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ASCE-EWRI Congress 2020

Henderson, NV, May, 2020

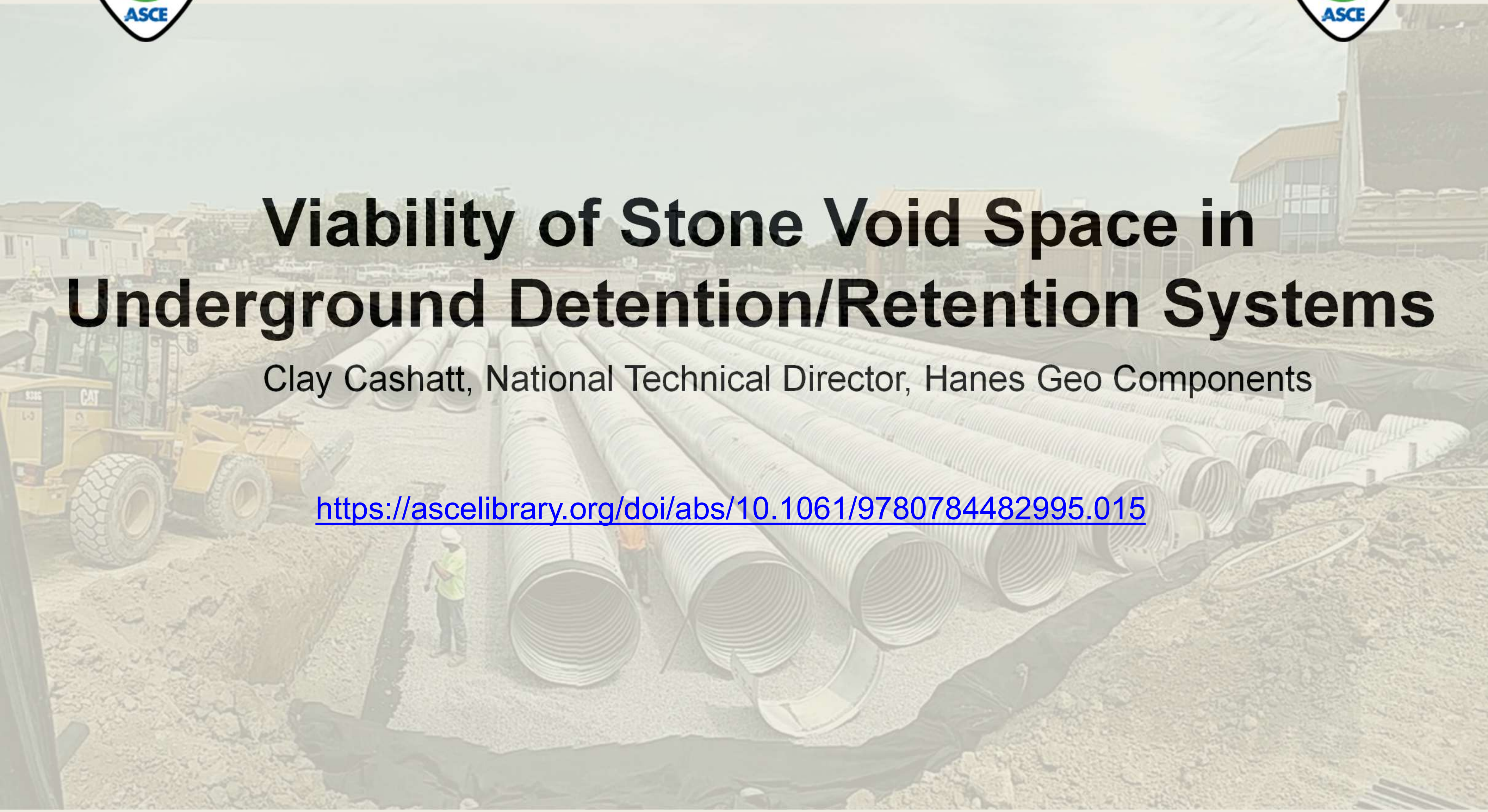
(Submitted/Approved)

Viability of Stone Void Space in Underground Detention/Retention Systems

Clay Cashatt[1]
Hanes Geo Components

ABSTRACT

Many designers and regulators are faced with increasing storage demands for regional and site-specific detention requirements. This is especially true in the Gulf Coast and Atlantic regions where major storms over the past two decades have redefined traditional flood plain maps and design rainfall intensities. Coupled with rising land values, Underground Detention/Retention Systems (UDS's) offer a safe and effective means of reclaiming land usage. The efficiency - total storage relative to total excavation - of the UDS greatly impacts cost and the resulting benefit of electing to use underground storage versus an open pond. Therefore, many manufacturers and designers find every available means of supplying required storm water storage, including utilization of air within stone backfill. Available materials, construction methods, and proper designs dramatically impact the long-term reliability of stone void space and associated risk of flooding.



Viability of Stone Void Space in Underground Detention/Retention Systems

Clay Cashatt, National Technical Director, Hanes Geo Components

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Clay Cashatt

- B.S., Civil Engineering (Construction Materials) - Texas A&M
- Started Career with CONTECH in 1999 – 5 years Houston, TX
  - Storm Sewer pipe for City, County, MUD's, HCFCD, Private
- Mirafi as Regional Engineer for Geosynthetics – Austin, TX
  - Filter fabric, geogrids, soil solutions
- Hill Country Site Supply 2006-2016 (Houston, Centex, DFW)
  - Drainage Pipe, Geosynthetics, Erosion Control
- Currently the National Technical Director for Hanes Geo
  - 50+ locations in North America
  - Largest Distributor of Geosynthetics and Erosion Control Products
- Holds several patents related to stormwater
  - VoidSaver underground detention system
  - StormSkimmer variable flow sediment basin skimmer

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Why Underground Detention?

- Increased Rainfall Intensities / Required Storage
  - Particularly along Gulf Coast
  - Harvey & Atlas 14
- Population Growth
- Available Land
- Land Values

Current Practice

40% air seems to be the default void ratio.

Current Practice

Tank and Chamber systems promote geotextiles and isolation chambers.

Regulations

Most UDSs are on private projects

- Engineer pressed by owner to save money
  - To over-design could cost them their client
- Some will specify a conservative systems for a slight price increase
- Many will design per the minimum required
  - Or whatever is dictated by the local agency
  - Most agencies have no regulations on stone use

Agencies already know about volume impacts of TSS

- HCFCD monitors sediment load in basins and channel
  - Understand design vs. available capacity
- State agencies such as TCEQ dictate defined sediment loading
  - Typically it is water quality related
  - How does that affect volume?
- Some agencies already limit void space usage
  - Restrict – voids not allowed at all
  - Reduce – Allow < 40%... Example: City of Dallas = 20%.

Is 40% Really the Right Number???

Considering:….

- Material availability/variability
- Construction-phase impacts
- Long-term Total Suspended Solids (TSS)

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Many designers and regulators are faced with increasing storage demands for regional and site-specific detention requirements. This is especially true in the Gulf Coast and Atlantic regions where major storms over the past two decades have redefined traditional flood plain maps and design rainfall intensities. Coupled with rising land values, Underground Detention/Retention Systems (UDS's) offer a safe and effective means of reclaiming land usage. The efficiency - total storage relative to total excavation - of the UDS greatly impacts cost and the resulting benefit of electing to use underground storage versus an open pond. Therefore, many manufacturers and designers find every available means of supplying required storm water storage, including utilization of air within stone backfill. Available materials, construction methods, and proper designs dramatically impact the long-term reliability of stone void space and associated risk of flooding.

Materials

$$Efficiency\ \% = \left(\frac{Total\ Supplied\ Storage}{Total\ Required\ Excavation}\right) x100\%$$

Materials

Porosity of Structural Backfill

Tech Sheet # 1
November 2012

General:
StormTech advises that a porosity of 40% is appropriate to use for the storage capacity of structural aggregate used in the bedding and embedment zones around StormTech chambers. This memo provides technical support for the use of a porosity of 40%. The major

40% porosity is appropriate for the clean, open graded, angular aggregate material StormTech recommends for foundation and embedment.

