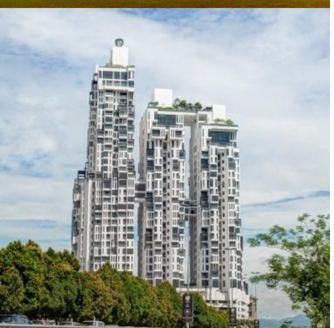





Urbanisation > Built Environment > Sustainability > Challenges in the design for Rainwater Systems. Are current codes and standards keeping pace with the needs and demands from Architects or are they becoming irrelevant?

Urbanisation is taking place on a global scale. The nature and design of buildings, structures and infrastructure is changing because there is pressure to ensure the ‘built environment’ is ‘sustainable’. Rainwater is one of the key sources of moisture which affects buildings and its building envelope which is the roof and the facade. What are the new challenges for Rainwater Systems in these new buildings and structures?

It depends on where you are! Decisions of what water to collect, how to collect, where to collect, dictate solutions. However, what is common to all solutions is that the rainwater system must perform and be capable of collecting the rainwater from identified areas and spaces and transporting the rainwater to its designated discharge point safely and without leakage. Many countries are actively collecting the rainwater for re-use and others are temporarily storing the water to reduce overloading infrastructure drainage. Different uses! Different solutions!

What are these solutions? Current global codes and standards are generally relics from the history books and have not kept pace with the effects of urbanization. Industry is driving change despite the shortcomings of the codes and standards. This Seminar aims to provide a different perspective.

Presentation Topics:

Drainage of ‘Open to Sky’ areas

- What is ‘open to sky’ drainage?
- Review of current international codes and practices
- Insights into the design and use of gravity drainage systems
- A brief introduction to the use of Siphonic Systems. A game changer!

Drainage of ‘Wind-Driven Rain Spaces’

- What are Wind-Driven Spaces?
- Absence of codes and standards
- Review of current practices
- What are the Risks for Specifiers?
- An introduction to an engineered solution

Case Studies:

‘Open to Sky’ areas and ‘Wind-Driven Spaces’

Urbanisation > Built Environment > Sustainability > Challenges in the design for Rainwater Systems.

Are current codes and standards keeping pace with the needs and demands from Architects or are they becoming irrelevant?

Yap Kern Ling

Business Development Manager & Group Director

- **Presentation Topics:**
- **Drainage of ‘Open to Sky’ areas**
  - What is ‘open to sky’ drainage?
  - Review of current international codes and practices
  - Insights into the design and use of gravity drainage systems
  - A brief introduction to the use of Siphonic Systems. A game changer!

- **Drainage of ‘Wind-Driven Rain Spaces’**
  - What are Wind-Driven Spaces?
  - Absence of codes and standards
  - Review of current practices
  - What are the Risks for Specifiers?
  - An introduction to an engineered solution

- **Case Studies:**
- **‘Open to Sky’ areas and ‘Wind-Driven Spaces’**

FASTFLOW

(3) Downpipes shall have an aggregate internal area of at least 1000 $mm.^2$ for every 10 $m.^2$ of roof surface measured on the plan.

GOVERNMENT GAZETTE

SUBSIDIARY LEGISLATION SUPPLEMENT

Published by Authority

12. Footway levels.

PART X.

DRAINAGE AND SANITARY PROVISIONS.

Building Authority and the provisions of the Destruction of Disease Bearing Insects Act and the Water Pollution Control and Drainage Act, 1975, and the regulations made thereunder.

67. The roof of every building abutting on any street shall be provided with eaves gutters and rainwater downpipes in accordance with the requirements of regulation 70.

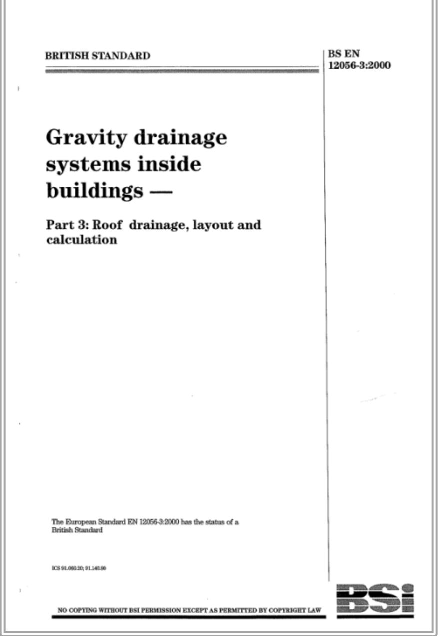
71. Every building lot or plot and the building or buildings erected thereon shall be adequately drained by at least one independent surface drain or other approved drain which shall be discharged to the street drain or other approved outlet drain.

FASTFLOW

Current Standards and Codes which are being used around the Region

British Standard

BS EN12056-3:2000


BRITISH STANDARD

BS EN 12056-3:2000

Gravity drainage systems inside buildings —

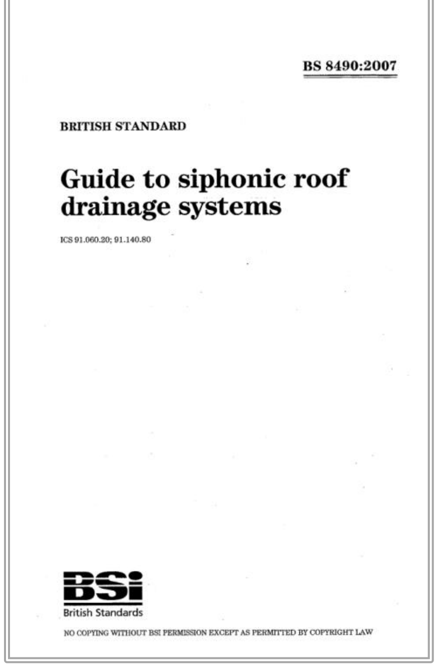
Part 3: Roof drainage, layout and calculation

