Storm Water Drainage System Report of Shree Hiranyakeshi Sahakari Sakkare Karkhane Niyamit., Sankeshwar, Tq- Hukkeri, Dist- Belgaum, State- Karnataka – 591 305.

Designing a simple storm water drainage system:-

The size of the drain for collecting and carrying storm water at a given catchment area is calculated as below:

Data required-

1. A map of the catchment area with gradient lines and contour lines, the gradients and boundaries can be calculated.

2. Rainfall intensity in the catchment area.

The rainfall intensity of the area is found out from the local IDF -curves (intensity-duration-frequency curve), if IDF-curve is not available, rainfall intensity of 100 mm/hr shall be considered (this value is for tropical countries, with catchment areas smaller than 150 ha).

Analysis of the catchment area-

The gradient of the catchment area, terrain configuration in the catchment area can be found out from the Map and the Runoff factors for the different terrain are given as below.

Table 1: Coefficient of Runoff Values for Different Terrain.

Sr. No.	Terrain type	'C' Coefficient of Runoff (Flat terrain)
1	Clayey soil	0.8
2	Parking area	0.8
3	Greenbelts	0.15

From the study the average gradients of respective area is 2% and rainfall intensity is taken as 100 mm/hr (i.e. 4 inch/hr).

- **Storm water Discharge calculations:**

Using Rational formula i.e. Q = CIA

Where Q - is design peak runoff rate Ft^3/sec.

I - Rainfall Intensity value in inch/hr.

A - Catchment area in Acre.
C – Unit less quantity called Coefficient of Runoff, shown in table1.

- **Velocity Calculations:**

1. Minimum Velocity for Preventing Sedimentation-

To ensure that deposition of suspended solids does not take place, self-cleansing velocities using Shield's formula is considered in the design of drainage.

$V=1/n\ [R^{(1/6)}\ \{K_S\ (S_S - 1)\ d_P\}]^{0.5}$

Where, n – Mannings "n"

R - Hydraulic Mean Radius in m

K_S - Dimensionless constant with a value of about 0.04 to start motion of granular particles and about 0.8 for adequate self cleansing of sewers.

SS – Specific gravity of particles

d_P – Particle size in mm

In above formula velocity depend on the particle size and specific gravity and slightly dependent on conduit shape and depth of flow.

Table 2: Design velocities to be ensured in gravity flow

Sr. No.	Criteria	Value
1	Minimum velocity at initial peak flow	0.6 m/s
2	Minimum velocity at ultimate peak flow	0.8 m/s
3	Maximum velocity	3 m/s

Source: WPCF, ASCE, 1982

2. Maximum Velocity-

Erosion is caused by sand and other gritty material and is compounded by high velocities and hence the maximum velocity shall be limited to 3 m/s.

Mannings formula for gravity flow -

$$V=1/n\ [R^{(2/3)}.S^{(1/2)}]$$

Where, V – Velocity

S – Slope of hydraulic gradient

R – Hydraulic radius in meter (R=A/P, A – wetted area & P – Wetted perimeter)

n – Mannigs coefficient of roughness (n for concrete is 0.011)

I. Storm water Discharge calculations:

Using Rational formula i.e. Q=CIA

Where Q - Design peak runoff rate in cfs

I - Rainfall Intensity value in inch/hr (taken as 4 inch/hr).

A - Catchment area in Acre.

C – Unit less quantity called Coefficient of Runoff, (taken from Table1).

Table3: Storm water discharge calculations.