- Most of the porosity data available is based on a compacted condition. StormTech requires compaction of the foundation (bedding) and allows dumped aggregate

Test data indicates that the average porosity of all gradations of the *compacted* foundation is approximately 40%.

therefore exceeds 40% for typical StormTech systems.

Porosity is protected from soils migration by a non-woven geotextile that surrounds the entire system.

Materials

Compilation of Known Test Data:

Sample	Data Source	Porosity	Bulk Density	Test / Description
AASHTO # 4	StormTech lab		94.3 lbs/ft^3	dumped, corrected[1]
AASHTO # 57	StormTech lab	39.9%	87.2 lbs/ft^3	dumped, corrected[1]
AASHTO # 4	StormTech lab		103.0 lbs/ft^3	jigged & tamped, corrected[1]
AASHTO # 57	StormTech lab	45.4%	97.7 lbs/ft^3	jigged & tamped, corrected[1]
AASHTO # 57	NTH lab			tapped & agitated, dried[2]
AASHTO # 57	NTH lab	37.4%		tapped & agitated, dried[2]
AASHTO # 3	NTH lab			tapped & agitated, dried[2]
-1 ½"	Anderson Eng. Con	38.7%	96.8 lbs/ft^3	dry rodded, C29[3]
-1 ½"	Anderson Eng. Con		101.7 lbs/ft^3	dry rodded, C29[3]
-1 ½"	Anderson Eng. Con	35.3%	98.6 lbs/ft^3	dry rodded, C29[3]
-1 ½"	Anderson Eng. Con		93.6 lbs/ft^3	dry rodded, C29[3]
-1 ½"	Anderson Eng. Con	37.8%	98.7 lbs/ft^3	dry rodded, C29[3]
-3/4"	Anderson Eng. Con		100.3 lbs/ft^3	dry rodded, C29[3]
-3/4"	Anderson Eng. Con	41.3%	97.9 bs/ft^3	dry rodded, C29[3]
AASHTO # 4	Universal Eng. Serv		78.6 lbs/ft^3	rodded C29[4]
AASHTO # 57	Universal Eng. Serv	38.2%	79.8 lbs/ft^3	rodded C29[4]
AASHTO # 4	Universal Eng. Serv		70.8 lbs/ft^3	rodded C29[5]
AASHTO # 57	Universal Eng. Serv	38.5%	74.8 lbs/ft^3	rodded C29[5]
-1 ½" Crushed Rock	CTL Thompson TX		90.5 lbs/ft^3	rodded C29[6]
-1" Crushed Rock	CTL Thompson TX	38.9%	91.6 lbs/ft^3	rodded C29[6]
-1 ½" Crushed Conc	CTL Thompson TX		77.1 lbs/ft^3	rodded C29[6]

Materials

Aggregate Processing

Materials

Aggregate Testing

ASTM C29/29M -17a: Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate

ASTM C127 -15: Standard Test Method for Relative Density (Specific Gravity) and Absorption of Coarse Aggregate

Materials

Compilation of Known Test Data:

Sample	Data Source	Porosity	Bulk Density	Test / Description
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-1" Crushed Rock	CTL Thompson TX	38.9%	91.6 lbs/ft^3	rodded C29[6]
-1 ½" Crushed Conc	CTL Thompson TX		77.1 lbs/ft^3	rodded C29[6]

Materials

Plant	Product Name	Rodded pcf	Bulk Dry	% Voids
Biotite Muscovite Gneiss with Monzonite	#467	104.8	2.73	38.58226
	#67/#67	101.5	2.73	40.51621
	057 - #57/#6	100.6	2.73	41.04366
	078-#78M	98.5	2.73	42.27435
	No.57 Sone	102	2.72	39.90385
	No.789 Stone	100	2.72	41.0822
	No 6M	99	2.72	41.67138
	No.4 Stone	98	2.72	42.26056
Limestone	068	99.4	2.70	41.0019
	057	99.0	2.70	41.23932
	005	97.4	2.70	42.18898
	VA #78	94.2	2.70	44.08832
	VA #8	90.2	2.70	46.46249
Marble Schist	No. 57 Stone	106	2.79	39.11405
	No. 67 Stone	105	2.79	39.68845
	No. 7 Stone	105	2.79	39.68845
	NC 78 Stone	105	2.79	39.68845
	No. 89M Stone	103	2.79	40.83724
	No. 5 Stone	102	2.79	41.41163
	No. 5 Stone	95	2.61	41.66912
	No. 6M Stone	94	2.61	42.28313
	No. 789 Stone	94	2.61	42.28313
Meta-siltstone	#67/#67*	97.5	2.72	42.6511
	006/057	96.7	2.72	43.12165
	#467/467M	96.2	2.72	43.41575
	078-78M*	95.0	2.72	44.12158
Diorite & Quartz Diorite	NC #57M	110.5	2.79	36.56622
	OUT OF SPEC CLEAN	108.2	2.79	37.88656
	#57 Out of Spec REC	108.2	2.79	37.88656
	#67	108.2	2.79	37.88656
	#467	106.3	2.79	38.97728
	1/4" CLEAN	104.7	2.79	39.89578
	#78	102.2	2.79	41.33093
	BALLAST 4	100.3	2.79	42.42165
Quartz Diorite	OUT OF SPEC CLEAN	112.7	2.84	36.3417
	NC67	108.5	2.84	38.71406
	NC57	106.5	2.84	39.84375
	NC #467m	104.7	2.84	40.86048
	NC5	104.7	2.84	40.86048
	AREA 4	102.4	2.84	42.15962
	78M	100.5	2.84	43.23283
	No.57 Stone	99	2.63	39.67534
	No.6M Stone	98	2.63	40.28468
	No.5 Stone	96	2.63	41.50336
	No.67 Stone	96	2.63	41.50336
	No.4 Stone	95	2.63	42.1127
	No.7M Stone	95	2.63	42.1127
	No.89M Stone	95	2.63	42.1127
	No.789 Stone	94	2.63	42.72204
	501 Unwashed No.5	93	2.63	43.33138
	601 Unwashed No.6M	92	2.63	43.94072
	701 Unwashed No.7	92	2.63	43.94072
	891 Unwashed No.89	92	2.63	43.94072
	401 Unwashed No.4	90	2.63	45.1594
Granite porphyry & Monzonite	8a	97.1	2.63	40.83309
	5	96.8	2.63	41.01589
	67	96.5	2.63	41.19869
	57	94.1	2.63	42.66111
	8	90.4	2.63	44.91567
	No. 67 Stone	105	2.66	36.74089
	34 Stone	103.7	2.66	37.5241
	No. 57 Stone	102	2.66	38.54829
	No. 789 Stone	101	2.66	39.15076
Quartz Diorite & Granite	#57	110.3	2.72	34.99272
	#78	106.2	2.72	37.40913
	#8 Stone	104.6	2.72	38.35212
	#67	100.8	2.72	40.59172
	NON SPEC CLEAN	99.3	2.72	41.47577
	#5	99.1	2.72	41.59364
	89	98.2	2.72	42.12407
	BALLAST #4	92.7	2.72	45.3656
Clinoamphibole & Gneiss	#467M	98.9	2.65	40.29678
	#67	98.5	2.65	40.53824
	#57	96.9	2.65	41.50412
	#78M	96.9	2.65	41.50412
	#467M	104.6	2.71	38.12547
	#57	104.4	2.71	38.24378
	#67	104.4	2.71	38.24378
	#78M	100.2	2.71	40.72822
Limestone	PEA GRAVEL	99.9	2.70	40.72708
	Frederick #9	99.9	2.70	40.72708
	HE-6	99.9	2.70	40.72708
	AASHTO #7	97.6	2.70	42.09172
	#7M	97.6	2.70	42.09172
	AASHTO #57	96.1	2.70	42.98171
	AASHTO #8	95.4	2.70	43.39703
	AASHTO #67	93.5	2.70	44.52435
	AASHTO #6	93.1	2.70	44.76167