The European Standard EN 12056-3:2000 has the status of a British Standard

BSi

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

BS 8490:2007


BS 8490:2007

BRITISH STANDARD

Guide to siphonic roof drainage systems

ICS 91.060.20; 91.140.80

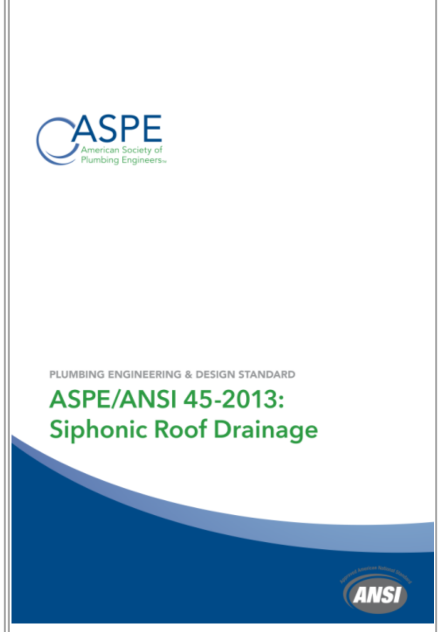
BSi British Standards

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

- ✓ Britain & EU
- ✓ Malaysia
- ✓ Thailand
- ✓ Myanmar

American Standard

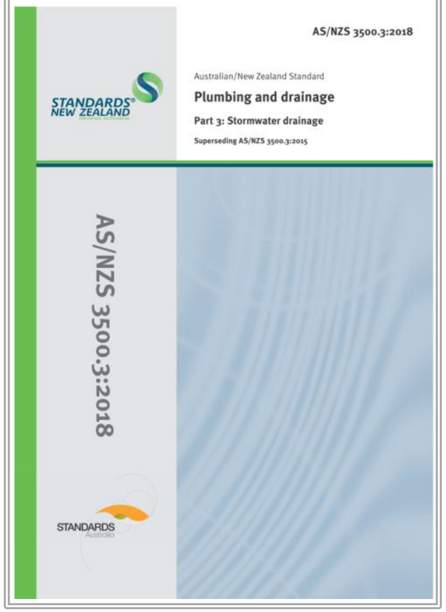
ASPE 45: 2013



- ✓ America

Australia / New Zealand

AS/NZS3500.3-2018



- ✓ Australia
- ✓ New Zealand
- ✓ Philippines

FASTFLOW

Current Standard [Code of practice] which is being used around in Singapore

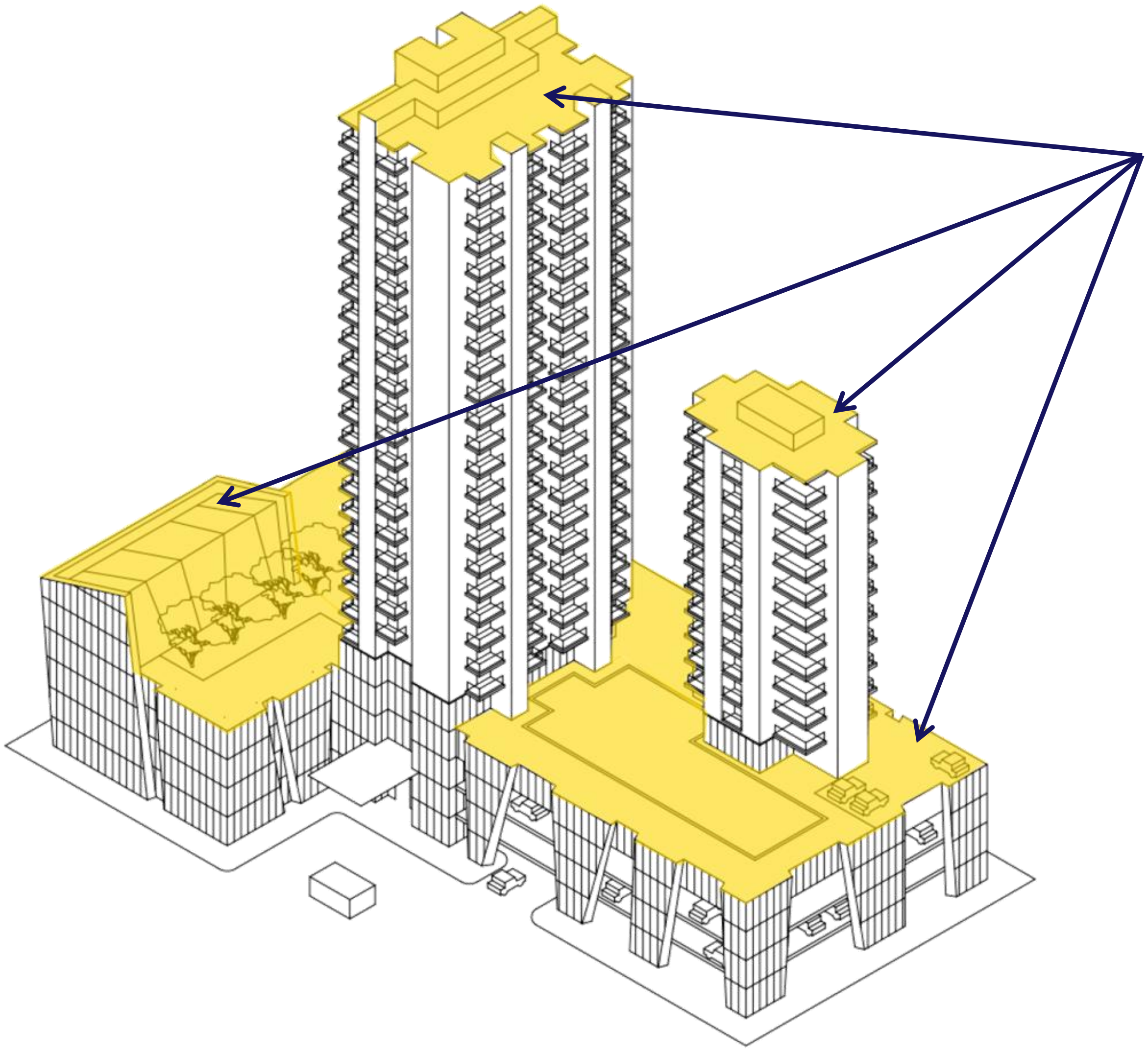
Singapore Standard

SINGAPORE STANDARD
SS 525 : 2006

CODE OF PRACTICE FOR
Drainage of roofs
(Formerly CP 26 : 1993)

✓ Singapore

Roof Drainage is also known as Open-To-Sky Drainage



Drainage of surface water from roofs and walls

FASTFLOW

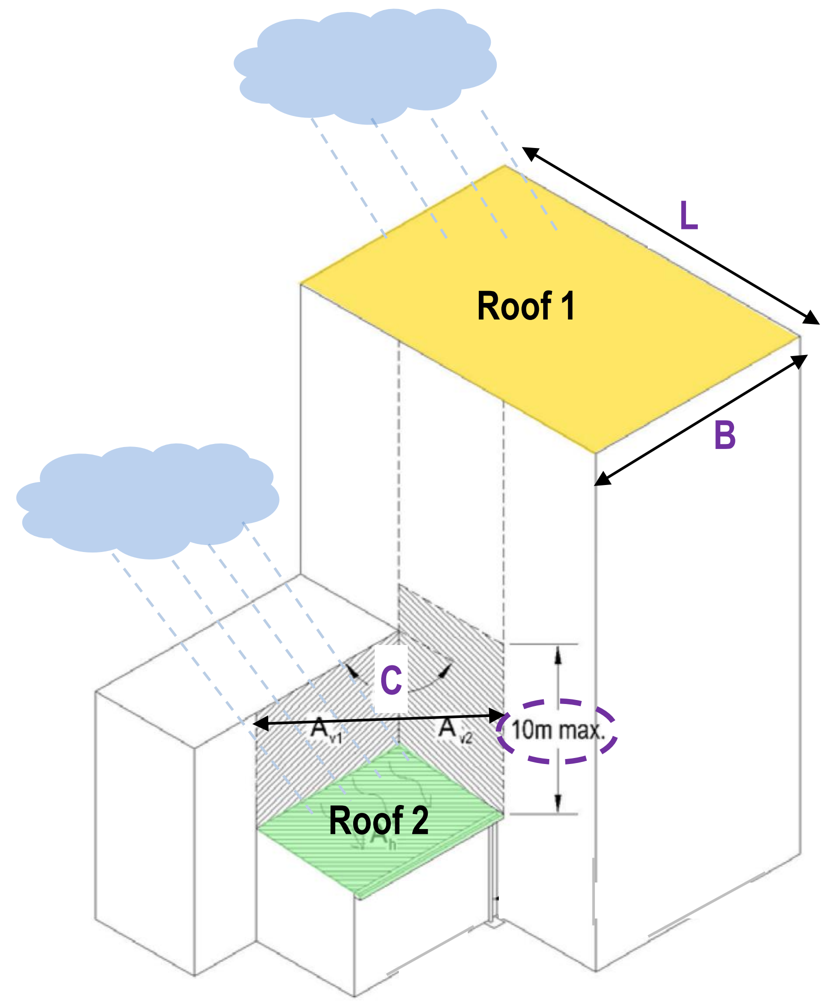
How much rainwater needs to be drained?

