FujiClean USA™ LLC
Toward Clean Water…

February 14, 2020

TO: Interested Parties

FROM: Scott Samuelson, Managing Director

SUBJECT: Acceptable Uplift Methods for CE- and CEN-Series Tanks

The question continually arises as to acceptable uplift restraint methods for securing Fuji Clean CE- and CEN-Series tanks. There are many alternative methods. Provided in this memorandum is information regarding two methods that have been used. Please understand that this information is general in nature. It is the responsibility of the designer to confirm that the information is applicable for any specific installation. Also, please note that applicable public health and environmental regulations may require different factors of safety and restraint methods that the examples illustrated here. Please consult with appropriate, credentialed design professionals in the specific jurisdiction where uplift restraint is being considered.

Method 1—Concrete Slab Sized to Resist Buoyant Forces

Method 1 is the most conservative approach. This approach assumes that an empty Fuji Clean tank will be completely submerged in a soil undergoing a "quick condition," i.e., the soil provides no restraining force. In this example both the Fuji Clean unit and the concrete slab are subject to uplift forces. The result is that the effective concrete weight is lessened from the influence of the water. This calculation is simple.

TABLE 1--CONCRETE UPLIFT RESTRAINT REQUIRED FOR FUJI CLEAN CE- AND CEN-SERIES MODELS BASED ON TANK VOLUME AND SUBMERGENCE TO TANK LID

MODEL		VOLUME (GAL)	UPLIFT (LBS)	CONCRETE VOLUME (CY) @2365 LB/CY	CONCRETE VOLUME (CY) WITH 10% FS	CONCRETE VOLUME (CY) WITH 25% FS	CONCRETE VOLUME (CY) WITH 50% FS
CE5		654	5,458	2.31	2.54	2.88	3.46
CE7	CEN5	884	7,377	3.12	3.43	3.90	4.68
CE10	CEN7	1,211	10,106	4.27	4.70	5.34	6.41
CE14	CEN10	1,758	14,671	6.20	6.82	7.75	9.31
CE21	CEN14	2,582	21,547	9.11	10.02	11.39	13.67
CE30	CEN21	3,517	29,350	12.41	13.65	15.51	18.62

Table 2 shows the corresponding slab dimensions for each of the Factors of Safety presented in Table 1.

TABLE 2--CONCRETE SLAB DIMENSIONS FOR UPLIFT RESTRAINT FACTORS OF SAFETY (FS)								
MODEL		MODEL WIDTH (FT)	MODEL LENGTH (FT)	CONCRETE VOLUME (CY) @2365 LB/CY	SLAB THICKNESS (FT)	SLAB THICKNESS @ 1.1 FS (FT)	SLAB THICKNESS @ 1.25 FS (FT)	SLAB THICKNESS @ 1.5 FS (FT)
CE5		3.6042	7.0052	2.31	2.47	2.71	3.08	3.70
CE7	CEN5	4.0208	7.8958	3.12	2.65	2.92	3.32	3.98
CE10	CEN7	4.6875	8.1979	4.27	3.00	3.30	3.75	4.50
CE14	CEN10	5.7500	9.9167	6.20	2.94	3.23	3.67	4.41
CE21	CEN14	6.0000	12.7292	9.11	3.22	3.54	4.03	4.83
CE30	CEN21	6.4792	16.2500	12.41	3.18	3.50	3.98	4.77