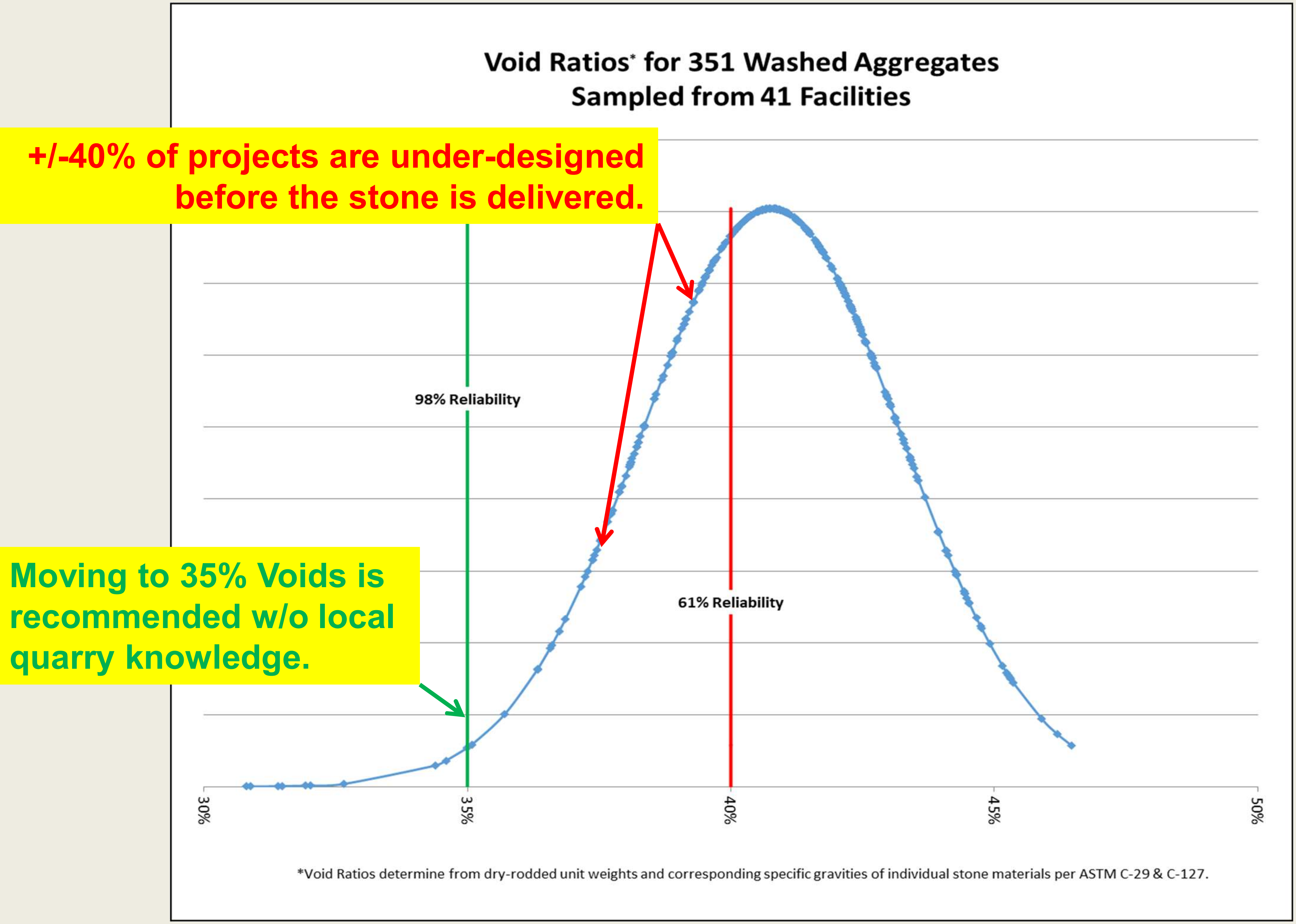
Plant	Product Name	Rodded pcf	Bulk Dry	% Voids
Silica Gravel	Pea Gravel	108	2.57	32.65489
Granodiorite & quartz diorite	604	104.6	2.69	37.72923
	O57	101.6	2.69	39.51519
	O67	101.6	2.69	39.51519
	O68	101.6	2.69	39.51519
	467	100.8	2.69	39.99145
	541	100.6	2.69	40.11052
	O78	99.4	2.69	40.82491
	178 NC78m	99.0	2.69	41.06303
	OO8	99.0	2.69	41.06303
	602	97.2	2.69	42.13462
	115 8p	94.8	2.69	43.56339
	601	93.2	2.69	44.51591
Quartz monzonite and quartz diorite	67/#67	103.3	2.73	39.40091
	057 - #57	101.3	2.73	40.57417
	078-#78M	99.3	2.73	41.74744
	005-#5	97.9	2.73	42.56872
	6M Stone	114	2.64	30.79837
	No. 57 Stone	113	2.64	31.4054
	No. 67 Stone	112	2.64	32.01243
	Unwashed #7	102	2.64	38.08275
	Unwashed 89	102	2.64	38.08275
	Unwashed #5	101	2.64	38.68978
	Unwashed #6	100	2.64	39.29681
	No. 7 Stone	100	2.64	39.29681
	No. 89M Stone	99	2.64	39.90385
	No. 4 Stone	98	2.64	40.51088
	No. 789 Stone	98	2.64	40.51088
	891 Unwashed No.89	111	2.74	35.07861
	No.57 Stone	101	2.74	40.92738
	No.5 Stone	98	2.74	42.68201
	601 Unwashed No.6M	97	2.74	43.26689
	No.6M Stone	97	2.74	43.26689
	No.789 Stone	95	2.74	44.43665
	701 Unwashed No.7	92	2.74	46.19128
Diabase	541	111	2.92	38.99711
	Va#57	109.2	2.92	39.98635
	Va#68	107.8	2.92	40.75575
	#7	107.6	2.92	40.86567
	Va #78	107.6	2.92	40.86567
	#67	106.8	2.92	41.30533
	#5 ballast	105.4	2.92	42.07474
	#5	105.4	2.92	42.07474
	1 CLEAN	105.2	2.92	42.18465
	3/4 CLEAN	104.8	2.92	42.40448
	Va# 8	103	2.92	43.39372
	1/2 CLEAN	102	2.92	43.94329
	7/16 CLEAN	99.6	2.92	45.26227
Granite Gneiss	068	102	2.62	37.53656
	057	97.8	2.62	40.10858
	008	97.0	2.62	40.59849
	115	97	2.62	40.59849
	Va #5	96.9	2.62	40.65973
	078	96.2	2.62	41.0884
Quartz diorite and granodiorite	#67/#67	106.0	2.85	40.42608
	005 - #5	105.0	2.85	40.9881
	006 - #6	103.0	2.85	42.11213
	078-#78M	103.0	2.85	42.11213
Amphibolite gneiss & amphibolite	#67	107	2.84	39.59289
	#5	103.3	2.84	41.68174
	#57M	103.3	2.84	41.68174
	NC #6	101.9	2.84	42.47211
	#78	100.9	2.84	43.03666
	No. 67 Stone	101	2.6	37.74655
	No. 57 Stone	100	2.6	38.36292
	6M Stone	100	2.6	38.36292
	No.789 Stone	98	2.6	39.59566
	No. 89 Stone	97	2.6	40.21203
	Unwashed #6	95	2.6	41.44477
	Unwashed #7	95	2.6	41.44477
	Unwashed 89	94	2.6	42.06114
Granite Gneiss	057 - #57	99.5	2.66	40.09982
	#467	99.1	2.66	40.34062
	078-78M	94.5	2.66	43.10987
Diorite & Quartz Diorite	#67	111	2.95	39.63983
	#5	109.8	2.95	40.29237
	#467	108.8	2.95	40.83616
	#78	107.7	2.95	41.43432
	BALLAST #4	107	2.95	41.81497
	89M	100.6	2.95	45.2952
Silica Gravel	#5 Stone	102.8	2.62	37.23457
	#57 Stone	102	2.62	37.72302
Silica Gravel	#8 Stone	101.2	2.62	38.21147
	#8P Stone	101.2	2.62	38.21147
	#6 Stone	100.1	2.62	38.88308
	57	105.1	2.57	34.38403
	8A	99.7	2.57	37.75536
Silica Gravel	#67	99.3	2.57	38.00509

