Coarse Grained</td>
<td>&gt;4.76</td>
<td>Individual grains can easily be distinguished by eye.</td>
</tr>
<tr>
<td>Coarse Grained</td>
<td>2.0-4.76</td>
<td>Individual grains can be distinguished by eye.</td>
</tr>
<tr>
<td>Medium Grained</td>
<td>0.42-2.0</td>
<td>Individual grains can be distinguished by eye.</td>
</tr>
<tr>
<td>Fine Grained</td>
<td>0.047-0.42</td>
<td>Individual grains cannot be distinguished by unaided eye.</td>
</tr>
<tr>
<td>Very Fine Grained</td>
<td>&lt;0.074</td>
<td></td>
</tr>
</tbody>
</table>

VOIDS & BEDDING THICKNESS

<table>
<thead>
<tr>
<th>Voids</th>
<th>Description</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pit</td>
<td>Voids barely seen with naked eye to 6 mm (¼-in)</td>
<td></td>
</tr>
<tr>
<td>Vug</td>
<td>Voids 6 to 50 mm (¼ to 2-in) in diameter</td>
<td></td>
</tr>
<tr>
<td>Cavity</td>
<td>50 to 6000 mm (2 to 24-in) in diameter</td>
<td></td>
</tr>
<tr>
<td>Cave</td>
<td>&gt;6000 mm</td>
<td></td>
</tr>
<tr>
<td>Thick Bedded</td>
<td>&gt; 3” thick</td>
<td></td>
</tr>
<tr>
<td>Medium Bedded</td>
<td>1” to 3” thick</td>
<td></td>
</tr>
<tr>
<td>Thin Bedded</td>
<td>4” to 1” thick</td>
<td></td>
</tr>
<tr>
<td>Very Thin Bedded</td>
<td>½” to ½” thick</td>
<td></td>
</tr>
<tr>
<td>Thickly Laminated</td>
<td>⅛” to ⅛” thick</td>
<td></td>
</tr>
<tr>
<td>Thinly Laminated</td>
<td>⅛” or less (paper thin)</td>
<td></td>
</tr>
</tbody>
</table>

DRILLING NOTES

Drilling and Sampling Symbols

- NQ – Rock Core (2-in. diameter)
- HQ – Rock Core (3-in. diameter)
- HSA – Hollow Stem Auger
- CFA – Continuous Flight (Solid Stem) Auger
- SS – Split Spoon Sampler
- ST – Shelby Tube
- WB – Wash Bore or Mud Rotary
- TP – Test-Pit
- HA – Hand Auger

Soil Sample Types

- Shelby Tube Samples: Relatively undisturbed soil samples were obtained from the borings using thin wall (Shelby) tube samplers pushed hydraulically into the soil in advance of drilling. This sampling, which is considered to be undisturbed, was performed in accordance with the requirements of ASTM D 1587. This type of sample is considered best for the testing of “in-situ” soil properties such as natural density and strength characteristics. The use of this sampling method is basically restricted to soil containing little to no chert fragments and to softer shale deposits.

- Split Spoon Samples: The Standard Penetration Test is conducted in conjunction with the split-barrel sampling procedure. The “N” value corresponds to the number of blows required to drive the last foot of an 18-in. long, 2-in. O.D. split-barrel sampler with a 140 lb. hammer falling a distance of 30 in. The Standard Penetration Test is carried out according to ASTM D-1586.

Water Level Measurements

Water levels indicated on the boring logs are levels measured in the borings at the times indicated. In permeable materials, the indicated levels may reflect the location of groundwater. In low permeability soils, shallow groundwater may indicate a perched condition. Caution is merited when interpreting short-term water level readings from open bore holes. Accurate water levels are best determined from piezometers.

Automatic Hammer

Palmerton and Parrish’s CME’s are equipped with automatic hammers. The conventional method used to obtain disturbed soil samples used a safety hammer operated by company personnel with a cat head and rope. However, use of an automatic hammer allows a greater mechanical efficiency to be achieved in the field while performing a Standard Penetration resistance test based upon automatic hammer efficiencies calibrated using dynamic testing techniques.

*Modified after Ref. ASTM D2487-93 & D2488-93
**Modified after Ref. Oregon DOT 1987 & FHWA 1997
***Modified after Ref. AASHTO 1988, DM 7.1 1982, and Oregon DOT 1987
APPENDIX III

IMPORTANT INFORMATION REGARDING YOUR GEOTECHNICAL REPORT
Important Information about Your Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

While you cannot eliminate all such risks, you can manage them. The following information is provided to help.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared solely for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. And no one—not even you—should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client’s goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:
- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:
- the function of the proposed structure, as when it’s changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, always inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. Do not rely on a geotechnical engineering report whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. Always contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report’s Recommendations Are Not Final

Do not overly rely on the construction recommendations included in your report. Those recommendations are not final, because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual
subsurface conditions revealed during construction. The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.

**A Geotechnical Engineering Report Is Subject to Misinterpretation**

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

**Do Not Redraw the Engineer's Logs**

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

**Give Contractors a Complete Report and Guidance**

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, but place it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited. Encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

**Read Responsibility Provisions Closely**

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled “limitations” many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. Read these provisions closely. Ask questions. Your geotechnical engineer should respond fully and frankly.

**Geoenvironmental Concerns Are Not Covered**

The equipment, techniques, and personnel used to perform a geoenvironmental study differ significantly from those used to perform a geotechnical study. For that reason, a geotechnical engineering report does not usually relate any environmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Unanticipated environmental problems have led to numerous project failures. If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. Do not rely on an environmental report prepared for someone else.

**Obtain Professional Assistance To Deal with Mold**

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the express purpose of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.

**Rely, On Your ASFE-Member Geotechnical Engineer for Additional Assistance**

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you ASFE-member geotechnical engineer for more information.