GEOTECHNICAL AND PAVEMENT DESIGN CONSULTATION
PAVEMENT DESIGN GUIDELINES AND
TYPICAL PAVEMENT SECTIONS

City of Denton, Texas

CTL Project No. DA08429-135

CTL | THOMPSON
TEXAS, LLC

May 6, 2010

City of Denton
Engineering Department
901A Texas Street
Denton, Texas 76209

Attention: Mr. Tim Fisher

Re: GEOTECHNICAL AND PAVEMENT DESIGN CONSULTATION
Pavement Design Guidelines and Typical Pavement Sections
City of Denton, Texas
Job No. DA08429-135

Dear Mr. Fisher:

CTL | Thompson Texas, LLC (CTL) has completed the geotechnical and pavement deisgn consultation for the above referenced project, and herewith submits three (3) copies of our report.

We appreciate the opportunity to be of professional service to City of Denton. We will be available at your request to discuss any questions, which may arise concerning this report. If we can be of further assistance, please contact us.

Very truly yours,

CTL | Thompson Texas, LLC
Firm Registration No. F-7727

STATE OF TEXAS
MICHAEL P. BATUNA
92147
5/6/2010
LICENSED
PROFESSIONAL ENGINEER

Michael P. Batuna, P.E.
Associate Engineer

Reviewed By:

Richard J. Hammerberg, P.E.
Senior Principal Engineer

Dist: Mail: City of Denton
Email: Tim.Fisher@cityofdenton.com
Keith.Gabbard@cityofdenton.com

MPB/ RJH/jp
DA08429-135.rpt

TABLE OF CONTENTS
CTL Job No. DA08429-135

GEOTECHNICAL AND PAVEMENT DESIGN CONSULTATION
PAVEMENT DESIGN GUIDELINES AND TYPICAL PAVEMENT SECTIONS
CITY OF DENTON, TEXAS

SCOPE

This report presents the results of our Pavement Design Guidelines and Typical Pavement Sections for the City of Denton, Texas. The purpose of our investigation was to review and evaluate current pavement design standards and provide alternative for rigid and flexible pavement for the City of Denton, Texas. The study has been prepared and submitted in general accordance with CTL | Thompson Texas, LLC (CTL) proposal DA-09-187, dated December 7, 2009.

This report was prepared based on data provided to us by City of Denton and our experience with other pavement design standards. We reviewed the current City of Denton typical pavement section and the subsequent suggested design criteria prepared by the Pavement Focus Committee. The pavement alternative presented in this report was based upon American Association of State Highway and Transportation Officials (AASHTO) design criteria and our experience.

PAVEMENT DESIGN

It is our understanding that for the purpose of this study, the city has selected Jointed Reinforced Portland Cement Concrete Pavement (JRPCCP) and Asphaltic Cement Concrete Pavement (ACCP) as the pavement type for roadways in the City of Denton. Pavement design is based upon knowing, with adequate confidence, the nature and volume of traffic for the design period and character and support characteristics of the subgrade soils. Given the variability in these assumed or measured values, it is common to use a variability approach to the design.

The typical pavement sections were designed using the 1993 American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures* and the 1998 AASHTO supplement *Part II - Rigid Pavement Design and Rigid Pavement Joint Design*. Typical JRPCCP and ACCP sections were analyzed using the AASHTOWare DARWin® (version 3.1) software program.

The asphalt pavement section was designed using the perpetual pavement approach to achieve the desired 40 year life. Perpetual pavement design combines a rut and wear resistant top layer with a fatigue resistant base layer. Fatigue distress that originates from the bottom of the pavement should be minimized. Pavement section was designed using the 20 year expected traffic levels. The resulted pavement section is then followed by fatigue analyses.

Fatigue analyses can be performed using layered elastic computer program such as WESLEA. The program analyzes the pavement structure stress and strain responses due to traffic loadings. Tensile strain at the bottom of the composite HMA layers of 70 to 100 micro strain and compressive strain at the top of subgrade of about 200 to 250 micro strains is typically used as fatigue limit. Further study is being conducted to evaluate these fatigue limits.

The perpetual pavement design analyzes the pavement structure and limits the pavement distress confined to the upper layer of the structure. Therefore, over the pavement design period, only removal and replacement of the upper layer is necessary and leaving the bottom layers intact. The upper wearing surface may consist of Stone Matrix Asphalt (SMA) and the lower fatigue resistant layer should consist of an asphalt rich Hot Mix Asphalt (HMA) with low air voids in place. The following material properties are used in the pavement design analysis.

