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August 8, 2019

Drexel, Barrell & Co.
1800 38th Street
Boulder, CO 80301

Attn: Mr. Derek Schuler, P.E, PTOE
Transportation Group Leader

RE: **Geotechnical Engineering Addendum No. 1 – Pavement Thickness Design**
144th Avenue Widening and Improvements
East 144th Avenue between York Street & Colorado Boulevard
Thornton, Colorado
CGG Project No. 18.22.099

We previously prepared a Geotechnical Engineering Report (GER) for improvements to an approximately 5,250 lineal feet portion of East 144th Avenue east of York Street and west of Colorado Boulevard in Thornton, Colorado (CGG Project No. 18.22.099, report date June 20, 2018). This addendum letter provides recommendations regarding revised pavement thickness design and responses to comments from the City of Thornton Engineering department. Other recommendations as provided in the GER's should be followed.

- **Revised Pavement Sections:** We understand that, following discussion with the project team including the Client and the City of Thornton, the original pavement thickness design for rehabilitated pavement sections (following a mill of the existing) would not match existing curb and gutter elevations for a significant portion of the alignment to be rehabilitated. The following pavement thickness design has been communicated to the design team and the City of Thornton in April of 2019. We understand that rehabilitation will be performed west of Madison Street and full-depth reconstruction will be performed east of Madison Street. The revised pavement sections also reflect updated traffic volumes provided by the Client. The calculations for all revised pavement sections are attached.

  - **Revised Design Traffic Values:** Design traffic values, used to determine pavement thickness are defined as 18-kip equivalent daily load applications ($EDLA_{20}$) and 18-kip equivalent single axle loads ($ESAL_{20}$) based on a 20-year design, per the Standards. The pavement rehabilitation alternatives were developed to provide a 20-year design life. We understand that proposed public roadway within the alignment are to be re-classified Minor Arterial Streets with four (4) lanes of travel, per the City of Thornton Transportation Plan 2009. The following presents updated design traffic values, as provided to our office by Drexel, Barrell & Co. The original values were determined from Table 500-4 of the Standards.

Traffic Value	Design Values	Revised Design Traffic Values
Minor Arterial $EDLA_{20}$	465	120
Minor Arterial $ESAL_{20}$	3,394,500	873,845

- **Pavement Rehabilitation (West of Madison Street)**: Rehabilitation of existing pavement sections will consist of a 2-inch mill and overlay in order to match the existing crown and curb and gutter elevations. In order to achieve this, the use of an interlayer product (Tensar GlasPave or equivalent) is recommended to reduce the potential for reflexive cracking. GlasPave should be installed on the milled surface (with asperity depth less than ½-inch) after application of a tack coat (PG 64-22 as recommended in the report and by Tensar). Pre-existing cracks greater than ¼-inch should be filled with a crack sealant and potholes should be repaired prior to placement. GlasPave will reduce reflective cracking and act as a moisture-barrier, thereby extending the pavement life and reducing moisture infiltration to the base and subgrade. A 2-inch mill and overlay is sufficient for an average existing asphalt thickness of 12 inches remaining after mill when utilizing PG 64-22, fiber-reinforced asphalt. Please refer to the attached calculations for more detail. A comparison of the use of fiber-reinforced asphalt to standard hot-mix asphalt is included.

- **Pavement Reconstruction (East of Madison Street)**: Using the correlated design M_R value and the $EDLA_{20}/ESAL_{20}$ value outlined above, the required structural number (SN) for the proposed Public Streets was determined using the appropriate design Nomographs provided by CDOT and AASHTO. Other factors utilized for design included a drainage coefficient of 1.0, a reliability of 90 percent, a standard deviation of 0.44, and a serviceability loss of 2.5. Using these values, a minimum Structural Number (Design SN) of 5.43 was calculated using the AASHTO equations. The following table summarizes the recommended pavement sections.