2 Factors

Ae : effective catchment area (m^2)

I : design rainfall intensity (mm/hr)

Rate of Runoff, Q (l/s) = $\frac{Ae \times I}{3600}$



Illustrations of Ae

Roof 1 = plan area (i.e L x B)

Roof 2 = plan area + 50% elevation area up to 10m max

FASTFLOW

Singapore Standard SS 525 : 2006 Rainfall Intensity

"The aim of Qualified Person (Architects/Engineers) should normally be to achieve a balance between the cost of drainage system and the frequency and consequences of flooding." *(pg 13 clause 5)*

Jewel Changi Airport

330 mm/hr

For the design of surfaces where any overflowing or ponding is to be avoided.

3mins once in 50 years

Resorts World Sentosa

260 mm/hr

5mins once in 25years
10mins once in 50years
(according to PUB Code of Practice on surface water drainage)

200 mm/hr

For the design of sloping surfaces where ponding normally cannot be tolerated.

5mins once in 4 years
15mins once in 50 years

UMC Wafer Fab

165 mm/hr

For the design of flat surfaces where ponding can be tolerated

5mins once in 1 year
15mins once in 10years

Bin Centre

FASTFLOW

Gravity v. Siphonic

- Which to choose?
- Despite the concepts of gravity and siphonic being very different system they both serve the same purpose, they drain rainwater from roofs or Open to Sky areas.
- Rainwater drainage using Gravity Systems has been around for hundreds of years.
- Siphonic was first developed in 1968, just over 50 years ago. It was first used in Singapore in 1994, 25 years ago. **IT IS STILL NEW!**

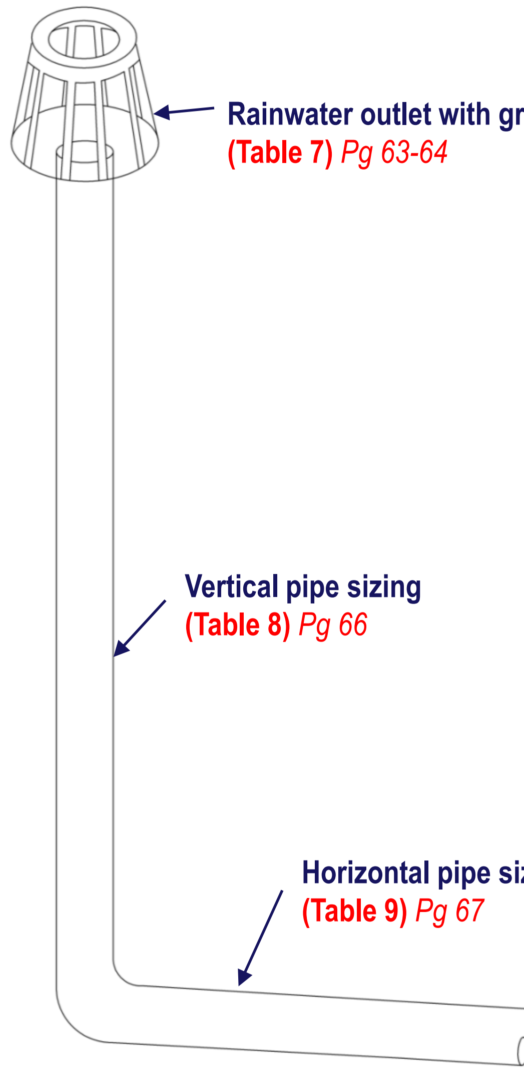
What is a Gravity System?

Single pipe system connecting from the roof rainwater outlet to the discharge point.

The pipe system works under atmospheric conditions with an air and water mixture in annular flow, i.e. non-pressure system.