Area No.	Area Description	C	I in inch/hr	A in m^2	Factor for (m^2 to Acre)	A in Acre	Q (cfs)	Factor for (cfs to m^3/s)	Q (m3/s)
1	Open Space	0.8	4	2855	4046.86	0.7055	2.257553	35.3147	0.064
	GB	0.15	4	3472	4046.86	0.8579	0.514769	35.3147	0.015
2	Open Space	0.8	4	2296	4046.86	0.5674	1.815531	35.3147	0.051
	GB	0.15	4	1974	4046.86	0.4878	0.292671	35.3147	0.008
3	GB	0.15	4	23222	4046.86	5.7383	3.442966	35.3147	0.097
4	Open Space	0.8	4	6381	4046.86	1.5768	5.04569	35.3147	0.143
	GB	0.15	4	2500	4046.86	0.6178	0.370658	35.3147	0.010
5	Open Space	0.8	4	6381	4046.86	1.5768	5.04569	35.3147	0.143
	GB	0.15	4	2500	4046.86	0.6178	0.370658	35.3147	0.010
6	Open Space	0.8	4	3455	4046.86	0.8537	2.731995	35.3147	0.077
	GB	0.15	4	22493	4046.86	5.5581	3.334882	35.3147	0.094
7	GB	0.15	4	9616	4046.86	2.3762	1.425698	35.3147	0.040
8	Open Space	0.8	4	3953	4046.86	0.9768	3.125781	35.3147	0.089
	GB	0.15	4	2852	4046.86	0.7047	0.422846	35.3147	0.012
9	Open Space	0.8	4	3223	4046.86	0.7964	2.548544	35.3147	0.072
	GB	0.15	4	2252	4046.86	0.5565	0.333888	35.3147	0.009
10	Open Space	0.8	4	4366	4046.86	1.0789	3.452356	35.3147	0.098
	GB	0.15	4	2852	4046.86	0.7047	0.422846	35.3147	0.012
11	Open Space	0.8	4	1740	4046.86	0.4300	1.375882	35.3147	0.039
12	Open Space	0.8	4	2754	4046.86	0.6805	2.177688	35.3147	0.062
	GB	0.15	4	14102	4046.86	3.4847	2.090806	35.3147	0.059
13	Open Space	0.8	4	7037	4046.86	1.7389	5.564413	35.3147	0.158
14	Open Space	0.8	4	28097	4046.86	6.9429	22.21732	35.3147	0.629
15	Open Space	0.8	4	9463	4046.86	2.3384	7.48274	35.3147	0.212
16	Open Space	0.8	4	15107	4046.86	3.7330	11.94566	35.3147	0.338
17	Open Space	0.8	4	36357	4046.86	8.9840	28.74881	35.3147	0.814

18	Open Space	0.8	4	47900	4046.86	11.8363	37.87628	35.3147	1.073
19	Open Space	0.8	4	17998	4046.86	4.4474	14.23168	35.3147	0.403
20	Open Space	0.8	4	10747	4046.86	2.6556	8.498045	35.3147	0.241
21	Open Space	0.8	4	20113	4046.86	4.9700	15.90408	35.3147	0.450
22	Open Space	0.8	4	6739	4046.86	1.6652	5.328773	35.3147	0.151
23	Open Space	0.8	4	14406	4046.86	3.5598	11.39135	35.3147	0.323
24	Open Space	0.8	4	7432	4046.86	1.8365	5.876754	35.3147	0.166

Note:

To convert m^2 to Acre: A (Acre) = [A (m^2) / 4046.86]

To convert Q (cfs) in to Q (m^3/s): [Q (m^3/s) = Q (cfs) / 35.3147]

Open Space – It is area of particular land inside the factory after deduction of greenbelt area, built up area and roads etc.

Table 4: Discharge calculation along the drainage path

Path	Description of path	Discharge
A	Total discharge of area **1**	0.0785
B	Total discharge of area **2**	0.0597
C	Total discharge of area **3**	0.0975
D	Total discharge of area **4**	0.1534
D'	Total discharge of **A** and area **3**	0.2319
E	Total discharge of area **5**	0.1534
E'	Total discharge of **B** and area **5**	0.2131
F	Total discharge of area **6**	0.1718
F'	Total discharge of drainage line **D'** and area **6**	0.4037
F"	Total discharge of drainage line **K'** and area **6**	0.2108
G	Total discharge of area **7**	0.0404
G'	Total discharge of drainage line **E'** and area **7**	0.2534
H	Total discharge of area **8**	0.0885
H'	Total discharge of **C** and area **8**	0.186
I	Total discharge of area **9**	0.0816
I'	Total discharge of drainage line **G'** and area **9**	0.3351
J	Total discharge of area **10**	0.1097

J'	Total discharge of drainage line **H'** and area **10**	0.1982
K	Total discharge of area **11**	0.039
K'	Total discharge of drainage line **I'** and area **11**	0.374
L	Total discharge of area **12**	0.1209
L'	Total discharge of drainage line **J'** and area **12**	0.3191
M	Total discharge of area **13**	0.1576
N	Half discharge of area **14**	0.6291
N'	Total discharge of **M** and area **14**	0.7867
O	Total discharge of area **15**	0.2119
O'	Total discharge of drainage line **N'** and area **15**	0.9986
P	Total discharge of area **16**	0.3383
Q	Total discharge of area **17**	0.8141
Q'	Total discharge of **P** and area **17**	1.1523
Q"	Total discharge of drainage line **O'** and drainage line **Q'**	2.1509
R	Total discharge of area **18**	1.0725
S	Total discharge of area **19**	0.403
S'	Total discharge of drainage line **Q''** and area **19**	2.5539
T	Total discharge of area **20**	0.2406
T'	Total discharge of **R** and area **20**	1.3132
U	Total discharge of area **21**	0.45
U'	Total discharge of drainage line **S'** and area **21**	3.0043
U"	Total discharge of drainage line **T'** and area **21**	1.7635
V	Total discharge of area **22**	0.151
W	Total discharge of area **23**	0.323
W'	Total discharge of V and area **23**	0.473
X	Total discharge of area **24**	0.166
X'	Total discharge of drainage line **U''** and area **24**	1.9299
X"	Total discharge of drainage line **W'** and area **24**	0.489