Traffic Area	Alt.	Pavement Section Thickness (Inches)			
		Asphalt Concrete Surface Fiber-Reinforced	Aggregate Base Course	Portland Cement Concrete	Total
Minor Arterial ***East 144th Avenue (E. of Madison St) Reconstruction*** $ESAL_{20}$=873,845	A	6	10	--	16
	B	9	--	--	12-½
	C	--	--	9-½	9-½

- **Responses to City Comments**: The following is a summary of our responses to comments made by the City of Thornton Engineering Department to the 90% plans submitted by Drexel, Barrell & Co. We are open to ongoing discussion with the project team on the following items:

- *Aggregate base course beneath new curb and gutter (Sheet TS01):* We recommended in our report that aggregate base course (ABC) should extend to back-of-curb and attached walks when utilizing composite pavement sections in addition to perforating stormwater inlets. Aggregate base course *should not be utilized* beneath new curb and gutter abutting full-depth pavement sections, as shown on Sheet TS01. We agree with the City that the presence of base course here would increase the likelihood that surface water may become trapped beneath these features and cause premature distress of the curb and gutter and edge of the pavement sections. We should aim to reduce the potential for surface water to infiltrate beneath the pavement and curb and gutter. Care should be given that compaction behind the curb be completed sufficiently so as to reduce this potential.

- *HMA sidewalk performance-graded binder selection (Sheet TS02):* We have recommended the use of PG 64-22 asphalt binder for all hot-mix asphalt (HMA) pavements at the site including as a tack coat prior to installation of the interlayer Tensar GlasPave. The provided plans also specify the use of PG 64-22 for HMA sidewalks, typical. However, we understand that the Colorado Asphalt Pavement Association (CAPA) has recommended the use of a different performance-graded binder on a similar nearby project (Trails). If the City has had positive experience utilizing a different HMA binder for similar uses (HMA sidewalks), we do not take exception, provided we have had a chance to review the specifications. PG 64-22 binder should be utilized for public roadway improvements and as a tack coat for rehabilitation interlayer products, as recommended by the manufacturers.

- *Subgrade preparation beneath widened lanes (Sheet SQ01):* The design pavement sections have changed substantially since submittal of our design report on June 20, 2018. In the original report, we recommended overexcavation of the shoulders in preparation of construction of new travel lanes in both directions and pavement subgrade beneath reconstructed sections to a depth of 3 feet below proposed pavement sections. In general terms, the clay samples obtained between York Street and Madison Street exhibited higher expansive potential. Because of the limited sampling and testing east of Madison Street, we believe it is prudent to expect similar subgrade soils are present there as well.

  The use of full-depth sections for new travel lanes adjacent to rehabilitated pavement sections will likely help prevent infiltration of moisture beneath the existing pavements. However, full-depth sections adjacent to a rehabilitated pavement or to a fully reconstructed pavement does not preclude heave due to expansive soils. Even low expansive materials may heave upon additional wetting, potentially resulting in pavement distress and other movement causing common cosmetic distress such as edge cracking, uneven curb and gutter, etc.

  Therefore, we believe that overexcavation of the up to highly expansive clayey fill soils is warranted wherever this process is feasible given other site constraints (active travel lanes, existing underground utilities, etc.). Where existing utilities prevent completing the subexcavation

to the recommended extents, we recommend the contractor complete subexcavation to within a safe distance of such facilities. The remaining materials over and around the existing utility should be evaluated by the geotechnical engineer in order to confirm or modify our recommendations as needed. At a minimum, we recommend subgrade be scarified to a depth of 12 inches, moisture conditioned and recompacted. Additional samples could be obtained by manual methods during construction to determine if expansive soil mitigation is warranted.

- *Lower road profile (Sheet PP06):* This section is within the portion of the alignment to be rehabilitated with a 2-inch mill and overlay. Lowering the road profile relative to the existing road profile will require milling greater than 2 inches of existing asphalt. Care should be taken to maintain as much of the existing asphalt profile as possible in order to meet our design recommendations. The profile must also meet existing curb and gutter elevations, if present.