Meta-argilite	NC 467	100.2	2.78	42.18076
	NC57	100	2.78	42.29616
	NC5	97.6	2.78	43.68106
	NC78M	96.9	2.78	44.08498
	1 1/2" STALITE	94.9	2.78	45.23906
Metagranite & quartz	VA #57	99.7	2.64	39.40584
	1/2" PRIME #601	97	2.64	41.04681
	VA 78	95.9	2.64	41.71535
	3/4" PRIME #602	95.3	2.64	42.08001
	VA #68 / MD #67	94.6	2.64	42.50544
	Va #8	94.5	2.64	42.56622
	115 Va #8P	94.5	2.64	42.56622
	1" PRIME #603	94.2	2.64	42.74855
	No. 57 Stone	98	2.57	38.89055
	601 Unwashed No. 6	98	2.57	38.89055
	No. 67 Stone	98	2.57	38.89055
	7891 Unwashed No. 789	98	2.57	38.89055
	501-Unwashed No. 5	97	2.57	39.51412
	No. 6M Stone	97	2.57	39.51412
	No. 789 Stone	96	2.57	40.13768
	No.57 Stone	100	2.6	38.36292
	67/Mixed Stone	100	2.6	38.36292
	No.6M Stone	98	2.6	39.59566
	No.5 Stone	94	2.6	42.06114
	No.789 Stone	94	2.6	42.06114
Granite	057	103.2	2.64	37.27866
	467	98.5	2.64	40.13516
	005	98.5	2.64	40.13516
	114 89m	98.2	2.64	40.31749
	006	97.6	2.64	40.68215
	541 4 bal	96.3	2.64	41.47224
	009	94.8	2.64	42.38389
	067	94.3	2.64	42.68777
	178 78m	93.9	2.64	42.93088
Limestone & dolostone	#57	106.4	2.79	38.88429
	#67	106	2.79	39.11405
	HANOVER #467	105.7	2.79	39.28637
	HANOVER #5	102.8	2.79	40.95212
	2"X 1/8" HC LS	102	2.79	41.41163
	FINE 8'S	101.1	2.79	41.92859
	FLUX STONE	100.7	2.79	42.15835
	1" X 1/4" HI CAL SCR	100.2	2.79	42.44555
	HICAL SCRUBBER	100.2	2.79	42.44555
	WHITE #7	100.1	2.79	42.50299
	#7	100.1	2.79	42.50299
	3/4" WHITE	100.1	2.79	42.50299
	H #7	100.1	2.79	42.50299
	AASHTO #9	99.3	2.79	42.9625
	#8 - M	99.2	2.79	43.01994
	#8	99.2	2.79	43.01994
	H #8	99.2	2.79	43.01994
Metagabbro & quartz diorite	RDM2	109.7	2.78	36.85595
	#57T	105.3	2.78	39.38862
	#5 Stone	102.8	2.78	40.82763
	#467	102.7	2.78	40.88519
	#57 Stone	102	2.78	41.28812
	Pea Gravel	101.8	2.78	41.40324
	#8 Stone	101.2	2.78	41.7486
	#8P Stone	101.2	2.78	41.7486
	#67	101.1	2.78	41.80616
	#7 Stone	100.6	2.78	42.09397
	HDG 7's	100.3	2.78	42.26665
	HdG 6's	100.1	2.78	42.38177
	#6 Stone	100.1	2.78	42.38177
Granite Gneiss	#67	104.4	2.66	37.14996
	#57	103.9	2.66	37.45096
	#467M	97.6	2.66	41.24364
	#78M	97.3	2.66	41.42424
	005- #5	96.3	2.66	42.02625
Granite & granodiorite	1/2"	101.6	2.68	39.29034
	68M	99.8	2.68	40.36591
	57	99.4	2.68	40.60492
	467m	99.2	2.68	40.72443
	5b	99.2	2.68	40.72443
	F57	98.3	2.68	41.26221
	1"	97.5	2.68	41.74024
	1 3/8"	96.6	2.68	42.27802
	68	96.6	2.68	42.27802
	8A	95.2	2.68	43.11457
	8	94.7	2.68	43.41334
	8p	94.7	2.68	43.41334
	3/4"	93.3	2.68	44.24989
Silica Gravel	Pea Gravel	102.1	2.57	36.33393
	Unwashed 789/Asphalt Sand	113	2.62	30.88178
	No. 57 Stone	99	2.62	39.4451
	501-Unwashed No. 5	98	2.62	40.05676
	601-Unwashed No. 6	98	2.62	40.05676
	No. 789 Stone	97	2.62	40.66843

Granite & quartz diorite	#5	99.2	2.57	38.06752
	9	96.4	2.57	39.81561
	57	108.1	2.77	37.37289
	67	108.1	2.77	37.37289
	8	101.4	2.77	41.2545
Quartz Monzonite	57 STONE - CLEAR CREEK	106.5	2.69	36.59811
	#57	101.3	2.69	39.69379
	078	100.6	2.69	40.11052
	SC #789	100.6	2.69	40.11052
	467M SEPTIC TANK STONE	99.8	2.69	40.58678
	67s	99.7	2.69	40.64631
	RAILROAD BALLAST	98.9	2.69	41.12257
	1 3/8" X 1"	97.9	2.69	41.71789
	GOLD HILL 78S	96.9	2.69	42.31321
	3/8" CLEAN	96.3	2.69	42.67041
	089	95	2.69	43.44433
	1" X 5/8"	93.6	2.69	44.27778
	5/8" X 3/8"	93.6	2.69	44.27778
Mylonite	3/4" Clean	110.7	2.59	31.47607
	5	100.7	2.59	37.66613
	57	100	2.59	38.09943
	68M	100	2.59	38.09943
	57M	99.9	2.59	38.16133
	68	99.7	2.59	38.28513
	78	98.3	2.59	39.15174
	78R	98.2	2.59	39.21364
	78M	97.6	2.59	39.58505
	8	96.9	2.59	40.01835
Basalt	VA #5	112.1	2.89	37.9232
	VA #67	109.2	2.89	39.52911
	VA #57	109.1	2.89	39.58449
	VA #78	106.7	2.89	40.91352
	VA #8	103.4	2.89	42.74093
	Pea Gravel	99.8	2.89	44.73448
Quartz monzonite & granite	068	98.3	2.70	41.75383
	057	97.1	2.70	42.46487
	005	96.6	2.70	42.76114
	457 sma 57	95.7	2.70	43.29442
	008	95.5	2.70	43.41293
	067	95.4	2.70	43.47218
	467	95.3	2.70	43.53144
	115 8p	93.8	2.70	44.42024
	268 sma 68	93.7	2.70	44.47949
	178 78m	93.4	2.70	44.65725
	278 sma 778	92.3	2.70	45.30904
	078	91.3	2.70	45.90158
Gabbro	NC #67	109.1	2.95	40.81438
	NON SPEC #67	107.9	2.95	41.46537
	NC #5	107.6	2.95	41.62812
	NC #57	107.1	2.95	41.89936
	NC #78	105.9	2.95	42.55035
	NO 9 WASHED	104.8	2.95	43.14709
Granite	5	100.7	2.60	37.93146
	57	100.0	2.60	38.36292
	68	99.7	2.60	38.54783
	8	90.4	2.60	44.28008
Amphibolite gneiss	#57	118.3	3.10	38.79689
	005- #5	117.0	3.10	39.46945
	#467M	111.4	3.10	42.36664
	#78M	107.4	3.10	44.43606
Amphibolite	VA #57	109.6	2.93	40.05426
	078	108	2.93	40.92938
	#67	107.4	2.93	41.25755
	VA #68	107.4	2.93	41.25755
	SMA #78	106.7	2.93	41.64041
	3/4" CLEAN	106	2.93	42.02328
	VA #8	105.5	2.93	42.29675
	8 Ps	105.5	2.93	42.29675
	SMA #6	104.3	2.93	42.95309
Quartz diorite gneiss and quartz diorite	467's	115.3	2.71	31.93191
	non spec clean	110.8	2.71	34.58852
	NC 57M	103.2	2.71	39.07523
	NC 67	102.1	2.71	39.72462
	#5	101.2	2.71	40.25594
	NC 78	101	2.71	40.37401
	#6	100.8	2.71	40.49208
	#4 BALLAST	99.8	2.71	41.08244
Dolostone & limestone	AASHTO #7	107.2	2.81	38.86303
	7H	107.2	2.81	38.86303
	AASHTO #467	104.9	2.81	40.17474
	AASHTO #8	104.8	2.81	40.23177
	AASHTO #8H	104.8	2.81	40.23177
	AASHTO #8-1%	104.8	2.81	40.23177
	#5	103.6	2.81	40.91614
	AASHTO #57	103.3	2.81	41.08723
	Type 3-A Anti-Skid	101.3	2.81	42.22785
	#9	101.3	2.81	42.22785

351 samples from 41 quarries and 28 types of stone.