Note:

Number used in the above table indicating the specific area locations, see in **Figure1.**

Alphabets used in the above table indicating drainage path inside the factory area see in **Figure1.**

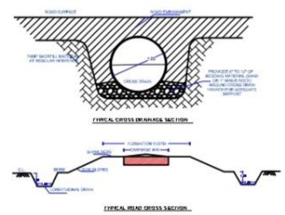
Descriptions of all the areas and drainage line and all the notations used in the report shown in F**igure 1**

SYMBOLS

SR NO	DESCRIPTION	SHOWN AS
1)	RAIN WATER HARVESTING PIPE LINE	(red line)
2)	STORM WATER GUTTER	(pink line)
3)	COMPOUND WALL	(blue line)
4)	CROSS DRAINAGE WORK	(symbol)
5)	AREA NUMBERS FOR RAINWATER CALCULATION	1,2,3,4,......
6)	CROSS DRAINAGE NUMBERS	I,II,III,IV,....
8)	PATH FOR DRAINAGE LINE	A,B,C,D,....

AREA UNDER UTILITIES

SR. NO.	DESCRIPTION	AREA IN Sq.M.
1)	SUGAR DIVISION	
i.	MILL HOUSE (OLD + NEW)	4903.83
ii.	BOILING HOUSE	4361.11
iii.	POWER HOUSE	794.62
iv.	STORE OFFICE	201.12
v.	GENERAL STORE & CHEMICAL SHED	1306.04
vi.	WORKSHOP	360.44
vii.	ENGG. OFFICE	112.60
viii.	TIMBER YARD	360.04
ix.	STORES	1113.31
x.	VEHICAL SHED & AUTOMOBILE WORKSHOP	2290.00
xi.	COOLING TOWER PH. I	818.33
xii.	DM PLANT	149.09
xiii	GODOWN 2 TO 5 & 8 TO 11	10878.82
xiv	GODOWN NO 3 8 & 11	2918.48
xv	GODOWN NO 12 TO 14	3708.87
xvi	SULPHUR GODOWN	215.87
2)	CO-GENRATION DIVISION	
i.	TURBO GENRATOR 1 & 2	1567.66
ii.	BOILER 1 & 2	1886.67
iii.	E S P 1 & 2	1644.31
iv.	COAL YARD	6616.43
v.	BAGASSE YARD	6662.84
3)	DISTILLERY DIVISION	
i.	MOLASSES TANK 1 TO 3	3010.63
ii.	MOLASSES PIT	632.62
iii.	RS	4611.05
iv.	WATER TANK	866.61
v.	WATER RESERVOIR	720.49
vi.	OTHER UNITS	607.63
3)	GUEST HOUSE	689.21
4)	GENERAL OFFICE	2713.94
5)	RAJAT NIWAS	400.28
6)	CANTEEN	605.36
6)	ETP	2966.96
TOTAL AREA UNDER UTILITIES		68068.81 Sq.M.



RAIN WATER HARVESTING AREA CALCULATIONS

SR NO	BUILDING NAME	BUILT UP AREA IN Sq.M	PEAK RAINFALL IN M/Hr	AVG RUNOFF COEFF (Avg)	AREA OF TANK REQUIRED (Sq.M.)	LENGTH (M.)	BREADTH (M.)	AREA OF TANK PROVIDED (Sq.M.)	HEIGHT (M.)
1)	GODOWN 2 TO 5 & 8 TO 11	10878.82	0.025	0.80	217.58	20.00	11.00	220.00	1.50
2)	GODOWN NO 3 8 & 11	2918.48	0.025	0.80	58.33	10.00	8.00	80.00	1.50
3)	GODOWN NO 12 TO 14	3708.87	0.025	0.80	74.17	10.00	7.50	75.00	1.50
4)	GUEST HOUSE	689.21	0.025	0.80	13.78	5.00	3.00	15.00	1.50
5)	OFFICE	2713.94	0.025	0.80	54.28	10.00	5.50	55.00	1.50
6)	RAJAT NIWAS	400.28	0.025	0.80	8.01	4.00	2.50	10.00	1.50
7)	CANTEEN	605.35	0.025	0.80	12.11	5.00	3.00	15.00	1.50
	POWER HOUSE	464.00	0.025	0.80	9.28	4.00	2.50	10.00	1.50

Figure1: Drainage Map

Drainage line design

A. Area, Breadth and Height calculations of the Drainage system:

Where, Q – Discharge or runoff flow in m^3/s

V_{as} – Assumed velocity in m/s

A- Cross section area of drainage line (m^2)

