Oldcastle Infrastructure™
A CRH COMPANY

CUDO® CUBES

Operations and Maintenance Manual
(Underground Retention/Detention/Infiltration/Water Reuse Systems)

Water

CUDO® Stormwater Cube - Modular Stormwater Systems

Description / Basic Function

CUDO is a modular stormwater system comprised of a grouping of modular polypropylene or concrete cubes that when constructed form an underground storage area for stormwater. This system can be used for infiltration, retention, detention or water reuse. CUDO can help achieve runoff detainment and storage to help attenuate the peak flow to pre-construction levels and can help conform to current Low Impact Development requirements.

Infiltration

The purpose of a CUDO infiltration system is to capture stormwater runoff, store the runoff, and then allow it to percolate into the ground via the open space area of the cubes and perforations in the side wall. The system is backfilled with a Class I material defined by ASTM D2321 as a cleaned open graded rock or a Class II permeable sand. The rock or sand provide additional storage capacity but also allow for a percolation interface with the native material. The ground water is "recharged" with this type of system.

Detention

The purpose of a CUDO detention system is to capture stormwater runoff, store the runoff, and then allow it to be released at a controlled rate through an appropriately sized orifice control. A detention system helps attenuate the peak flow from the site assuring that pre-development runoff flows are not exceeded as a result of the development. A CUDO detention requires the cubes to be encapsulated with an impermeable liner for the polypropylene system or the seams of the concrete system to be sealed with a water proof mastic.

Retention

A CUDO retention system is a hybrid system. It is a combination of a detention system and an infiltration system. A retention system is utilized to attenuate peak flow as well as promote groundwater re-charge. A retention system is outfitted with an overflow pipe at the top of the system which allows the system to fill for infiltration but also outlet if the ground is saturated.

Water Reuse

The purpose of a water-reuse CUDO system is to capture and store water for future use. The system is constructed in a similar fashion to a detention system but instead of a controlled outlet the system is constructed with an emergency overflow. A water reuse system is a Low-Impact Development (LID) device that helps attenuate peak flows as well as conserve water. Water may be reused through an active pump system or passive irrigation.

Inspection/Cleanout Ports

Inspection and cleanout ports are 18-inch diameter vertical risers connected to the uppermost polypropylene CUDO cubes or up to 30-inch manhole access connected to the concrete CUDO. They are used for entrance into the system, or for access to place vacuum truck hoses or water-jetting devices or CCTV equipment. Ports are strategically located near inlet and outlet pipes and in other areas or probable deposition in the system. It is recommended to keep surface level access lids sealed and bolted at all times when the system is in service.

Inlet Bay

Some systems are configured so that pretreatment of the stormwater occurs within the CUDO system. In this case, the CUDO system will house an inlet bay. The inlet bay is separated from the rest of the CUDO system by sidewall plugs and is intended to separate gross pollutants, trash and debris and floatables from the CUDO system and pre-treatment device. The bay contains its own sump area and unique access ports.

Maintenance Overview for CUDO

State and Local regulations require that stormwater storage systems be maintained and serviced on a recurring basis. The purpose of maintaining a clean and obstruction free CUDO system is to ensure the system performs the intended function of the primary design. Trash and debris, floatables, gross pollutants and sediment can build up in the CUDO leading to clogging of the native soil interface or blockage of the inlet or outlet pipes. This can cause the system to function improperly by limiting storage volume, limiting the design percolation rates or impeding flow in and out of the system. Downstream and upstream, areas could run the risk of flooding and deleterious environmental impact.

Recommended Frequency of Service

It is recommended that the CUDO stormwater systems be serviced on a regularly occurring basis. Ultimately the frequency depends on the amount of runoff, pollutant loading, and interference from trash, debris and gross pollutants as well as proper maintenance of upstream pretreatment devices. However, it is recommended that each installation be inspected at least two times per year to assess service needs.

Recommended Timing of Service

Guidelines for the timing of service are as follows:

1. For areas with a definite rainy season the system should be serviced prior to and following the rainy season.
2. For areas subject to year-round rainfall service should occur on a regularly occurring basis. (A minimum of two times per year.)
3. For areas with winter snow and summer rain the system should be serviced prior to and after the snow season.
4. For installed devices that are subject to dry weather flows only (i.e. wash racks, parking garages, etc…) the unit should be serviced on a regularly occurring basis. (A minimum of two times per year.)