Components of Gravity System

SS525

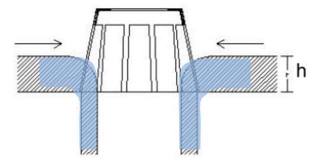


Rainwater outlet with grating
(Table 7) *Pg 63-64*

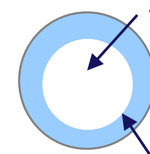
Vertical pipe sizing
(Table 8) *Pg 66*

Horizontal pipe sizing
(Table 9) *Pg 67*

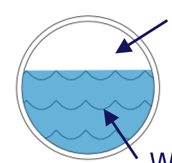
Weir Flow



Annular flow



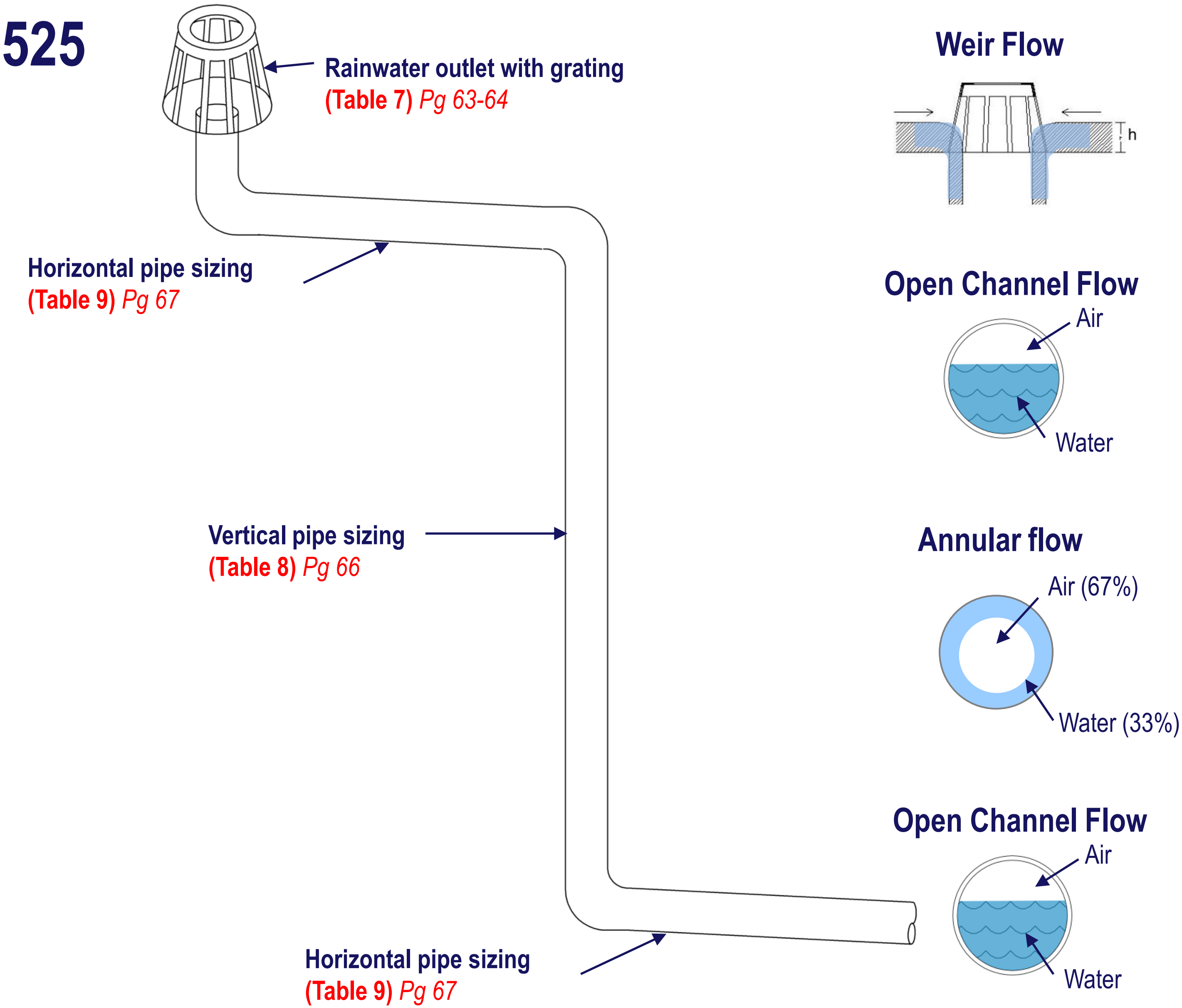
Open Channel Flow



FASTFLOW

Components of Gravity System

SS525

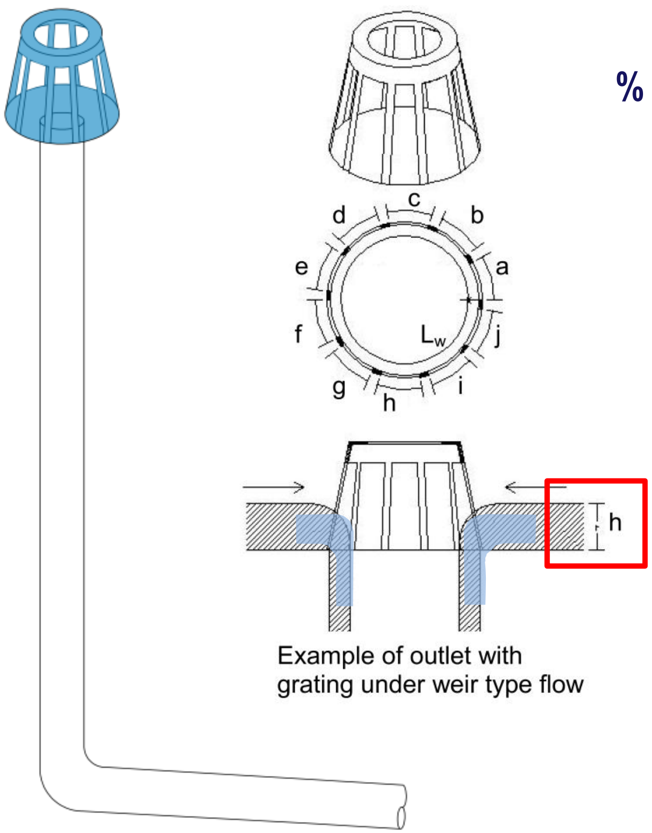


FASTFLOW

Capacity of rainwater outlet with grating

3 Factors

- *Rainwater Outlet size*
- *Percentage of clear opening*
- *Water depth around outlet*



Example of outlet with grating under weir type flow

% of <u>Clear Opening</u> x Capacity of circular gravity outlets with grating

(refer Table 7a)

$$\text{Clear Opening} = \frac{\text{Sum of clear openings } (a+b+c\ldots+j)}{\text{Perimeter of circular outlet, } Lw\ (\pi \times d)}$$

Table 7a (pg63)	*100% clear opening of circular gravity outlet*
Table 7b (pg64)	*90% clear opening of circular gravity outlet*
Table 7c (pg64)	*80% clear opening of circular gravity outlet*
Table 7d (pg65)	***70% clear opening of circular gravity outlet***
Table 7e (pg65)	*60% clear opening of circular gravity outlet*

Capacity of rainwater outlet with grating

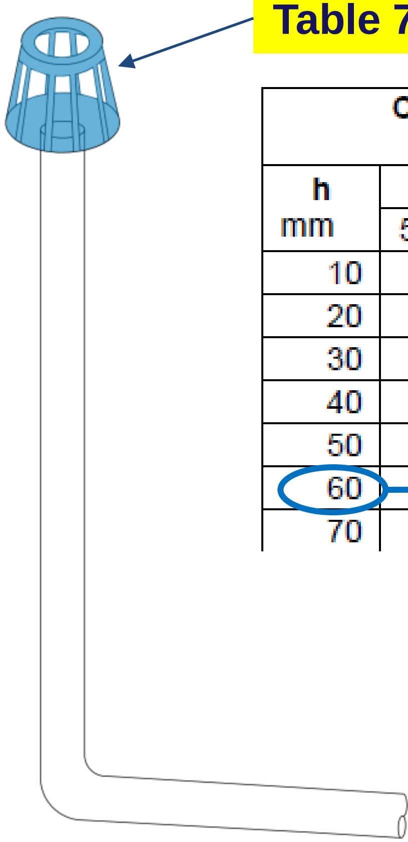
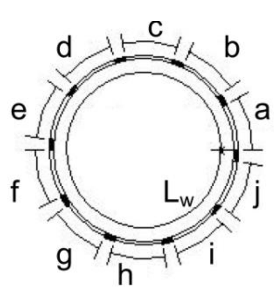
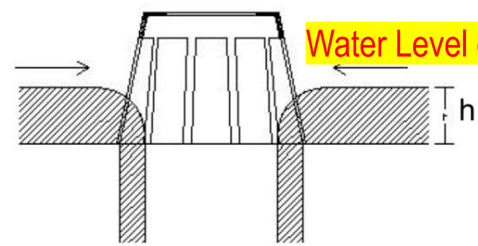