B – Breadth of the drainage line in meter

H – Height of the drainage system in meter

Table 5: Calculations of A, B, & H based on assumed velocity

Drainage Path	Q	V_{as}	A	L:B Ratio	A/1.5 or B2	B	H
A	0.0785	2.1	0.0374	1.5	0.0249	0.158	0.237
B	0.0597	1.9	0.0314	1.5	0.0209	0.145	0.217
C	0.0975	2.2	0.0443	1.5	0.0295	0.172	0.258
D	0.1534	2.5	0.0614	1.5	0.0409	0.202	0.303
D'	0.2319	2.7	0.0859	1.5	0.0573	0.239	0.359
E	0.1534	2.5	0.0614	1.5	0.0409	0.202	0.303
E'	0.2131	2.7	0.0789	1.5	0.0526	0.229	0.344
F	0.1718	2.5	0.0687	1.5	0.0458	0.214	0.321
F'	0.4037	3	0.1346	1.5	0.0897	0.300	0.449
F"	0.2108	2.7	0.0781	1.5	0.0520	0.228	0.342
G	0.0404	1.7	0.0238	1.5	0.0158	0.126	0.189
G'	0.2534	2.8	0.0905	1.5	0.0603	0.246	0.368
H	0.0885	2.2	0.0402	1.5	0.0268	0.164	0.246
H'	0.186	2.6	0.0715	1.5	0.0477	0.218	0.328
I	0.0816	2.1	0.0389	1.5	0.0259	0.161	0.241
I'	0.3351	2.9	0.1156	1.5	0.0770	0.278	0.416
J	0.1097	2.3	0.0477	1.5	0.0318	0.178	0.267

J'	0.1982	2.6	0.0762	1.5	0.0508	0.225	0.338
K	0.039	1.7	0.0229	1.5	0.0153	0.124	0.186
K'	0.374	3	0.1247	1.5	0.0831	0.288	0.432
L	0.1209	2.3	0.0526	1.5	0.0350	0.187	0.281
L'	0.3191	2.8	0.1140	1.5	0.0760	0.276	0.413
M	0.1576	2.5	0.0630	1.5	0.0420	0.205	0.308
N	0.6291	3	0.2097	1.5	0.1398	0.374	0.561
N'	0.7867	3	0.2622	1.5	0.1748	0.418	0.627
O	0.2119	2.7	0.0785	1.5	0.0523	0.229	0.343
O'	0.9986	3	0.3329	1.5	0.2219	0.471	0.707
P	0.3383	2.9	0.1167	1.5	0.0778	0.279	0.418
Q	0.8141	3	0.2714	1.5	0.1809	0.425	0.638
Q'	1.1523	3	0.3841	1.5	0.2561	0.506	0.759
Q"	2.1509	3	0.7170	1.5	0.4780	0.691	1.037
R	1.0725	3	0.3575	1.5	0.2383	0.488	0.732
S	0.403	3	0.1343	1.5	0.0896	0.299	0.449
S'	2.5539	3	0.8513	1.5	0.5675	0.753	1.130
T	0.2406	2.7	0.0891	1.5	0.0594	0.244	0.366
T'	1.3132	3	0.4377	1.5	0.2918	0.540	0.810
U	0.45	3	0.1500	1.5	0.1000	0.316	0.474
U'	3.0043	3	1.0014	1.5	0.6676	0.817	1.226
U"	1.7635	3	0.5878	1.5	0.3919	0.626	0.939
V	0.151	2.5	0.0604	1.5	0.0403	0.201	0.301
W	0.323	2.9	0.1114	1.5	0.0743	0.272	0.409
W'	0.473	3	0.1577	1.5	0.1051	0.324	0.486
X	0.166	2.6	0.0638	1.5	0.0426	0.206	0.309
X'	1.9299	3	0.6433	1.5	0.4289	0.655	0.982
X"	0.489	3	0.1630	1.5	0.1087	0.330	0.494

Note:

i. We know, A= Q/V, consider L/B ratio is 1.5 then calculate B & H.

ii. Therefore above mentioned that velocity of flow is not less than 0.8 m/s and not greater than 3.0 m/s. So, maintain the velocity of flow in between 0.8 m/s to 3.0 m/s.

B. Actual Velocity calculations by using Mnnings formula:

Manning's formula for gravity flow -

$$V=1/n\ [R^{(2/3)}.S^{(1/2)}]$$

Where, V_{act} – Velocity of flow in drainage line

B – Breadth of the drainage system in meter

h – Wetted height of the drainage system

h_{FB} – Free board

H – Height of drainage line.