Materials



Void Ratios* for 351 Washed Aggregates
Sampled from 41 Facilities
+/-40% of projects are under-designed before the stone is delivered.
98% Reliability
61% Reliability
Moving to 35% Voids is recommended w/o local quarry knowledge.
30%
35%
40%
45%
50%
*Void Ratios determine from dry-rodded unit weights and corresponding specific gravities of individual stone materials per ASTM C-29 & C-127.

Materials

Cherry Crushed Concrete (Houston)

Plant	Crusher type	Material Type	Date Sampled	3" %ret	2.5"% ret	1.75"% ret	1" re	% ret	#50 % ret	%Error	UW Rodded (pcf)	UW Loose (pcf)	Average Gbulk	%Voids Rodded	%Voids Loose
Holmes	Jaw Cone	Screened CC 1.5"	10/10/2020	0.0%	0.0%	0.0%	64.	7.1%	98.3%	0.43%	82.3	72.9		39.5%	46.6%
Crawford	Jaw Cone	Screened CC 1.5"	9/30/2020	0.0%	0.0%	0.0%	81.	8.9%	99.4%	-0.02%	81.4	76.8	2.19	40.2%	43.7%
Crawford	Jaw Cone	Screened CC 1.5"	10/1/2020	0.0%	0.0%	0.0%	58.	8.8%	99.3%	-0.03%	81.5	75.7	2.16	40.2%	44.5%
Holmes	Jaw Cone	Screened CC 1.5"	10/4/2020	0.0%	0.0%	0.0%	74.	8.8%	99.3%	-0.01%	78.9	71.0	2.17	42.0%	47.9%
FM 521	Jaw Cone	Screened CC 1.5"	10/6/2020	0.0%	0.0%	0.0%	71.	8.2%	98.9%	-0.01%	81.4	76.8	2.22	40.2%	43.7%
FM 521	Jaw Cone	Screened CC 1.5"	10/9/2020	0.0%	0.0%	60.8%	77.	9.0%	99.4%	0.00%	84.1	73.7	2.19	38.2%	45.9%
Averages				0.00	0.00	10.1%	71.	8.5%	99.1%	0.00	81.60	74.47	2.19	40.1%	45.4%
Std													0.02	1.1%	1.6%

Average Gbulk	%Voids Rodded	%Voids Loose
	39.5%	46.6%
2.19	40.2%	43.7%
2.16	40.2%	44.5%
2.17	42.0%	47.9%
2.22	40.2%	43.7%
2.19	38.2%	45.9%
2.19	40.1%	45.4%
0.02	1.1%	1.6%

Construction Phase - Open Pits

Construction Phase - Open Pits

Construction Phase - Open Pits

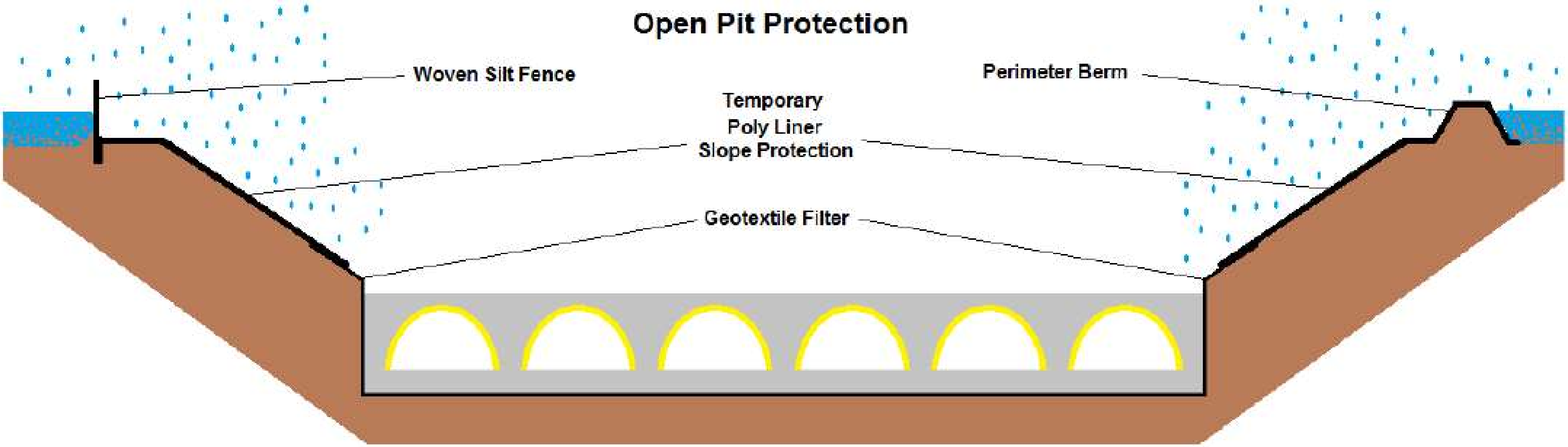


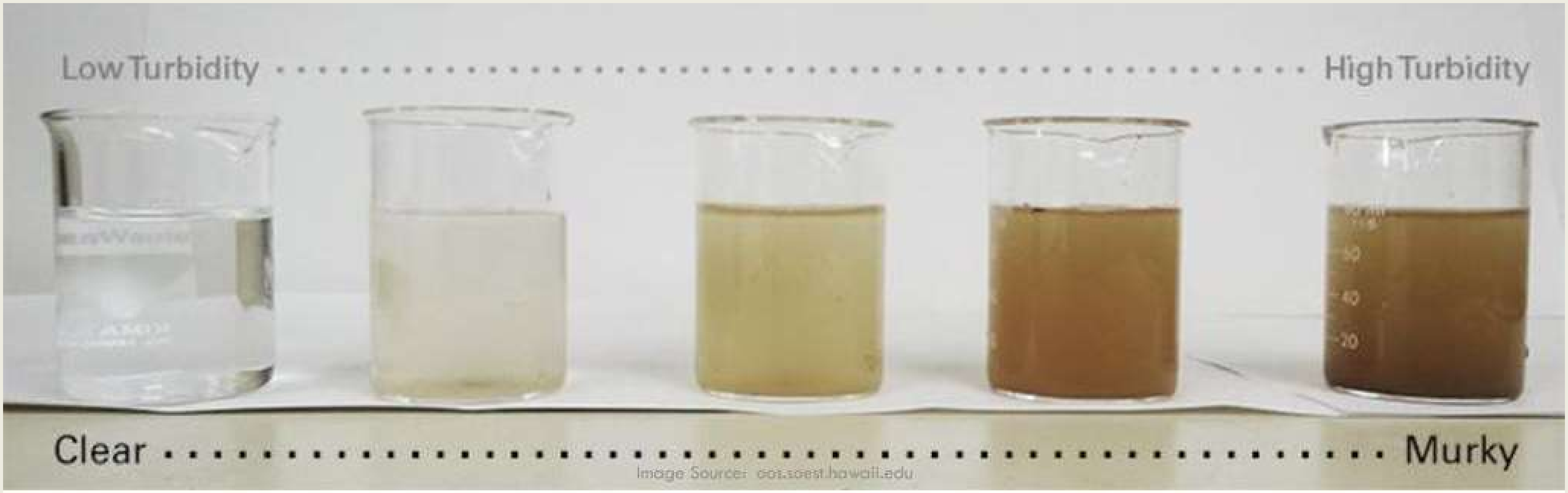
Image 5 – Examples of BMPs used to protect against contaminated runoff.