Inspection

An inspection should be performed when the system is new. This allows the owner to establish a baseline condition for comparison to future inspections. Sediment build up can typically be monitored without entering the system. (No confined space entry.) Initial and subsequent inspection data should be recorded and filed for reference. Some regulatory agencies require that the results of the inspections be documented and reported. Inspection reports should comply with regulatory requirements and be submitted as required.

Inspection Procedures

5. Locate the inspection, cleanout and access ports. Inspection and cleanout ports are typically 18-inch diameter. Access ports are typically 24-inch or 30-inch diameter. Pictures should be taken to document the location or a site map should be generated to detail the as-built locations of the ports.
6. Unbolt and remove the access port lids.
7. Insert a measuring device into the opening making note of a point of reference to determine the quantity of sediment and other accumulated material. If access is required to measure, ensure only certified confined space entry personnel having appropriate equipment are allowed to enter the system.
8. In addition, for accessible concrete CUDO systems personnel should utilize appropriate confined space entry procedures to enter the system and photograph its condition.
9. Inspect inlet and outlet locations for obstructions. Obstructions should be removed at this time.
10. Inspect the structural components of the system.
11. Fill in the CUDO Inspection/Maintenance Data Sheet and send a copy to the regulatory agency if necessary.

Disinfection of Water Reuse System

Periodic disinfection of water held for reuse may be required to abate bacteria and algae growth. This may be done using calcium hypochlorite tablets or by the addition of an ozone generator in a small recirculation system.

Maintenance

Cleanout of the CUDO system should be considered if there is sediment buildup of two or more inches at over 50% of the inspection ports. Cleaning shall be performed if sediment buildup is two inches or more over 75% of the system floor. In the event of a spill of a foreign substance, cleanout of the system should be considered.

Maintenance Procedures

1. Locate the inspection, cleanout and access ports. Inspection and cleanout ports are typically 18-inch diameter. Access ports are typically 24-inch or 30-inch diameter. Pictures should be taken to document the location or a site map should be generated to detail the as-built locations of the ports.
2. Unbolt and remove the access port lids.
3. Measure the sediment buildup at each port. If access is required to measure ensure only certified confined space entry personnel having appropriate equipment are allowed to enter the system.
4. A thorough cleaning of the system (inlets, outlets, ports, and inlet bays) shall be performed by either a vacuum truck or by manual methods.
5. Inspect inlet and outlet locations for obstructions. Obstructions should be removed at this time.
6. Inspect the structural components of the system.
7. Fill in the CUDO Inspection/Maintenance Data Sheet and send a copy to the regulatory agency if necessary.

Inspection / Maintenance Requirements

Below are some recommendations for equipment and training of personnel to inspect and maintain a CUDO system.

Personnel: OSHA Confined Space Entry Training is a prerequisite for entrance into a system. In the state of California personnel should be CalOSHA certified.

Equipment: Record Taking (pen, paper, voice recorder)
Proper Clothing (appropriate footwear, gloves, hardhat, safety glasses, etc.)
Flashlight
Tape Measure
Measuring Stick
Pry Bar
Traffic Control (flagging, barricades, signage, cones, etc.)
First Aid Materials
Debris and Contaminant Containers
Vacuum Truck

Disposal of Gross Pollutants, Hydrocarbons, and Sediment

The collected gross pollutants, hydrocarbons and sediment shall be offloaded from the vacuum truck into DOT-approved containers for disposal. Once in the container, the maintenance contractor has possession and is responsible for disposal in accordance with local, state and federal agency requirements.

Note: As the generator, the landowner is ultimately responsible for the proper disposal of the collected materials. The collected debris, hydrocarbons and sediment must be disposed of in accordance with local, state and federal agency requirements.

DESIGN COMPUTATIONS FOR:
CUDO® WATER STORAGE SYSTEM

PREPARED FOR:

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OBJECTIVE:

Determine the distributed load acting on the CUDO Water Storage Cube per AASHTO LRFD for live loads and earth loads and recommended minimum and maximum cover heights.