H_T – Total height of drainage line (Provided height of drainage line i.e. $H_T = H + h_{FB}$)

S – Slope of drainage line

P_w – Wetted Perimeter [i.e. $P_w = B + (2\times h)$]

A_w – Wetted area (i.e. $A_w = B \times h$)

R – Hydraulic radius in meter ($R= A_w/P$)

n – Manning's coefficient of roughness (n for concrete is 0.011 & 1/n = 90.91)

Note:

- Assumed velocity of flow is bringing very close to actual velocity of the flow by adopting trial and error method.
- The minimum width and height of concrete Gutter is considered as 0.3m & 0.45 m respectively and necessary free board is given to the drainage system.
- Final size of Gutter is considered as **$B\times H_T$**

Table 6: Actual velocity calculation by using Manning's formula.

Drainage Path	B	H	B×H	Area occupy by flow	'B' of flow	'h' of flow	h_{FB}	H_T	P_w	A_w	R	$R^{2/3}$	1/n	S	$S^{1/2}$	V_{act}
A	0.3	0.45	0.135	0.037	0.3	0.1247	--	0.45	0.549	0.037	0.068	0.167	90.91	0.0200	0.141	2.144
B	0.3	0.45	0.135	0.031	0.3	0.1047	--	0.45	0.509	0.031	0.062	0.156	90.91	0.0200	0.141	2.006
C	0.3	0.45	0.135	0.044	0.3	0.1477	--	0.45	0.595	0.044	0.074	0.177	90.91	0.0200	0.141	2.275
D	0.3	0.45	0.135	0.061	0.3	0.2047	--	0.45	0.709	0.061	0.087	0.196	90.91	0.0200	0.141	2.516
D'	0.3	0.45	0.135	0.086	0.3	0.2863	--	0.45	0.873	0.086	0.098	0.213	90.91	0.0200	0.141	2.741
E	0.3	0.45	0.135	0.0614	0.3	0.2047	--	0.45	0.709	0.061	0.087	0.196	90.91	0.0200	0.141	2.516
E'	0.3	0.45	0.135	0.0789	0.3	0.2630	--	0.45	0.826	0.079	0.096	0.209	90.91	0.0200	0.141	2.687
F	0.3	0.45	0.135	0.0687	0.3	0.2290	--	0.45	0.758	0.069	0.091	0.202	90.91	0.0200	0.141	2.594
F'	0.3	0.5	0.150	0.1346	0.3	0.4487	0.1	0.6	1.197	0.135	0.112	0.233	90.91	0.0200	0.141	2.995
F''	0.3	0.45	0.135	0.0781	0.3	0.2603	--	0.45	0.821	0.078	0.095	0.208	90.91	0.0200	0.141	2.680
G	0.3	0.45	0.135	0.0238	0.3	0.0793	--	0.45	0.459	0.024	0.052	0.139	90.91	0.0200	0.141	1.789
G'	0.3	0.45	0.135	0.0905	0.3	0.3017	--	0.45	0.903	0.091	0.100	0.216	90.91	0.0200	0.141	2.773
H	0.3	0.45	0.135	0.0402	0.3	0.1340	--	0.45	0.568	0.040	0.071	0.171	90.91	0.0200	0.141	2.200
H'	0.3	0.45	0.135	0.072	0.3	0.2383	--	0.45	0.777	0.072	0.092	0.204	90.91	0.0200	0.141	2.621
I	0.3	0.45	0.135	0.039	0.3	0.1297	--	0.45	0.559	0.039	0.070	0.169	90.91	0.0200	0.141	2.174
I'	0.3	0.45	0.135	0.116	0.3	0.3853	0.05	0.5	1.071	0.116	0.108	0.227	90.91	0.0200	0.141	2.915
J	0.3	0.45	0.135	0.048	0.3	0.1590	--	0.45	0.618	0.048	0.077	0.181	90.91	0.0200	0.141	2.331
J'	0.3	0.45	0.135	0.076	0.3	0.2540	--	0.45	0.808	0.076	0.094	0.207	90.91	0.0200	0.141	2.664
K	0.3	0.45	0.135	0.023	0.3	0.0763	--	0.45	0.453	0.023	0.051	0.137	90.91	0.0200	0.141	1.759
K'	0.32	0.47	0.150	0.125	0.32	0.3897	0.05	0.52	1.099	0.125	0.113	0.234	90.91	**0.0198**	0.141	**2.997**
L	0.3	0.45	0.135	0.053	0.3	0.1753	--	0.45	0.651	0.053	0.081	0.187	90.91	0.0200	0.141	2.404
L'	0.3	0.45	0.135	0.114	0.3	0.3800	0.05	0.5	1.060	0.114	0.108	0.226	90.91	0.0200	0.141	2.908
M	0.3	0.45	0.135	0.063	0.3	0.2100	--	0.45	0.720	0.063	0.088	0.197	90.91	0.0200	0.141	2.534
N	0.37	0.56	0.207	0.210	0.37	0.5668	0.1	0.66	1.504	0.210	0.139	0.269	90.91	**0.0150**	0.122	**2.994**