- *Subgrade preparation beneath Signal Ditch box culvert (Sheets ST01 and IR06):* At the time of exploration, it was not known that the existing drainage culverts would be required to be replaced/modified. Thus, earthwork recommendations and foundation design for the Signal Ditch box culvert and the box culvert extension at Station 34+75 were not included in the scope of services of our geotechnical investigation. We understand that a culvert extension will be added to the existing culvert located at Station 34+75 and that the Signal Ditch box culvert will be replaced.

  Based on the limited information available from our borings, we believe that native sandy lean clay, clayey to silty sand, or interbedded claystone to sandstone bedrock will likely be exposed at the base of all proposed box culvert and wing wall foundations. Based on the provided plans, the base of the box culvert extension will be approximately 12 to 15 feet below proposed site pavements. As indicated by a majority of our deeper borings, sedimentary bedrock is likely present at these depths. However, we also have data for this portion of the alignment that indicates that soft sandy lean clay soils could be present at these depths in this area. ***These materials will likely require mitigation for support of the extension.***

  The base of the Signal Ditch culvert and its associated wing walls will be approximately 7-½ feet below proposed site pavements. Claystone to sandstone bedrock is present at a depth of about 8 feet below existing grades on this portion of the alignment. The bedrock materials will likely provide sufficient bearing for the proposed box culvert, embankment, and wing walls, as proposed. ***It should be noted that we do not have borings that extend sufficiently beneath proposed foundation depths located within close proximity to either of the culverts.***

  We understand that the proposed box culverts will be founded upon bedding consisting of about 12 inches of CDOT Class 6 Aggregate Base Course (ABC). ***We believe it is prudent to budget and schedule for stabilization of the subgrade soils below the box culverts in order to provide for a stable subgrade over which to compact the road base.*** Stabilization can usually be economically

achieved by compacting larger crushed aggregate or rip-rap into the unstable soils until a stable base develops. In our experience, crushed rock or recycled concrete materials on the order of 3 to 6 inches in size would be effective in most situations. Depending upon subgrade conditions encountered during construction, consideration can also be given to providing geotextile layer(s) beneath box culverts or head and wing walls. ***We should be contacted during excavation in order to provide further guidance regarding subgrade stabilization at the site.***

Provided that a stable base is provided below foundations, we estimate that spread footing foundations will provide acceptable support for the proposed structures. For this site, footings and foundation walls should be designed to accommodate total foundation movement on the order of 1-½ inches. If further limiting movement is desired, we should be contacted to provide for deep foundation recommendations.

The following foundation design criteria may be used for the structural design of foundations at the site.

Criteria	**Design Value**
Bearing Strata	Approved, stabilized native soils or bedrock
Maximum net allowable bearing pressure[1]	2,000 psf
Min. depth below grade, exterior wall footings[2]	36 inches
Estimated maximum total foundation movement[3]	1-½ inches

1. The design bearing pressure above applies to dead loads plus design live load conditions. The design bearing pressure may be increased by 1/3 when considering total loads that include wind or seismic conditions.
2. Finished grade is the lowest adjacent grade for footings.

The engineer should evaluate foundation subgrade soils in order to confirm or modify our recommendations for the bearing soils. ***All subgrade soils below new fill, foundations, and pavements should be scarified to a minimum depth of 12 inches, moisture conditioned and compacted as discussed below just prior to construction of these elements to ensure that moisture loss due to drying has been minimized.***

We hope that this meets your needs at the current time. We have appreciated being of service to you in the geotechnical engineering phase of this project, and are prepared to assist you during the construction phases as well. If you have any questions concerning this report or any of our testing, construction observation, design or consulting services, please do not hesitate to contact us.

Sincerely,

Cole Garner Geotechnical

Patrick Maloney, G.I.T.
Project Manager

Andrew J. Garner, P.E.
Principal, COO

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ANDREW J. GARNER
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PROFESSIONAL ENGINEER

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: New Travel Lanes, Minor Collector

SN Determination

$ESAL_{20}$ =	873,845	*ESALs Applications Over Design Period*	Typ. Range 0.1 to 80 million
R =	90 %	*Reliability*	Typ. Range 80 to 95%
S_o =	0.44	*Standard Deviation*	Typ. Range 0.3 to 0.5
M_r =	3,025 psi	*Subgrade Resilient Modulus*	Typ. Range 3000 to 9000 psi
P_i =	4.5	*Initial Serviceability*	Typ. Range 4.4 to 4.8
P_t =	2.5	*Terminal Serviceability*	Typ. Range 2.0 to 3.0