MATERIAL PROPERTIES	
Design Parameters	**Resilient Modulus Design Values**
Stone Matrix Asphalt (SMA)	500,000
Hot Mix Asphalt (HMA) Grading D with 0.3% Asphaltic Concrete (AC)	350,000
Stabilized Subgrade (SS)	30,000
Compacted Subgrade	5,000

The pavement condition should be monitored to verify that top down fatigue cracking and surface distress is confined to no deeper than the thickness of the surface course. Typical thickness of surface course is two to three inches thick. The pavement design includes maintenance and rehabilitation strategies for a 40-year period. Long lasting asphalt pavement can be achieved by proper material selection and asphalt mix design along with appropriate placement of the material within the pavement structure.

TRAFFIC ANALYSIS

Current and projected traffic numbers are dependent on the different roadway design conditions, traffic distributions, design lives, and other factors to develop design ESALs (Equivalent 18 kip Single-Axle Loads) are presented. Traffic data shall be analyzed using the available traffic data study values from City of Denton, North Central Texas Council of Governments (NCTCOG), Texas Department of Transportation (TxDOT) or site specific study by traffic analysis consultant.

The traffic data shall be converted into Equivalent 18-kip Single-Axle Loads (ESALs) according to the pavement type and estimated thickness. Steps required to calculate the ESALs are as follows:

1. Select Average Daily Traffic (ADT), Total;
2. Select the analysis period based upon pavement type;
3. Select or determine the annual growth rate;
4. Determine traffic distribution consisting of percentage of traffic for each vehicle type;
5. Determine the Load Equivalency Factor (LEF) for JRPCCP or ACCP according to AASHTO Guide (1993).
6. Estimate directional and lane distribution factor;
7. Determine percentages of trucks and trucks distribution;
8. Calculate ESALs for pavement design and analyses.

Vehicle traffic distribution is typically obtained from historical traffic data taken from similar roadways. It can vary depending upon land use and may consist of up to 10 traffic categories. Three traffic categories are being used in this pavement design. Vehicles are categorized to include passenger cars, single axle light trucks, and 80-kip tandem axle heavy trucks.

The damaging effect of truck traffic on pavement outweighs the effect of passenger cars on pavement. It is critical to use engineering judgment when analyzing percentage of truck traffic based on the available traffic data or traffic study. Engineering judgment should be used when selecting truck percentages for traffic analysis. Underestimating the truck traffic could significantly reduce the serviceable life of the pavement.

Truck traffic typically consists of single and tandem axles. Truck traffic distribution of 60 percent single axle and 40 percent tandem axle trucks is the recommended distribution. Traffic data shall be analyzed for tandem axle trucks with Gross Vehicle Weight (GVW) of 80 kips. A range of truck traffic percentages can be determined from available traffic data or from analyses of comparable roadway systems paralleling the proposed route.

Traffic Calculations

This section presents detailed traffic analyses for each of the two selected pavement conditions; i.e. Jointed Reinforced Portland Cement Concrete Pavement (JRPCCP) and Asphaltic Cement Concrete Pavement (ACCP). Each pavement condition has its own specific requirements, Load Equivalency Factors (LEF), and procedures. Note the traffic volume must be tempered to not exceed the maximum lane capacity.

Jointed Reinforced Portland Cement Concrete Pavement (JRPCCP)

JRPCCP has been selected by the City as the rigid pavement type for roadways. Design is based upon the AASHTO Guide for Design of Pavement Structures (1993) with the following requirements:

1. A pavement design life of 40 years is desired by the City of Denton for JRPCCP.

2. Total ADT (2-way) used for design purposes should reflect numbers that will be experienced by the majority of Primary Arterial, Commercial Collector, Residential Collector and Local Residential roadway. The traffic number should be based on conservative projections of the traffic data assumptions.

3. For analysis purposes, the percentage of heavy trucks should be classified further into single axle and tandem axle. Percentage of truck traffic should be increased for heavy duty pavement design.

4. A Directional Distributional factor (D_D) of 0.5 is typically used for traffic analysis unless there is significant difference in the number of traffic experienced in one roadway direction compared to the other roadway direction.

5. **A Lane Distribution Factor (D_L); according to AASHTO:**

Ultimate Number of Lanes In Each Direction	Percent of 18-kip ESAL in Design Lane
1	100
2	80 – 100
3	60 – 80
4	50 – 75

6. **Annual Growth Rate (g) is determined using the current and projected ADT data provided by the adjusted demographic. Annual growth rate can be calculated using the following equation:**

$$g = [(ADT_i / ADT_0)^{1/n}] - 1$$

Where ADT_0 = current year ADT
ADT_i = projected year ADT
n = analysis period (years)

7. **Growth Factor (GF) is based on the annual growth rate (g); traffic growth factor can be calculated as:**

$$GF = \frac{(1 + g)^n - 1}{g}$$

where g = annual growth rate, percent
n = analysis period (years)