Table 7(d) – Capacities of grated circular outlets (70% Opening)

Capacity of circular gravity outlets with grating (l/s) (70 % clear opening) Q = 0.7 x values from Table 7(a)								
h mm	Internal diameter of outlet							
	50 mm	75 mm	100 mm	125 mm	150 mm	200 mm	250 mm	300 mm
10	0.14	0.22	0.29	0.36	0.43	0.58	0.72	0.87
20	0.41	0.61	0.82	1.02	1.23	1.64	2.05	2.46
30	0.63	1.13	1.51	1.88	2.26	3.01	3.76	4.52
40	0.72	1.63	2.32	2.90	3.48	4.64	5.80	6.95
50	0.81	1.82	3.24	4.05	4.86	6.48	8.10	9.72
60	0.89	2.00	3.55	5.32	**6.39**	8.52	10.65	12.78
70	0.96	2.16	3.83	5.99	[illegible]	10.73	13.42	16.10





Example of outlet with grating under weir type flow

Vertical Pipe Drainage Capacity (Wyly-Eaton Equation)

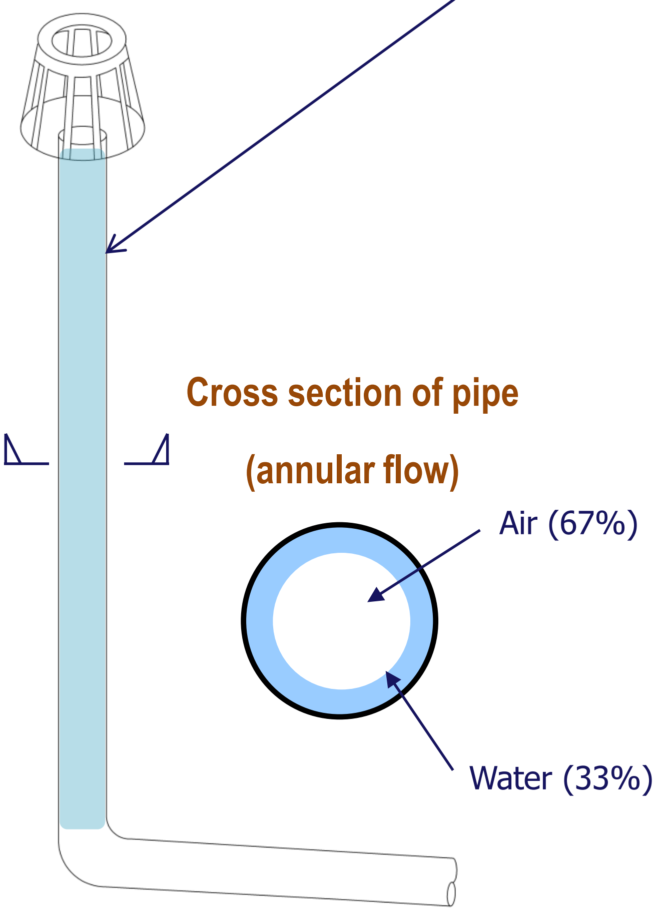


Table 8 – Capacities of vertical rainwater pipes

Internal diameter of rainwater pipe, d_i mm	**Capacity Q_{RWP}** l/s
	Filling degree f=0.33
140	26.3
150	**31.6**
160	37.5
170	44.1
180	51.4
190	59.3
200	68.0
220	87.7
240	110.6
260	137.0
280	166.9

Horizontal Pipe Drainage Capacity (Colebrook-White Formula)

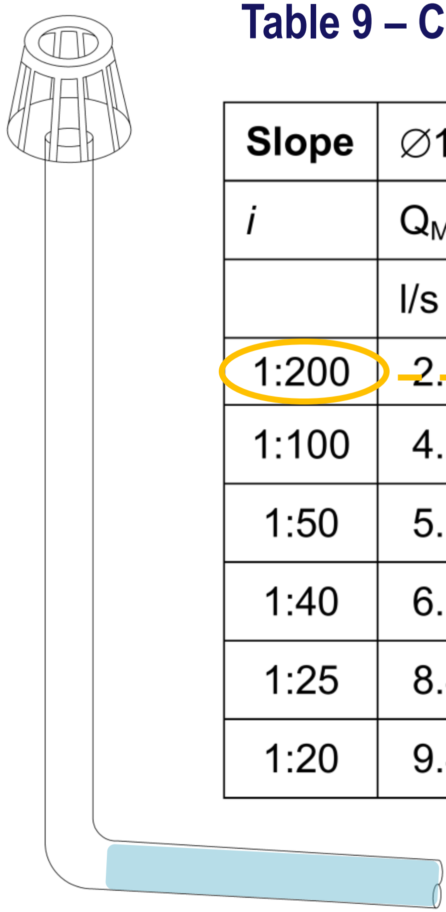
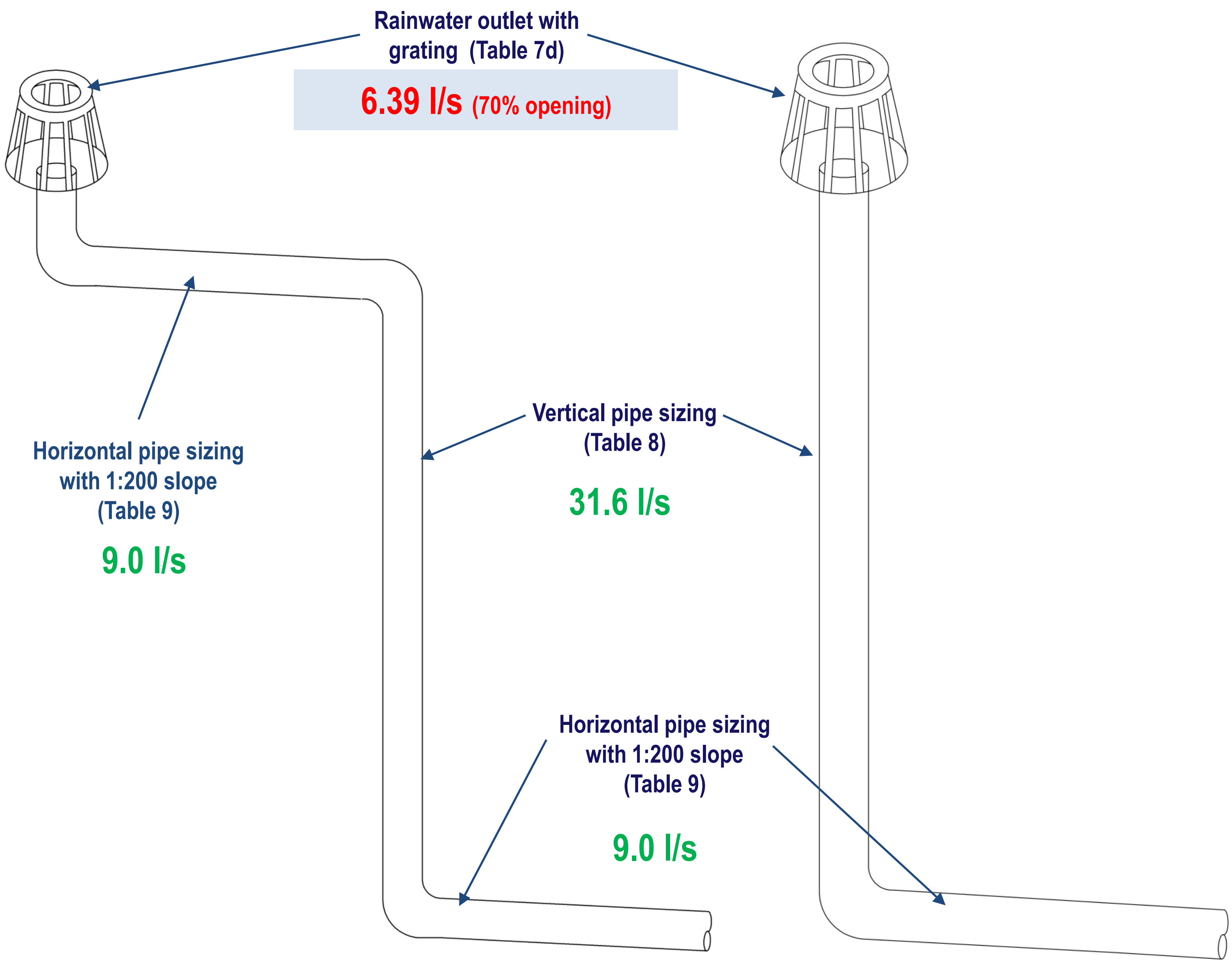