N'	0.42	0.63	0.265	0.262	0.42	0.6243	0.1	0.73	1.669	0.262	0.157	0.291	90.91	**0.0128**	0.113	**2.995**
O	0.3	0.45	0.135	0.079	0.3	0.2617	--	0.45	0.823	0.079	0.095	0.209	90.91	0.0200	0.141	2.683
O'	0.47	0.71	0.334	0.333	0.47	0.7083	0.1	0.81	1.887	0.333	0.176	0.315	90.91	**0.0110**	0.105	**3.000**
P	0.3	0.45	0.135	0.117	0.3	0.3890	0.05	0.5	1.078	0.117	0.108	0.227	90.91	0.0200	0.141	2.920
Q	0.43	0.64	0.275	0.271	0.43	0.6312	0.1	0.74	1.692	0.271	0.160	0.295	90.91	**0.0125**	0.112	**3.000**
Q'	0.5	0.8	0.400	0.384	0.5	0.7682	0.1	0.9	2.036	0.384	0.189	0.329	90.91	**0.0100**	0.100	**2.990**
Q''	0.7	1	0.700	0.717	0.7	1.0243	0.2	1.2	2.749	0.717	0.261	0.408	90.91	**0.0065**	0.081	**2.992**
R	0.49	0.73	0.358	0.358	0.49	0.7296	0.1	0.83	1.949	0.358	0.183	0.323	90.91	**0.0104**	0.102	**2.993**
S	0.3	0.45	0.135	0.134	0.3	0.4477	0.1	0.55	1.195	0.134	0.112	0.233	90.91	0.0200	0.141	2.994
S'	0.75	1.2	0.900	0.851	0.75	1.1351	0.2	1.4	3.020	0.851	0.282	0.430	90.91	**0.0059**	0.077	**3.002**
T	0.3	0.45	0.135	0.089	0.3	0.2970	--	0.45	0.894	0.089	0.100	0.215	90.91	0.0200	0.141	2.764
T'	0.54	0.81	0.437	0.438	0.54	0.8106	0.2	1.01	2.161	0.438	0.203	0.345	90.91	**0.0091**	0.095	**2.991**
U	0.32	0.47	0.150	0.150	0.32	0.4688	0.1	0.57	1.258	0.150	0.119	0.242	90.91	**0.0186**	0.136	**3.004**
U'	0.82	1.2	0.984	1.001	0.82	1.2207	0.2	1.4	3.261	1.001	0.307	0.455	90.91	**0.0053**	0.073	**3.003**
U''	0.63	0.94	0.592	0.588	0.63	0.9330	0.2	1.14	2.496	0.588	0.235	0.381	90.91	**0.0075**	0.087	**3.002**
V	0.3	0.45	0.135	0.060	0.3	0.2013	--	0.45	0.703	0.060	0.086	0.195	90.91	0.0200	0.141	2.504
W	0.3	0.45	0.135	0.111	0.3	0.3713	0.05	0.5	1.043	0.111	0.107	0.225	90.91	0.0200	0.141	2.895
W'	0.33	0.48	0.158	0.158	0.33	0.4779	0.1	0.58	1.286	0.158	0.123	0.247	90.91	**0.0178**	0.133	**2.994**
X	0.3	0.45	0.135	0.067	0.3	0.2227	--	0.45	0.745	0.067	0.090	0.200	90.91	0.0200	0.141	2.575
X'	0.66	0.98	0.647	0.643	0.66	0.9747	0.2	1.18	2.609	0.643	0.247	0.393	90.91	**0.0071**	0.084	**3.001**
X''	0.33	0.5	0.165	0.163	0.33	0.4939	0.1	0.6	1.318	0.163	0.124	0.248	90.91	**0.0177**	0.133	**3.002**

Note: In **table 6** shows bolt alphabets in drainage path row indicates that exceeds the velocity of flow more than 3 m/s. Therefore to maintain the flow of drainage line by adjusting slop of the drainage line, which shown in **table 7**.

C. Restrictions on Velocity of Flow:

To maintained the velocity of flow in between 0.8 m/s to 3.0 m/s, by adjusting slop of the drainage line.

Some of the drainage path exceeds the velocity of flow more than 3.0 m/s. Therefore by adjusting the slop of the drainage line we can maintain the velocity of flow below 3.0 m/s.

Table 7: Calculations to maintained velocity of flow by adjusting slop of the drainage line.