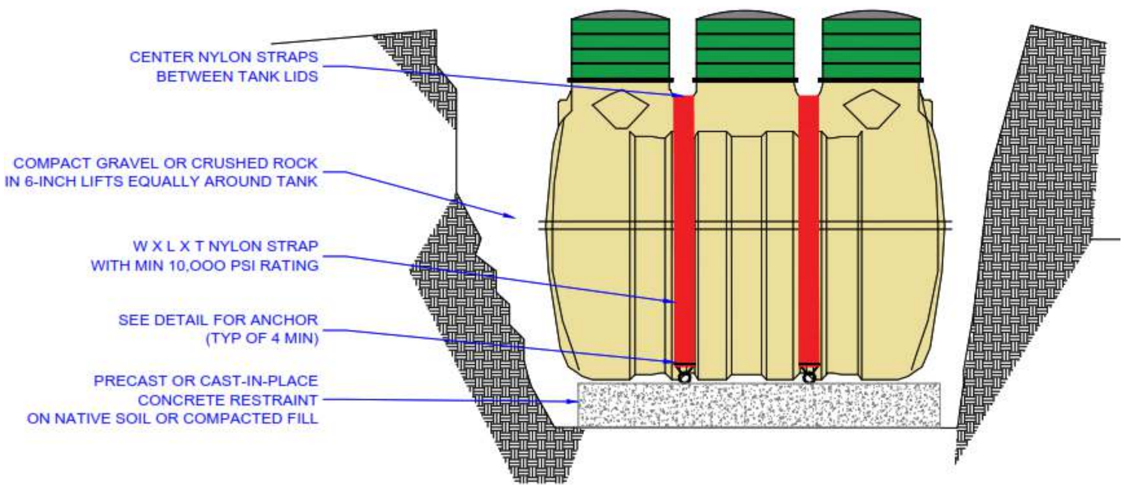

Figure 1—Uplift Restraint Slab

Method 2—Empirical Method Using Inclined Plate

Various researchers have examined the issue of uplift restraint using plates installed in compacted or *in situ* soil. One cited method was developed by (Merifield, 2006). Their method relies on frictional forces and soil weight. The result of their research is a series of charts that may be used to estimate the ultimate restraint capacity of a plate installed in backfilled soil. This information was used by Niroumand and Kassim (Niroumand, 2016) to develop a technique to estimate the restraint capacity of inclined anchor plates placed in cohesive and cohesionless soils.

The problem is represented as shown in Figure 2. A plate is installed at an angle in a compacted cohesionless soil, such as a sand. The sand is compacted. Empirical tests of pull-out force are plotted and used to develop a model, which is plotted for general use. The general equation is shown below for square and strip anchor plates. Deadmen, which are essentially rectangular anchor plates, are interpolated from Figures 3 and 4. The total bearing capacity is the sum of the calculation and the weight of the deadmen.