Construction Phase – Storm Sewer System

Construction Phase – Storm Sewer System
Voids Protection Options

- Do nothing
  - Account for losses in design
- Typical BMPs – Inlet protection, street sweeping, polymers
  - Requires good onsite inspection and reputable contractors
- Upstream Treatment
  - Filter systems
- Don't use the void space during construction
  - Plug or Bypass the system
  - Product configuration

Long-Term TSS

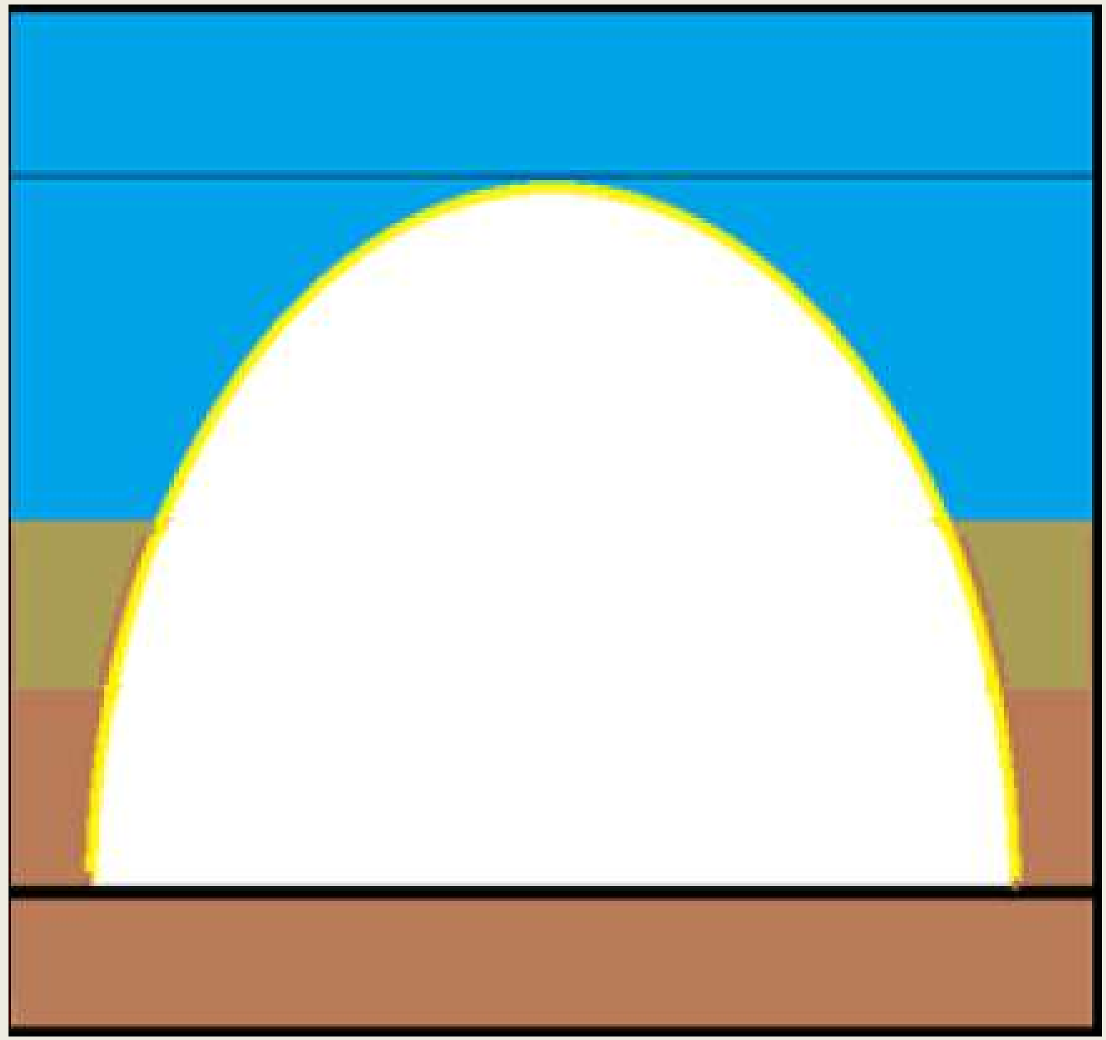


TCEQ - TSS can be over 1000lb/ac/yr = 10cf/ac/yr

Design

Long-Term TSS

Lower extremities are naturally more prone to clogging.



Design

Long-Term TSS

Taller system bedding will clog faster than comparable shorter system.