Description of Path	n	$R^{2/3}$	V	$S^{1/2}$	S
K'	0.011	0.234	3	0.1410	0.0199
N	0.011	0.269	3	0.1227	0.0150
N'	0.011	0.291	3	0.1134	0.0129
O'	0.011	0.315	3	0.1048	0.0110
Q	0.011	0.295	3	0.1119	0.0125
Q'	0.011	0.329	3	0.1003	0.0101
Q''	0.011	0.408	3	0.0809	0.0065
R	0.011	0.323	3	0.1022	0.0104
S'	0.011	0.43	3	0.0767	0.0059
T'	0.011	0.345	3	0.0957	0.0091
U	0.011	0.242	3	0.1364	0.0186
U'	0.011	0.455	3	0.0725	0.0053
U''	0.011	0.381	3	0.0866	0.0075
W'	0.011	0.247	3	0.1336	0.0178
X'	0.011	0.393	3	0.0840	0.0071
X''	0.011	0.248	3	0.1331	0.0177

Note: $V=1/n\ [R^{(2/3)}.S^{(1/2)}]$, i.e. $S^{(1/2)} = V.\ n/R^{(2/3)}$

Here, velocity of flow exceed the 3.0 m/s, hence velocity is taken as 3.0 m/s for cross calculation purpose.

III. Calculations on Cross Drainage Work:

A. Discharge calculation for cross drainage work:

Table 8: Discharge calculation of the cross drainage along path

Path	Description of path	Discharge
I	Total discharge of area 1	0.0785
II	Total discharge of area 2	0.0597
III	Total discharge from drainage line D’	0.0975
IV	Total discharge from drainage line E’	0.1534
V	Total discharge of area 3	0.2319
VI	Total discharge from drainage line G’	0.1534
VII	Total discharge from drainage line H’	0.2131
VIII	Total discharge from drainage line I’	0.1718
IX	Total discharge from drainage line J’	0.4037
X	Total discharge from drainage line K’	0.2108
XI	Total discharge from drainage line (F’+F’’- F)	0.0404
XII	Total discharge from drainage line L’	0.2534
XIII	Total discharge of area 13	0.0885
XIV	Total discharge from drainage line Q’’	0.186
XV	Total discharge from drainage line S’	0.0816
XVI	Total discharge of area 18	0.3351
XVII	Total discharge from drainage line T’	0.1097
XVIII	Total discharge from drainage line (U’+U’’- U)	0.1982
XIX	Total discharge of area 22	0.039
XX	Total discharge from drainage line T’	0.374

B. Calculations of area and diameter of cross drainage pipe based on assumed velocity:

Where, Q – Discharge in m^3/s

V – Assumed velocity in m/s

A- Area in m^2

d – Diameter of the cross drainage system in meter.

Table 9: Calculations of Area & diameter of cross drainage pipe based on assumed velocity

Description of CD path	Q	V	A	π/4	d2	d	D*
I	0.0785	1.9	0.041316	0.7854	0.052605	0.229357	**0.3**
II	0.0597	1.8	0.033167	0.7854	0.042229	0.205497	**0.3**
III	0.2319	2.5	0.09276	0.7854	0.118105	0.343665	**0.4**
IV	0.2131	2.4	0.088792	0.7854	0.113053	0.336233	**0.4**
V	0.0975	2	0.04875	0.7854	0.06207	0.249139	**0.3**
VI	0.2534	2.5	0.10136	0.7854	0.129055	0.359243	**0.4**
VII	0.186	2.3	0.08087	0.7854	0.102966	0.320883	**0.4**
VIII	0.3351	2.7	0.124111	0.7854	0.158023	0.397521	**0.45**
IX	0.1982	2.4	0.082583	0.7854	0.105148	0.324266	**0.4**
X	0.374	2.8	0.133571	0.7854	0.170068	0.412393	**0.45**
XI	0.4426	2.9	0.152621	0.7854	0.194322	0.44082	**0.6**
XII	0.3191	2.7	0.118185	0.7854	0.150478	0.387915	**0.45**
XIII	0.1576	2.2	0.071636	0.7854	0.09121	0.30201	**0.4**
XIV	2.1509	3	0.716967	0.7854	0.912868	0.955441	**1**
XV	2.5539	3	0.8513	0.7854	1.083906	1.041108	**1.2**
XVI	1.0725	3	0.3575	0.7854	0.455182	0.674672	**0.8**
XVII	1.3132	3	0.437733	0.7854	0.557338	0.746551	**0.8**
XVIII	4.3174	3	1.439133	0.7854	1.832357	1.353646	**1.6**
XIX	0.151	2.2	0.068636	0.7854	0.08739	0.295619	**0.4**
XX	0.473	3	0.157667	0.7854	0.200747	0.448048	**0.6**

Note: D* – Diameter of pipe, which shall be provided, (i.e. 'D*' replaces to 'd' due to availability of pipe in the market size and safety purpose).

C. Actual Velocity Calculations:

Actual Velocity calculations by using Manning's formula:

Manning's formula for gravity flow -

$$V=1/n\ [R^{(2/3)}.S^{(1/2)}]$$

Where, V – Velocity in m/s.