$$Q'_{u-\psi} = F'_{q-\psi}\gamma h B H'$$

Equation 1—Calculation of the Ultimate Bearing Capacity of an Inclined Plate

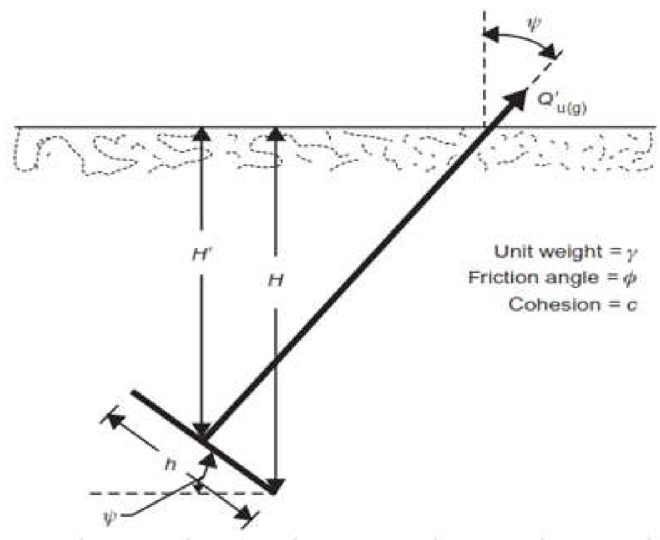

Figure 2—Inclined Plate Model Conditions

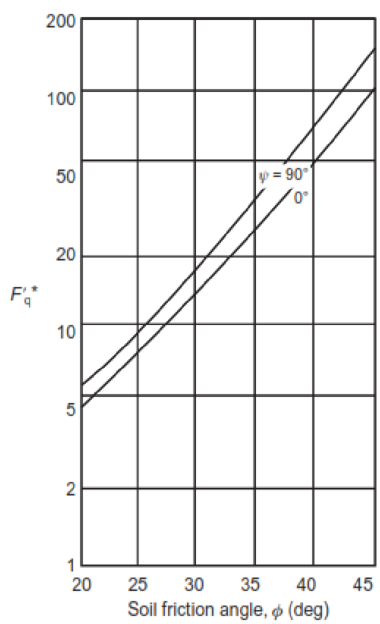

Figure 3—F'$_q$ Graph for a Square Anchor Plate

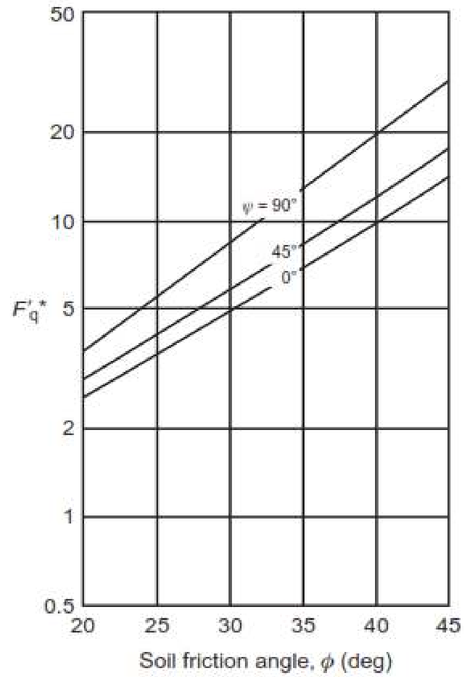

Figure 4—F'$_q$ Graph for a Strip Anchor Plate

The following tables provide the design values, design constants, and calculations for estimating the bearing capacity of concrete deadmen installed in a cohesionless sand. The question will arise as to whether the deadman length has an impact for rectangular deadmen. The answer is "yes," but the length has already been factored by testing deadmen of different lengths. The references contain additional information interested parties can review to understand the research behind Figures 3 and 4. The authors recommend that a factor of safety (FS) of 3.0 or higher for all designs.

Table 3 includes details about the deadmen.

TABLE 3--DEADMAN VALUES		
DIMENSION	**VALUE**	**UNIT**
LENGTH	8 or 12	FT
WIDTH (*h*)	1.5	FT
HEIGHT	0.67	FT
VOLUME	10.67	FT^3
DRY WEIGHT	1,600	LBS
WET WEIGHT	934	LBS
UNIT SATURATED LENGTH	117	LB/FT
SOIL ANGLE	35	O

Table 4 contains values the soil and concrete.

TABLE 4--DESIGN CONSTANTS		
ITEM	**VALUE**	**UNIT**
CONCRETE DENSITY	150	LB/FT^3
WATER DENSITY	62.4	LB/FT^3
DRY SOIL DENSITY	114	LB/FT^3
SATURATED CONCRETE DENSITY	87.6	LB/FT^3
SATURATED SOIL DENSITY	51.6	LB/FT^3
ANCHOR ANGLE	75	$^{\circ}$

Table 5 is the calculation of the estimated capacity deadmen with a safety factor of 1.6 or greater. The author recommends a factor of safety of 3.0 or higher. Applicable regulations may set factors of safety at 1.25 or 1.5. It is the designer's decision to apply an appropriate factor of safety based on his or her knowledge specific to each design.

TABLE 5--CALCULATED BEARING CAPACITY AND DEADMEN SELECTION FOR INCLINED PLATE			
MODEL	**NUMBER OF DEADMEN**	**FACTOR OF SAFETY FOR 8' DEADMEN**	**FACTOR OF SAFETY FOR 12' DEADMEN**
CE5	2	2.60	2.73
CE7/CEN5	2	1.94	1.99
CE10/CEN7	2	1.58	1.62
CE14/CEN10	2	2.33	2.39
CE21/CEN14	4	1.68	1.72
CE30/CEN21	6	1.98	2.03

Please recall that these calculations are an example of an ideal sand; the designer is responsible to confirm the applicability of any design approach for each specific site under consideration.

Installation and Operation

The calculations assume an empty tank and highwater at the rim, two simultaneous conditions that unlikely during operation. Regardless, the design should include an observation port next to the tank so maintenance providers can judge the height of soil saturation. Tank pumping will be prohibited during high groundwater events.