Design SN 4.51

Composite AC+ABC Alternative on A-7-6 Subgrade

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.44	1.00	**6.50**	2.86
2	ABC	0.14	1.00	**12.00**	1.68
				Trial SN	4.54

Design SN to Match 4.51

Design is sufficient

Full-Depth AC Alternative on A-7-6 Subgrade

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.44	1.00	**10.50**	4.62
				Trial SN	4.62

Design SN to Match 4.51

Design is sufficient

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: New Travel Lanes, Minor Collector

SN Determination

$ESAL_{20}$ =	873,845	*ESALs Applications Over Design Period*	Typ. Range 0.1 to 80 million
R =	90 %	*Reliability*	Typ. Range 80 to 95%
S_o =	0.44	*Standard Deviation*	Typ. Range 0.3 to 0.5
M_r =	3,025 psi	*Subgrade Resilient Modulus*	Typ. Range 3000 to 9000 psi
P_i =	4.5	*Initial Serviceability*	Typ. Range 4.4 to 4.8
P_t =	2.5	*Terminal Serviceability*	Typ. Range 2.0 to 3.0

Design SN 4.51

Composite AC+ABC Alternative on A-7-6 Subgrade

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.52	1.00	**6.00**	3.12
2	ABC	0.14	1.00	**10.00**	1.40
				Trial SN	4.52

Design SN to Match 4.51

Design is sufficient

Full-Depth AC Alternative on A-7-6 Subgrade

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.52	1.00	**9.00**	4.68
				Trial SN	4.68

Design SN to Match 4.51

Design is sufficient

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: Rehabilitation - York St. to Madison St.

SN Determination

$ESAL_{20}$ =	873,845	*ESALs Applications Over Design Period*	Typ. Range 0.1 to 80 million
R =	90 %	*Reliability*	Typ. Range 80 to 95%
S_o =	0.44	*Standard Deviation*	Typ. Range 0.3 to 0.5
M_r =	3,025 psi	*Subgrade Resilient Modulus*	Typ. Range 3000 to 9000 psi
P_i =	4.5	*Initial Serviceability*	Typ. Range 4.4 to 4.8
P_t =	2.5	*Terminal Serviceability*	Typ. Range 2.0 to 3.0

Design SN 4.51

Overlay Design, Average Existing Pavement = 13 inches, Assume 2" Mill Depth

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.44	1.00	**2.00**	0.88
2	Existing AC	0.30	1.00	**12.50**	3.75
				Trial SN	4.63

Design SN to Match 4.51

Design is sufficient

AASHTO FLEXIBLE PAVEMENT DESIGN

Project: East 144th Avenue Improvements
Location: York Street to Colorado Blvd., Thornton, CO

CGG Project No.: 18.22.099
Scenario: Rehabilitation - York St. to Madison St.

SN Determination

$ESAL_{20}$ =	873,845	*ESALs Applications Over Design Period*	Typ. Range 0.1 to 80 million
R =	90 %	*Reliability*	Typ. Range 80 to 95%
S_o =	0.44	*Standard Deviation*	Typ. Range 0.3 to 0.5
M_r =	3,025 psi	*Subgrade Resilient Modulus*	Typ. Range 3000 to 9000 psi
P_i =	4.5	*Initial Serviceability*	Typ. Range 4.4 to 4.8
P_t =	2.5	*Terminal Serviceability*	Typ. Range 2.0 to 3.0

Design SN 4.51

Overlay Design, Average Existing Pavement = 13 inches, Assume 2" Mill Depth

Layer No.	Description	Layer Coefficient, ai	Drainage Coefficient, mi	Layer Thickness, in	SN
1	AC	0.52	1.00	**2.00**	1.04
2	Existing AC	0.30	1.00	**12.00**	3.60
				Trial SN	4.64

Design SN to Match 4.51

Design is sufficient