8. **A Load Equivalency Factor for each vehicle type can then be determined based on the axle configuration (single, tandem or tridem), terminal Serviceability (p_t), axle load (kips), and slab thickness (inch) in accordance with the 1993 AASHTO Guide for Design of Pavement Structures.**

Traffic input consists of Average Daily Traffic (ADT), the Traffic Distribution (D_D and D_L), Growth Factors (GF) and Load Equivalency Factors (LEF); the design, ESALs for each vehicle type can be calculated as:

$$ESALs = D_L \times [(\text{Total ADT} \times D_D) \times \%\text{ of ADT} \times 365\text{ days} \times \text{Design Period-years} \times LEF)] \times GF$$

$$\text{Total ESALs} = \Sigma\ \text{ESALs per vehicle type}$$

Asphalt Cement Concrete Pavement (ACCP)

Design value requirements for ACCP are similar to JRPCCP. The design ESAL can be calculated using the same equations provided in JRCP section. Differences are listed as follows:

1. **Perpetual pavement section should be designed using 20 year projected traffic for Asphaltic Cement Concrete Pavement (ACCP).**
2. **Calculated pavement thickness should be checked for fatigue and rutting analysis.**
3. **Specify maintenance recommendations for 40 year design life**

TYPICAL PAVEMENT SECTIONS

Based on previous meetings with City of Denton, the projected volume used for the traffic analyses of the various roadways was based on the 2004 TxDOT Average Daily Traffic (ADT) counts listed by NCTCOG for City of Denton. The Equivalent 18-kip Single Axle Loads (ESAL) was calculated based on the AASHTO design method for a 40 year Jointed Reinforced Portland Cement Concrete Pavement (JRPCCP) design life and a 20 year Asphaltic Cement Concrete Pavement (ACCP) design life. Due to the uncertainty of the projected traffic volume throughout the design life of the pavement, traffic analysis values as listed in Table-I and pavement design values as listed in Table-II should be used as a minimum.

TABLE-I
TRAFFIC ANALYSIS INPUT

DESIGN PARAMETER	DESIGN VALUE			
	Primary Arterial	Commercial Collector	Residential Collector	Local Residential
Jointed Reinforced Portland Cement Concrete Pavement (JRPCCP) Design Life, years	40	40	40	40
40 year JRPCCP ESAL, million	10	5	2	1
Asphaltic Cement Concrete Pavement (ACCP) Design Life, years	20	20	20	20
20 year ACCP ESAL, million	4	2	1	0.75
Total number of lanes	6	4	2	2
Lane Distribution Factor	0.7	1.0	1.0	1.0
Growth Rate, percent	2	2	1	1
Truck percentage, percent	4	2	1	1

TABLE-II PAVEMENT DESIGN INPUT				
DESIGN PARAMETER	DESIGN VALUE			
	Primary Arterial	Commercial Collector	Residential Collector	Local Residential
Reliability	95	95	90	90
Design Serviceability Loss	2.0	2.0	2.5	2.5
28-day Mean PCCP Modulus of Rupture	620 psi	620 psi	620 psi	620 psi
28-day Mean Elastic Modulus of Slab	5,000,000 psi	5,000,000 psi	5,000,000 psi	5,000,000 psi
Mean Effective k-value	150 psi/in	150 psi/in	150 psi/in	150 psi/in
PCCP Overall Standard Deviation	0.39	0.39	0.39	0.39
PCCP Load Transfer Coefficient	2.9	2.9	2.9	2.9
ACCP Overall Standard Deviation	0.49	0.49	0.49	0.49
Overall Drainage Coefficient	1.0	1.0	1.0	1.0

The typical pavement section was designed using the 1993 American Association of State Highway and Transportation Officials (AASHTO) *Guide for Design of Pavement Structures* and the 1998 AASHTO supplement *Part II - Rigid Pavement Design and Rigid Pavement Joint Design*. Typical JRPCCP AND ACCP sections were analyzed using the AASHTOWare DARWin® (version 3.1) and WESLEA software programs.

The calculated pavement sections incorporate a stabilized pavement subgrade with subgrade treatment when warranted. The pavement subgrade should be designed as such that it can be incorporated as a structural component within the pavement structure. Subgrade treatment analysis should be performed to address differential movement potential due to expansive soils. Subgrade stabilization and subgrade treatment guidelines are not part of this study. Heavy duty pavement should be designed based on site specific truck traffic conditions and projections.

Typical Jointed Reinforced Portland Cement Concrete Pavement (JRPCCP) are presented in Table-III. The JRPCCP thickness includes an additional ½ inch for future maintenance involving diamond grinding. Typical Asphaltic Cement Concrete Pavement (ACCP) section are presented in Table-IV.