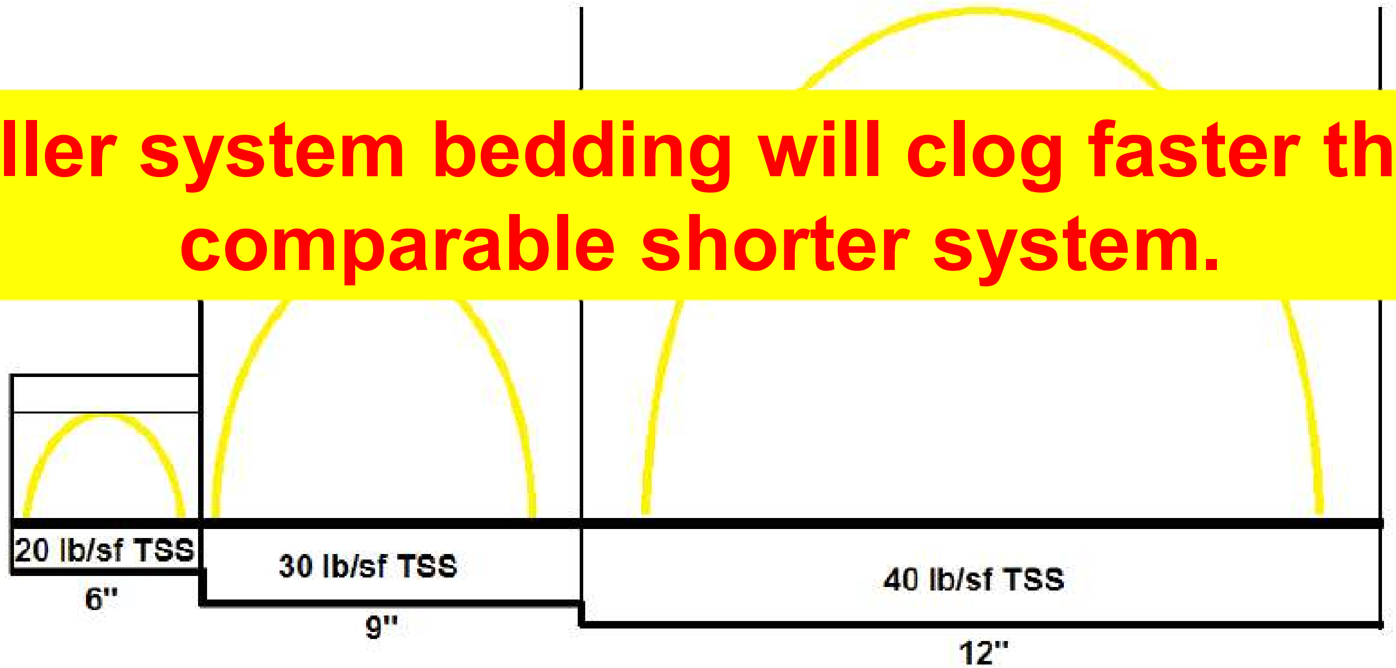


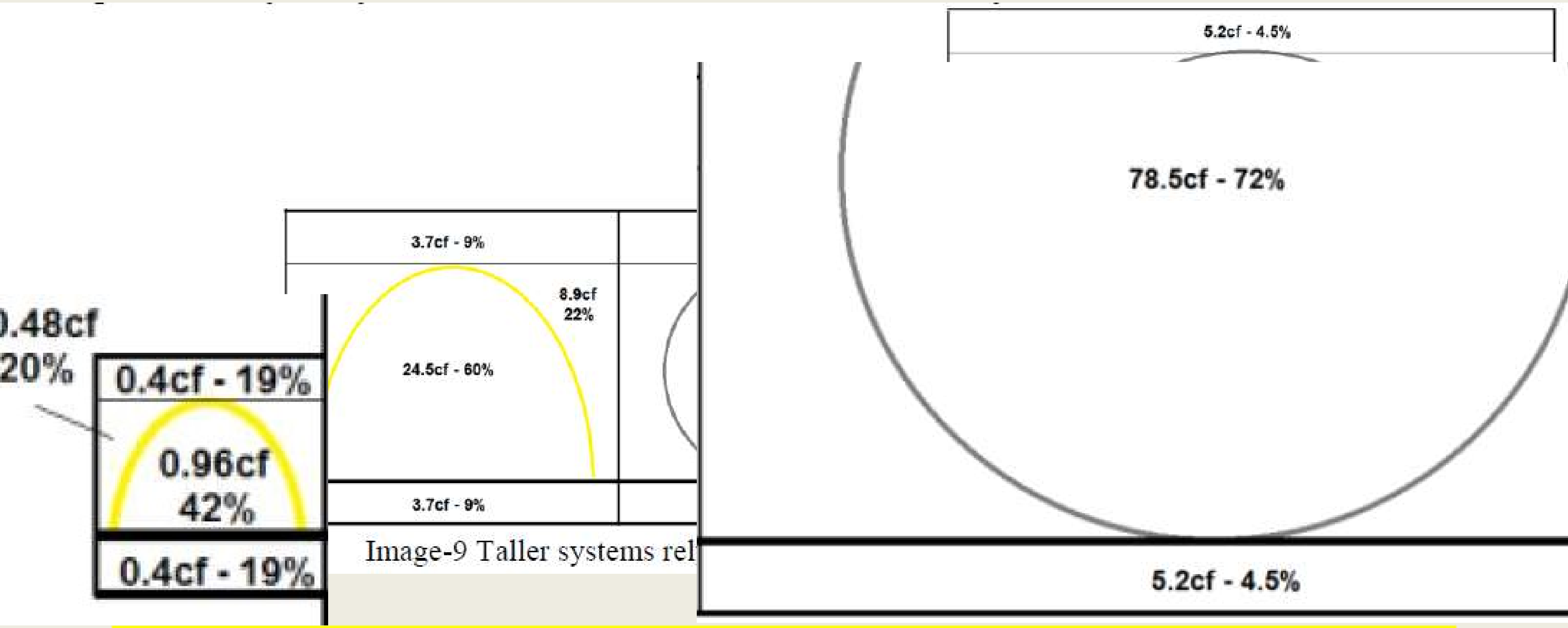
Image-10 Sediment capacity of bedding

So, for example, assuming the bedding is pristine after construction, using Images-9 & 10:

- A 3-acre site with required storage of 10,000cf using a 12" arch product and 6" bedding would require a surface area of about 9000sf. It could yield 3000lb/yr of TSS and could fully clog in roughly 60 years. 9000sf x 20lb/sf x yr/3000lb = 60 years.
- The same 3-acre site using a 60" arch product and 12" bedding would only require a surface area of about 2300sf. 2300sf x 40lb/sf x yr/3000lb = 31 years.

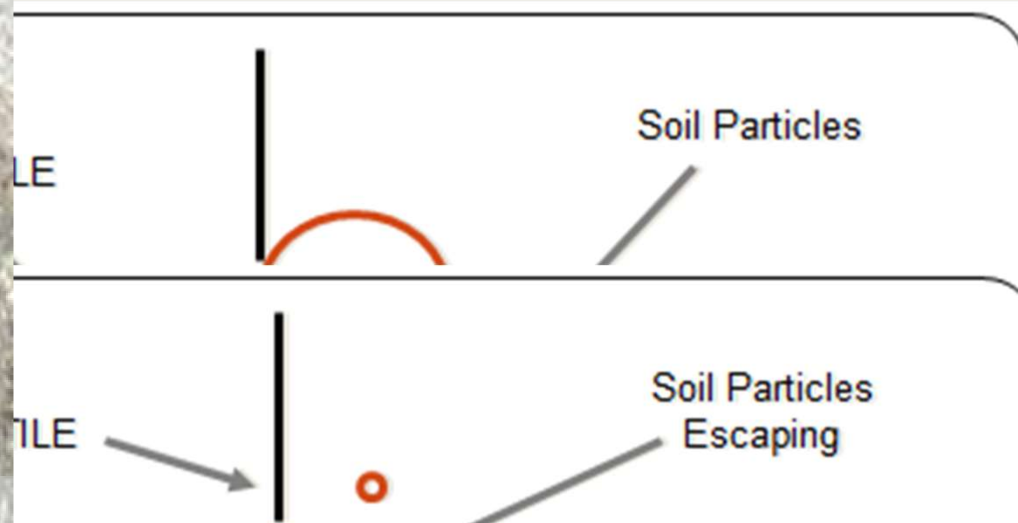
Design

Long-Term TSS



Shorter systems have higher flooding risk if the bedding clogs – designer should consider using a sacrificial bedding

Design



- Risk of piping of s
  - Clogs bedding
- Improper use of G

NEW ASTM STANDARDS FOR EVALUATING STORMWATER CONTROL MEASURES

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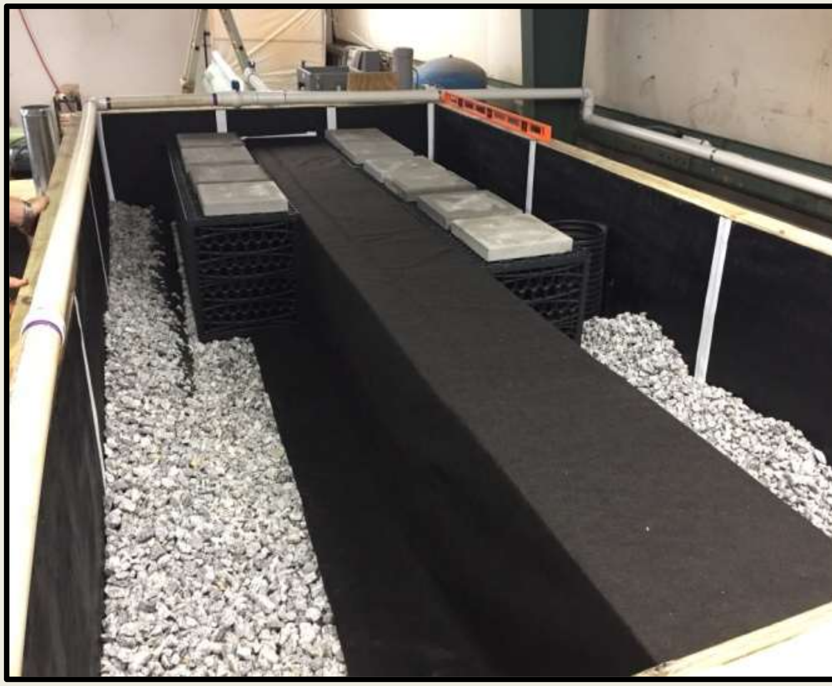
ABSTRACT

Manufactured Treatment Devices (MTDs) are post-construction stormwater control measures (SCMs) that are used as offline or inline treatment devices along storm drain pipe lines to remove stormwater borne pollutants. An MTD can employ settling, filtration, and/or other processes to remove pollutants from runoff. The increased use of MTDs and the increasing number of systems have prompted the need for consensus standards to characterize the performance of these technologies. It has been recognized that it is important to establish, through the testing of full-sized commercial units, the limits for an MTD's pollution removal capabilities. To-date, performance evaluations have been governed by leading regulators, such as the New Jersey Department of Environmental Protection (via the NJCAT program) and the Washington State Department of Ecology (via the TAPE program). But, looking to the future, regulators and the MTD industry are working together to establish a nationwide verification/certification program based on international standards developed by ASTM. Development of standards for these post-construction MTDs is largely taking place in ASTM's Subcommittee C27.70 on Precast Concrete Products for Stormwater Management. A few ASTM standards (C1745, C1746, and C1814) have been developed to-date, but several more are under development. This paper reviews the current programs being used to characterize MTD performance and then details the consensus standards that are being developed within the ASTM process to evaluate the water quality enhancement effectiveness of the larger family of post-construction stormwater control measures (SCM's).