OVERVIEW:

The CUDO Water Storage Cube is manufactured from polypropylene by an injection molding process. The cubes consist of two halves that join together at the spring line of the circular opening of the cube, as well as a top and bottom grate. The cubes will be assembled and installed in rows and columns with no spacing between units.

Our evaluation included review of third party compressive test data, live and earth load calculations, and finite element analysis of the expected cube performance when subjected to live loads in a minimum cover scenario. Structural performance of the cube was assessed using current AASHTO procedures for design of thermoplastic culverts.

LABORATORY TESTING:

CUDO Stormwater Products, Inc. retained Testing Engineers, Inc. of San Leandro, California to perform a compressive test on three 24-in X 24-in x 24-in CUDO cubes. The testing was performed in general conformance with ASTM D2412, Standard Test Method for Determination of External Loading Characteristics of Plastic Pipe by Parallel Plate Loading. (A copy of this test report is included for reference.) It should be noted at the time this testing was completed there was/is no ASTM test uniquely tailored for modular filtration systems such as the CUDO and it was determined that this test is the most appropriate available test procedure.

The average ultimate load was determined to be 14,036.7lbs (14.0 K) for the 24-in x 24-in x 24-in CUDO cube. The load reference for this laboratory test is approximately 3,500lbs/sq-ft (3.5K/sq-ft).

LIVE LOAD AND EARTH LOAD CALCULATIONS:

Reference AASHTO Section 12-2006 Assumptions:

Load Factors:	Earth Load (EL) – 1.0 Live Load (LL) – 1.75 or As Required
Cover Height:	H = Total Cover Height H_S = Surface Treatment Cover Height H_F = Fill Cover Height
Soil Weight:	Surface = 145pcf Fill = 120pcf
Impact Factor:	IM = 1.3(1-0.125H) where H is cover height in feet
Earth Load:	$EL_S = H_S$ X 145pcf $EL_F = H_f$ X 120pcf
Live Load (HS20-44):	LL = 16,000 lbs
Wheel Contact Area:	Length (l) = 20-inches Width (w) = 10-inches
Live Load Distribution Factor:	= 1.75
Geogrid Distribution Factor:	= 2.60
Earth Load:	= (SF_{DL}) X (Unit Weight Surface) X (H_S) + (SF_{DL}) X (Unit Weight Fill) X (H_F)
Live Load:	= (IM) X (SF_{LL}) X (Live Load) / Distributed Load Area
Total Load:	= EL + LL

LIVE LOAD AND EARTH LOAD CALCULATIONS (CONTINUED):

The ultimate loading was calculated and then compared to the laboratory test results for ultimate loading of the cubes. The calculations for loading include both live load and earth loads. Although the earth load at minimum cover heights is very minimal in comparison to the live load, the earth loads have been included. The live load and earth load use assumptions as listed above and are in general conformance with AASHTO LRFD. In these calculations, it was assumed that the HS20-44 live load is a point load at surface with no wheel contact area. The load is distributed downward and outward with a distribution factor of 1.75. This is a conservative approach and considers that surface loads are not distributed over the footprint of the wheel contact area. Results of the calculations are found in Table 1.

Cover Height (H) in (in)	Impact Factor (IM)	Live Load Distribution (1.75) sq-in	H20 Live Load Transferred to cube (psi)	Earth Load Transferred to cube (psi)	Total Load Transferred to cube (psi)	Factor of Safety*
0	1.33	0	21280.0	0.0	21280.0	0.00
6	1.31	110	190.0	0.5	190.5	0.13
12	1.29	441	46.8	1.0	47.8	0.51
18	1.27	992	20.4	1.5	22.0	1.11
24	1.25	1764	11.3	2.0	13.3	1.82
30	1.23	2756	7.1	2.5	9.6	2.52
36	1.21	3969	4.9	3.0	7.9	3.08
42	1.19	5402	3.5	3.5	7.0	3.45
48	1.17	7056	2.6	4.0	6.7	3.64
54	1.14	8930	2.1	4.5	6.6	3.69
60	1.12	11025	1.6	5.0	6.7	3.65
66	1.10	13340	1.3	5.5	6.9	3.54
72	1.08	15876	1.1	6.0	7.1	3.41
78	1.06	18632	0.9	6.5	7.5	3.26
84	1.04	21609	0.8	7.0	7.8	3.11
90	1.02	24806	0.7	7.6	8.2	2.96
96	1.00	28224	0.6	8.1	8.6	2.82

*For design situations exceeding 60-inches of cover please contact the manufacturer for additional analysis.