TABLE-III JRPCCP (RIGID) PAVEMENT SECTION				
PAVEMENT SECTION	**DESIGN VALUE**			
	Primary Arterial	**Commercial Collector**	**Residential Collector**	**Local Residential**
Jointed Reinforced Portland Cement Concrete Pavement (JRPCCP)	11	10	8	7
Stabilized Subgrade	12	12	8	8
Subgrade Treatment – To Be Determined (TBD)	TBD	TBD	TBD	TBD

Flexible Asphaltic Cement Concrete Pavement (ACCP) analyses were performed according AASHTO design and rational (fatigue based) design. The rational pavement section consists of varying thickness ACP of over 12 inches of stabilized subgrade. An alternative rational pavement section consisting of flexible base and stabilized subgrade with reduced asphalt pavement thickness is also included. The ACCP typically consists of two inches of Stone Matrix Asphalt (SMA) over asphalt rich Hot Mix Asphalt (HMA).

TABLE-IV ACCP (FLEXIBLE) PAVEMENT SECTION				
PAVEMENT SECTION	**DESIGN VALUE**			
	Primary Arterial	**Commercial Collector**	**Residential Collector**	**Local Residential**
Asphaltic Cement Concrete Pavement	12	11	9	8
Stabilized Subgrade	12	12	12	12
Subgrade Treatment	TBD	TBD	TBD	TBD
OR				
Asphaltic Cement Concrete Pavement	10	9	8	7
Flex Base	6	6	4	4
Stabilized Subgrade	12	12	12	12
Subgrade Treatment To Be Determined (TBD)	TBD	TBD	TBD	TBD

It should be noted the designs are bound by the assumptions listed and are a function of the data provided. Changes in the traffic and subgrade conditions will materially affect the thickness recommendations.

The pavement section was designed with the assumption that the top 12 inches of pavement soil subgrade will be stabilized with either lime or Portland cement, depending on existing subgrade properties. Pavement subgrade should also be evaluated to determine subgrade treatment alternative to reduce potential for vertical soil movement.

Project specific subgrade stabilization and subgrade treatment analysis and design should be performed. It will provide the percentage of hydrated lime or Portland cement necessary for stabilization and also provide depth of moisture treatment or depth of removal and replacement with low plasticity select fill necessary to reduce potential for vertical soil movement. Further study should be performed to develop guidelines for pavement subgrade stabilization and subgrade treatment for various soil conditions within the City of Denton.

PAVEMENT MAINTENANCE STRATEGIES

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

The life and serviceability of the pavement system is dependent upon a well-planned pavement maintenance program. Pavement maintenance guidelines are provided in the following Tables V and VI. We also recommend a Pavement Information Management System to be instituted and a strict maintenance schedule to be implemented.

TABLE – V GENERAL RIGID PAVEMENT (JRCCP) MAINTENANCE PROGRAM	
YEAR	**PROGRAM**
7	Joint Seal and Crack Seal
14	Joint Seal and Crack Seal Patch and Slab Replacement
20	Diamond Grind 1/2 inch and reseal joints or cracks
27	Joint Seal and Crack Seal
35	Joint Seal and Crack Seal Patch and Slab Replacement
40 (40 year design)	Overlay with 3" ACCP Maintenance to follow ACCP Recommendations in Table VI

TABLE - V GENERAL FLEXIBLE PAVEMENT (ACCP) MAINTENANCE PROGRAM	
YEAR	**PROGRAM**
7	Crack Seal and 2 inches SMA Overlay
10	Crack Seal
15	2 inches Mill and 2 inches SMA Inlay
18	Crack Seal
22	Crack Seal and 2 inches SMA Inlay
25	Crack Seal
29	2 inches Mill and 2 inches SMA Inlay
32	Crack Seal
34	Crack Seal and 2 inches SMA Inlay
37	Crack Seal
40	Reconstruct the Asphalt section layer

QUALIFICATIONS

This report was prepared by CTL to aid in the evaluation of the site and to assist in providing pavement design guidelines and typical pavement sections for the City of Denton. We have developed our conclusions and recommendations in accordance with generally accepted professional geotechnical engineering principles and practices. We make no warranty, either express or implied. Our conclusions are based on the results of the field exploration, laboratory tests, and our interpretations of subsurface conditions and analyses; however, if conditions during construction appear different from those described in this report, we should be notified so that we may review and verify or modify, if necessary, our recommendations.

The reproduction of this report, or any part thereof, supplied to persons or agencies other than the client should indicate that this study was made for pavement design and construction purposes only and that verification of the subsurface conditions for purposes of construction activities are the responsibilities of others.