Design

Long-Term TSS

ASTM C1746 - Standard Test Method for Measurement of Suspended Sediment Removal Efficiency of Hydrodynamic Stormwater Separators and Underground Settling Devices



Design

Long-Term TSS

Table 2. Hydraulic Performance And Sediment Removal Efficiency

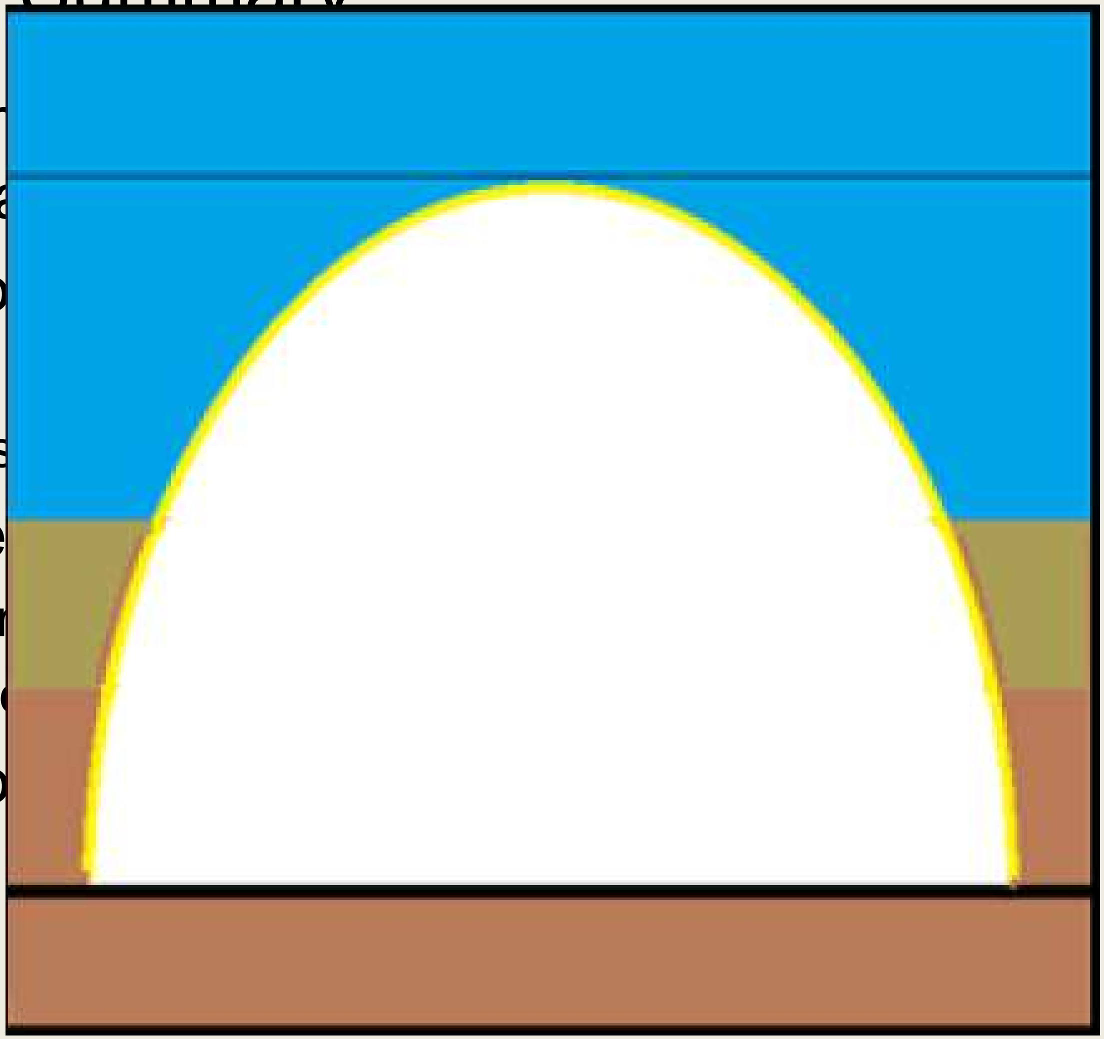
Test Date:	9/19/18	9/18/18	9/17/18	9/20/18	9/20/18	9/25/18
Flow Rate (gpm):	20.1	39.9	58.9	80.8	101.2	119.9
Hydraulic Loading Rate (gpm/ft^2):	1.30	2.59	3.83	5.25	6.57	7.79
Maximum Stage (in):	4.25	6.00	7.00	8.00	9.00	10.00
Depth in Chamber (in):	1.75	2.00	2.25	2.50	2.75	3.00
SOLIDS MASS BALANCE:						
Retained Solids - Within Units (lbs):	16.68	14.81	13.43	12.09	11.99	11.71
Passed Solids (lbs):	0.12	0.19	0.22	0.28	0.36	0.50
Actual Solids Injected (lbs):	23.12	22.59	23.58	22.73	23.00	22.92
Unaccounted Solids - Within Basin (lbs):	6.32	7.59	9.93	10.35	10.66	10.71

Geotextile allowed 27%-46% of TSS to pass into voids.

Design

Long-Term TSS Summary

- Bedding in taller system
percentage of total stora
- Clogged bedding in sho
since the total supplied
  - Perforated underdrains s
- Conservative design ne
  - Sacrificial Bedding Layer
  - Protects against constru
- Geotextiles provide poo



ASCE-EWRI Congress 2020

Henderson, NV, May, 2020

(Submitted/Approved)

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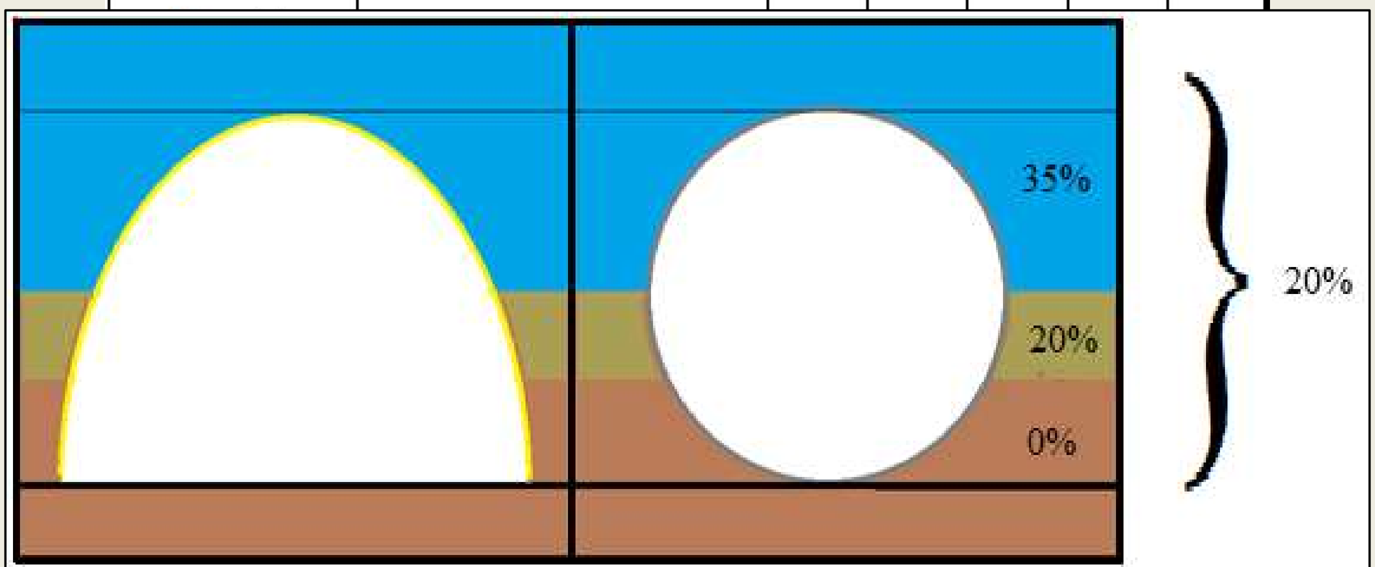
Design Recommendations

	Allowable Void Ratio*	20%	30%	35%	40%	40%+
	Certified tests of supplied material					✔
Design	Upstream Treatment or Restricted use of voids			✔	✔	✔
	Sacrificial bedding stone		✔	✔	✔	✔



*20% minimum ratio. Higher ratios applied to backfill material, only. Bedding ratio = 0%

Viability of Stone Void Space in Underground Detention/Retention Systems

ASCE-EWRI Congress 2020

Henderson, NV, May, 2020

https://ascelibrary.org/doi/abs/10.1061/9780784482995.015

Questions

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