Table 9 – Capacities of horizontal rainwater pipes

Slope	∅100		∅125		∅150		∅200		∅225		∅250	
i	Q_{Max}	v	Q_{Max}	v	Q_{Max}	v	Q_{Max}	v	Q_{Max}	v	Q_{Max}	v
	l/s	m/s	l/s	m/s	l/s	m/s	l/s	m/s	l/s	m/s	l/s	m/s
1:200	2.9	0.5	4.8	0.6	**9.0**	0.7	16.7	0.8	26.5	0.9	31.6	1.0
1:100	4.2	0.8	6.8	0.9	12.8	1.0	23.7	1.2	37.6	1.3	44.9	1.4
1:50	5.9	1.1	9.6	1.2	18.2	1.5	33.6	1.7	53.3	1.9	63.6	2.0
1:40	6.7	1.2	10.8	1.4	20.3	1.6	37.6	1.9	59.7	2.1	71.1	2.2
1:25	8.4	1.6	13.7	1.8	25.8	2.1	47.6	2.4	75.5	2.7	90.0	2.8
1:20	9.4	1.7	15.3	2.0	28.8	2.3	53.3	2.7	84.5	3.0	100.7	3.1


FASTFLOW
Rainwater outlet with grating (Table 7d)
6.39 l/s (70% opening)
Horizontal pipe sizing with 1:200 slope (Table 9)
9.0 l/s
Vertical pipe sizing (Table 8)
31.6 l/s
Horizontal pipe sizing with 1:200 slope (Table 9)
9.0 l/s

FASTFLOW

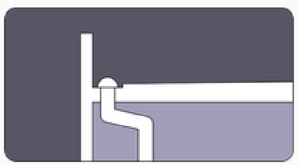
Software for the Design of Roof Drainage using Gravity System for Flat Roof

Gravity System Roof Drainage Calculator - SS 525: 2006

The following tools are programmed to facilitate the design of gravity roof drainage systems, including gutters, roof outlets, gravity rainwater pipes based on the design principles established in

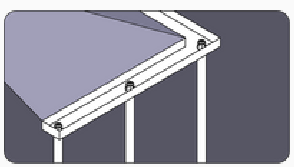
Singapore Standard SS525:2006 Code of Practice for Drainage of Roofs

These tools are provided free of charge to promote proper design of gravity rainwater drainage systems.
While every care has been taken to ensure that all the functions complies to the engineering and design principles as stated in SS525:2006, it is impossible to include all the requirements from the standards. It is important that the user should familiarise him/herself with other relevant requirements in the SS525:2006.
It is assumed that the user has sufficient understanding on good design practices to make use of the design tools.
By using the design tools, you understand and agree that we will not be held liable for any outcome or results whatsoever from the use of the design tools.



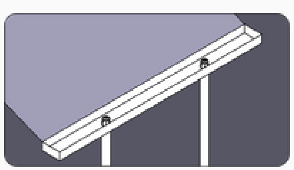
Flat Roof Drainage

Gravity rood drainage system design on flat roofs.



Gutter Drainage Type 1

Gravity rood drainage system design on gutters where outlets are located at the corners and the edges.
Note: suitable for gutters with angles.



Gutter Drainage Type 2

Gravity rood drainage system design on straight gutters where outlets are evenly distributed along the length of the gutter.

Rainwater Drainage Calculator for Flat Roofs

The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in ***SS525:2006 Code of Practice for Drainage of Roofs.***

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain.
The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

Project Information

Reference No:

Project Name

Roof Description

Catchment Area and Rainfall Intensity

Roof Area (A_h) 0 m.sq.

Elevational Area (up to height of 10m) (A_v) ? 0 m.sq.

Effective Elevational Area (50% of A_v) 0 m.sq.

Total Effective Catchment Area (A_e) **0.00** m.sq.

Rainfall Intensity (I) ? 330 mm/hr.

Total Flow Rate (Q_{roof}) **0.00** l/s.

Next >>

FASTFLOW

Rainwater Drainage Calculator for Flat Roofs

The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in ***SS525:2006 Code of Practice for Drainage of Roofs.***

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain. The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

Project Information

Reference No:	2018-07-04
Project Name	Industrial Building @ Tuas
Roof Description	RC Flat Roof @ Production Block

Catchment Area and Rainfall Intensity

Roof Area (A_h)	500 m.sq.
Elevational Area (up to height of 10m) (A_v) ?	100 m.sq.
Effective Elevational Area (50% of A_v)	50.00 m.sq.
Total Effective Catchment Area (A_e)	**550.00** m.sq.
Rainfall Intensity (I) ?	330 mm/hr.
Total Flow Rate (Q_{roof})	**50.42** l/s.

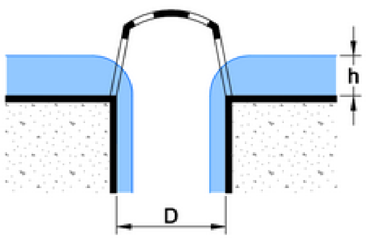
Next >>

Rainwater Drainage Calculator for Flat Roofs

The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in ***SS525:2006 Code of Practice for Drainage of Roofs.***

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain.
The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

Roof Drainage Outlets



Number of roof outlets: 2

Percentage of opening on strainer (leaf guard) ?: 70 %

Effective diameter of roof outlet (D): 150 mm

Notes: roof outlet diameter should be similar to diameter of rwdp ?