S – Slope of hydraulic gradient.

n – Manning's coefficient of roughness (n for concrete is 0.011 & 1/n = 90.91)

d – Calculated diameter of pipe (actual diameter of pipe calculated according to runoff flow)

P_w – Wetted perimeter (for running full condition $P_w = \pi*d$)

A_w – Wetted area ($A_w = \pi*d^2/4$)

R – Hydraulic radius in meter.

Note:

Consider the drainage pipe running full condition and also consider some extra diameter of pipe for safety purpose.

The available diameter of pipe in the market is 300, 400, 450, 600, 800, 1000, 1200, 1400, 1600, 1800, 2000 and 2200 mm. Hence replace the calculated diameter by this available pipe size.

Table 9: Actual velocity calculation by using Manning's formula

Description of cross drainage path	π	d	A_w	P_w	R	$R^{2/3}$	S	$S^{1/2}$	1/n	V
I	3.1428571	0.23	0.04156	0.722857143	0.0575	0.148974	0.02	0.141421	90.91	1.915
II	3.1428571	0.206	0.03334	0.647428571	0.0515	0.138422	0.02	0.141421	90.91	1.780
III	3.1428571	0.344	0.09298	1.081142857	0.086	0.194834	0.02	0.141421	90.91	2.505
IV	3.1428571	0.336	0.08870	1.056	0.084	0.191802	0.02	0.141421	90.91	2.466
V	3.1428571	0.249	0.04872	0.782571429	0.06225	0.15707	0.02	0.141421	90.91	2.019
VI	3.1428571	0.3592	0.10138	1.128914286	0.0898	0.200532	0.02	0.141421	90.91	2.578
VII	3.1428571	0.3209	0.08091	1.008542857	0.080225	0.186012	0.02	0.141421	90.91	2.391
VIII	3.1428571	0.3975	0.12415	1.249285714	0.099375	0.214545	0.02	0.141421	90.91	2.758
IX	3.1428571	0.3243	0.08263	1.019228571	0.081075	0.187323	0.02	0.141421	90.91	2.408
X	3.1428571	0.4124	0.13363	1.296114286	0.1031	0.219873	0.02	0.141421	90.91	2.827
XI	3.1428571	0.4408	0.15267	1.385371429	0.1102	0.229855	0.02	0.141421	90.91	2.955
XII	3.1428571	0.388	0.11828	1.219428571	0.097	0.211113	0.02	0.141421	90.91	2.714

XIII	3.1428571	0.302	0.07166	0.949142857	0.0755	0.178634	0.02	0.141421	90.91	2.297
XIV	3.1428571	0.9554	0.71719	3.002685714	0.23885	0.384961	**0.00735**	0.141421	90.91	**3.000**
XV	3.1428571	1.04	0.84983	3.268571429	0.26	0.407364	**0.00656**	0.141421	90.91	**2.999**
XVI	3.1428571	0.6747	0.35767	2.120485714	0.168675	0.305281	**0.01168**	0.141421	90.91	**2.999**
XVII	3.1428571	0.7466	0.43797	2.346457143	0.18665	0.326602	**0.01021**	0.141421	90.91	**3.000**
XVIII	3.1428571	1.354	1.44046	4.255428571	0.3385	0.485705	**0.00462**	0.141421	90.91	**3.001**
XIX	3.1428571	0.2956	0.06866	0.929028571	0.0739	0.176101	0.02	0.141421	90.91	2.264
XX	3.1428571	0.448	0.15770	1.408	0.112	0.232351	0.02	0.141421	90.91	2.987

Note: In **table 9** shows bolt alphabets in drainage path row indicates that exceeds the velocity of flow more than 3 m/s. Therefore to maintain the flow of drainage line by adjusting slop of the drainage line, which shown in **table 10**.

D. Restrictions on Velocity of Flow:

To maintained the velocity of flow in between 0.8 m/s to 3.0 m/s, by adjusting slop of the drainage line.

Some of the drainage path exceeds the velocity of flow more than 3.0 m/s. Therefore by adjusting the slop of the drainage line we can maintain the velocity of flow below 3.0 m/s.

Table 10: Calculations to maintained velocity of flow by adjusting slop of the cross drainage pipe

Description of cross drainage path	n	$R^{2/3}$	V	$S^{1/2}$	S
XIV	0.011	0.3850	3	0.0857	0.00735
XV	0.011	0.4074	3	0.0810	0.00656
XVI	0.011	0.3053	3	0.1081	0.01168
XVII	0.011	0.3266	3	0.1010	0.01021
XVIII	0.011	0.4857	3	0.0679	0.00462

Note: $V=1/n\ [R^{(2/3)}.S^{(1/2)}]$, i.e. $S^{(1/2)} = V.\ n/R^{(2/3)}$

Here, velocity of flow exceed the 3.0 m/s, hence velocity is taken as 3.0 m/s for cross calculation purpose.