Table 1

LIVE LOAD AND EARTH LOAD CALCULATIONS (CONTINUED):

Additional analysis was performed to determine the benefit of utilizing a geo-grid layer between the live load and the cubes. Using a program called Spectra Pave3 Version 1.0 developed by Tensar International Corporation it was found that when based on poor quality soil material (CBR 1 or R factor 5+/-) the spread factor is 2.60. This result is based on using Tensar geo-grid BX1200 or equal. The new load distribution factor was incorporated into the calculations and the results can be found in Table 2.

Cover Height (H) in (in)	Impact Factor (IM)	Live Load Distribution (2.6) sq-in	H20 Live Load Transferred to cube (psi)	Earth Load Transferred to cube (psi)	Total Load Transferred to cube (psi)	Factor of Safety*
0	1.33	0	21280.0	0.0	21280.0	0.00
6	1.31	243	86.1	0.5	86.6	0.28
12	1.29	973	21.2	1.0	22.2	1.10
18	1.27	2190	9.3	1.5	10.8	2.26
24	1.25	3894	5.1	2.0	7.1	3.40
30	1.23	6084	3.2	2.5	5.7	4.23
36	1.21	8761	2.2	3.0	5.2	4.65
42	1.19	11925	1.6	3.5	5.1	4.75
48	1.17	15575	1.2	4.0	5.2	4.65
54	1.14	19712	0.9	4.5	5.5	4.45
60	1.12	24336	0.7	5.0	5.8	4.21
66	1.10	29447	0.6	5.5	6.1	3.96
72	1.08	35044	0.5	6.0	6.5	3.72
78	1.06	41128	0.4	6.5	7.0	3.49
84	1.04	47699	0.3	7.0	7.4	3.28
90	1.02	54756	0.3	7.6	7.9	3.10
96	1.00	62300	0.3	8.1	8.3	2.92

*For design situations exceeding 60-inches of cover please contact the manufacturer for additional analysis.

Table 2

FINITE ELEMENT ANALYSIS:

A finite element analysis for the CUDO cube was performed using a finite element program, Visual Analysis 5.5, by Integrated Engineering Software (www.iesweb.com). The model is 3-D with 2-D plate elements incorporating material stiffness with HS20-44 truck live loading, earth load, dead load and soil lateral loading.

For this analysis, the following loadings and assumptions were utilized:

> Live Load (LL) is H20-44 impacted for 2 ft cover, but applied at 3 ft cover
>
> Earth Load (ELV) is applied vertically at 130pcf for cover weight
>
> Earth Load (ELL) is applied laterally at 120pcf using an active lateral earth pressure coefficient (ka) = 0.33
>
> Dead Load (DL) is the weight of the CUDO cube itself. This number is relatively small in comparison to the earth load and live load and is left at zero for this analysis.
>
> Material Stiffness = 75 ksi
>
> Tensile Strength = 3.5 ksi
>
> Material Thickness = 0.170 inch

The results of the analysis indicate that the greatest tensile stress for the 3 ft cover to finished grade is 1.25 ksi located near the point of joining the top and bottom half cubes. This allows for a Safety factor of 2.8 when compared to industry reported tensile strength of 3.5 ksi. The greatest tensile stress for 5 ft of cover to finished grade is 1.51 ksi. This results in a Safety Factor of 2.3 when compared to the industry reported tensile strength of 3.5 ksi.

CONCLUSION:

The CUDO cube can be installed with a minimum of 2ft of cover measured from the finished grade to the top of the cube with a geo-grid, Tensar BX1200 or equivalent, placed in the cover in accordance with the manufacturer's recommendations. Calculations indicate that the addition of the geo-grid helps to reduce point loads and live loads on the cube allowing for a safety factor of 3.4 at this depth. The analysis additionally supports the installation of the CUDO cube to a depth of 5ft measured from the top of the cube to finished grade. Backfill material shall be constructed per project geotechnical engineer requirements. Backfill construction equipment shall not apply loading greater than the design loading of 0.97K/sq-ft. For desired installation depths shallower or in excess of these recommendations the manufacturer should be contacted.

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