Design water depth at roof outlet (h) ?: 50 mm

Required flow rate per outlet (Q_i) = **25.21 l/s**

Reference to Table 7, capacity of roof outlet is **4.86 l/s**

Roof outlet do not have sufficient capacity to drain the necessary flow rate!!!

Please try the following

- **increase the number of roof outlet**
- **enlarge the diameter of roof outlet**
- **increase the water level on the roof**
- **use outlets with more efficient leaf strainer**

<< Prev | Next >>

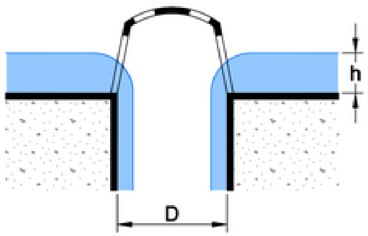
Rainwater Drainage Calculator for Flat Roofs

FASTFLOW

The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in ***SS525:2006 Code of Practice for Drainage of Roofs.***

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain.
The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

Roof Drainage Outlets



Number of roof outlets: 10

Percentage of opening on strainer (leaf guard) ?: 70 %

Effective diameter of roof outlet (D): 150 mm

Notes: roof outlet diameter should be similar to diameter of rwdp ?

Design water depth at roof outlet (h) ?: 50 mm

Required flow rate per outlet (Q_i) = **5.04 l/s**
Reference to Table 7, capacity of roof outlet is **4.86 l/s**

Roof outlet do not have sufficient capacity to drain the necessary flow rate!!!

Please try the following

- **increase the number of roof outlet**
- **enlarge the diameter of roof outlet**
- **increase the water level on the roof**
- **use outlets with more efficient leaf strainer**

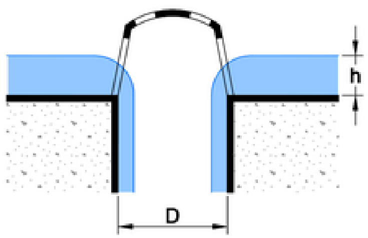
<< Prev   Next >>

Rainwater Drainage Calculator for Flat Roofs

*The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in **SS525:2006 Code of Practice for Drainage of Roofs.***

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain. The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

Roof Drainage Outlets



Number of roof outlets: 11

Percentage of opening on strainer (leaf guard) ?: 70 %

Effective diameter of roof outlet (D): 150 mm

Notes: roof outlet diameter should be similar to diameter of rwdp ?

Design water depth at roof outlet (h) ?: 50 mm

Required flow rate per outlet (Q_i) = **4.58 l/s**
Reference to Table 7, capacity of roof outlet is **4.86 l/s**

Roof outlet has sufficient capacity to drain the necessary flow rate.

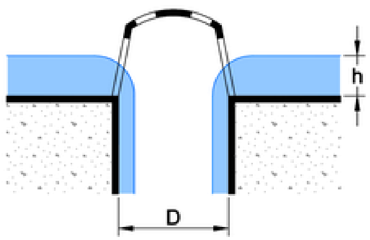
<< Prev | Next >>

Rainwater Drainage Calculator for Flat Roofs

*The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in **SS525:2006 Code of Practice for Drainage of Roofs**.*

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain.
The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

Roof Drainage Outlets



Number of roof outlets: 8

Percentage of opening on strainer (leaf guard) ?: 70 %

Effective diameter of roof outlet (D): 200 mm

Notes: roof outlet diameter should be similar to diameter of rwdp ?

Design water depth at roof outlet (h) ?: 50 mm

Required flow rate per outlet (Q_i) = **6.30 l/s**
Reference to Table 7, capacity of roof outlet is **6.48 l/s**
Roof outlet has sufficient capacity to drain the necessary flow rate.

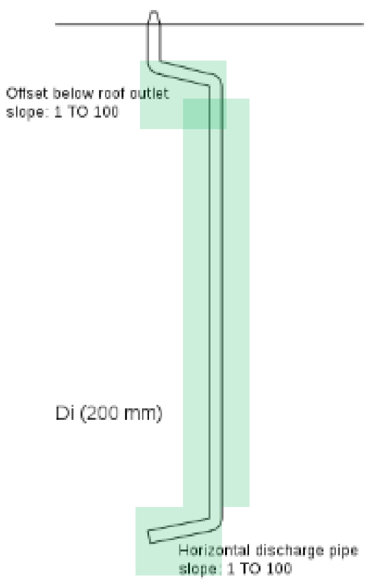
<< Prev | Next >>

Rainwater Drainage Calculator for Flat Roofs

The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in ***SS525:2006 Code of Practice for Drainage of Roofs.***

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain. The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

Rainwater Down Pipes



Required Flow Rate (Q) **6.30 l/s**

Pipe inner diameter (D_i) 200 mm

Note: pipe inner diameter should not be smaller than the diameter at the throat of roof outlet

Capacity of vertical pipe = 68.03 l/s.
Vertical section is sufficient to drain necessary flow rate.

Horizontal offset below roof outlet: Yes

Horizontal offset below roof outlet

Pipe gradient: 1 TO 100

(0.5729 degree)

Capacity of horizontal transfer below roof outlet = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

Intermediate floor horizontal offsets: None

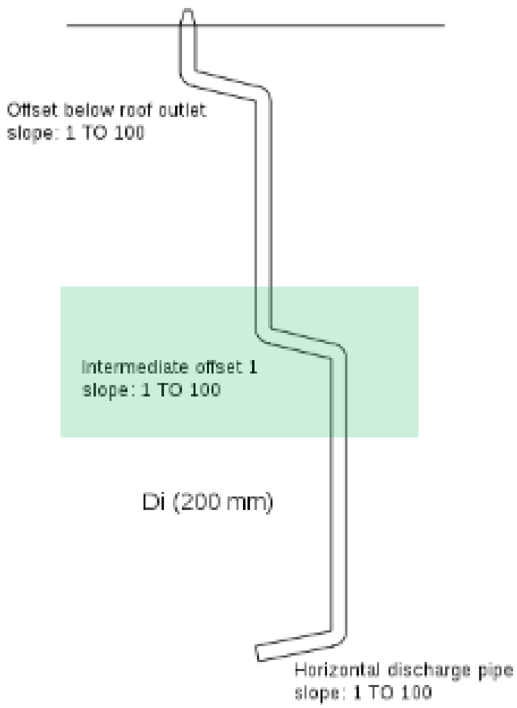
Horizontal discharge pipe: Yes

Horizontal discharge pipe

Pipe gradient: 1 TO 100

(0.5729 degree)

Capacity of horizontal discharge pipe = 29.57 l/s.
This section is sufficient to drain necessary flow rate.



Required Flow Rate (Q) **6.30 l/s**

Pipe inner diameter (D_i) 200 mm

Note: pipe inner diameter should not be smaller than the diameter at the throat of roof outlet

Capacity of vertical pipe = 68.03 l/s.
Vertical section is sufficient to drain necessary flow rate.

Horizontal offset below roof outlet Yes

Horizontal offset below roof outlet

Pipe gradient: 1 TO 100
(0.5729 degree)

Capacity of horizontal transfer below roof outlet = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

Intermediate floor horizontal offsets 1

Intermediate horizotal offset No.1

Pipe gradient: 1 TO 100
(0.5729 degree)

Capacity of horizotal offset 1 = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

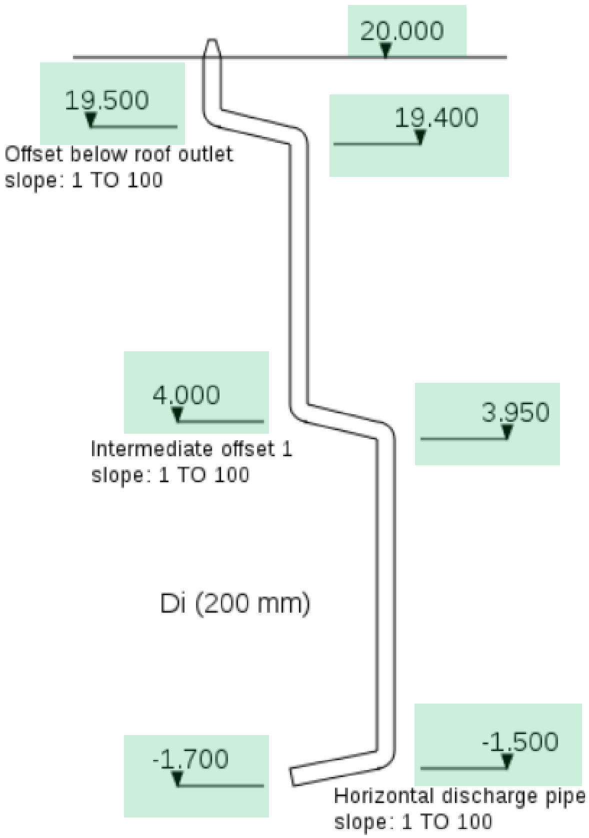
Horizontal discharge pipe Yes

Horizontal discharge pipe

Pipe gradient: 1 TO 100
(0.5729 degree)

Capacity of horizontal discharge pipe = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

Pipe levels calculator Off



Required Flow Rate (Q) **6.30 l/s**

Pipe inner diameter (D_i) 200 mm

Note: pipe inner diameter should not be smaller than the diameter at the throat of roof outlet

Capacity of vertical pipe = 68.03 l/s.
Vertical section is sufficient to drain necessary flow rate.

Roof outlet level 20 mm

Horizontal offset below roof outlet Yes

Horizontal offset below roof outlet

Pipe gradient: 1 TO 100
(0.5729 degree)

Offset pipe length 10 m

Offset upstream level 19.5

Offset downstream level 19.400

Capacity of horizontal transfer below roof outlet = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

Intermediate floor horizontal offsets 1

Intermediate horizotal offset No.1

Pipe gradient: 1 TO 100
(0.5729 degree)

Offset pipe length 5 m

Offset upstream level 4.0

Offset downstream level 3.950

Capacity of horizotal offset 1 = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

Rainwater Drainage Calculator for Flat Roofs

The roof drainage outlets and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in ***SS525:2006 Code of Practice for Drainage of Roofs.***

The calculations below are meant for drainage from flat roofs where water are expected to spread over the entire flat roof during rain.
The flat roof must have sufficient slope to allow water to flow towards the roof outlets.

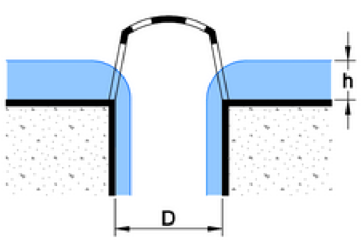
Project Information

Reference No:	**2018-07-04**
Project Name	**Industrial Building @ Tuas**
Roof Description	**RC Flat Roof @ Production Block**

Catchment Area and Rainfall Intensity

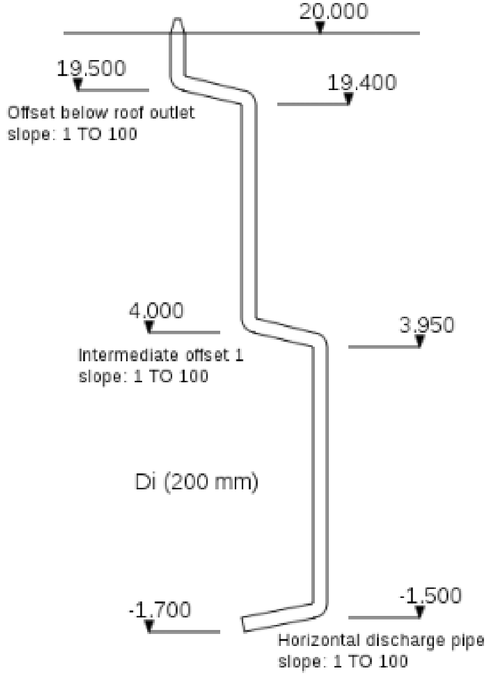
Roof Area (A_h)	500.00 m.sq.
Elevational Area (up to height of 10m) (A_v)	100.00 m.sq.
Effective Elevational Area (50% of A_v)	50.00 m.sq.
Total Effective Catchment Area (A_e)	**550.00** m.sq.
Rainfall Intensity (I)	330.00 mm/hr.
Total Flow Rate (Q_{roof})	**50.42** l/s.

Roof Drainage Outlets



Total flow rate (Q_{total}) = 50.42 l/s
Number of roof outlet = 8
Required flow rate per outlet (Q_i) = **6.30 l/s**
Design water depth around outlet (h) = **50 mm**
Outlet effective diameter = **200 mm**
Percentage of opening on leaf strainer = **70 %**
Length of weir (L_w) = 628.32 mm
Area of opening (A_o) = 31415.93 mm^2
$h <= 2 A_o / L_w$, Flow is weir flow.
Reference to Table 7, capacity of roof outlet is **6.48 l/s**
Roof outlet has sufficient capacity to drain the necessary flow rate.

Rainwater Down Pipes



Design flow rate (Q_i) = **6.30**l/s
Inner diameter of rwdp = **200** mm

Reference to Table 8 (Wyly-Eaton equation):
Capacity of vertical section of pipe = **68.03 l/s.**
Vertical section is sufficient to drain necessary flow rate.

Horizontal offset below roof outlet

Gradient of horizontal pipe = **1 TO 100**
(0.573 degrees)
Gradient is less than 10 degrees; capacity calculated based on Table 9 (Colebrook-White formula):
Capacity of horizontal transfer below roof outlet = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

Intermediate horizontal offset 1

Gradient of horizontal pipe = **1 TO 100**
(0.573 degrees)
Gradient is less than 10 degrees; capacity calculated based on Table 9 (Colebrook-White formula):
Capacity of horizontal offset 1 = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

Horizontal discharge pipe

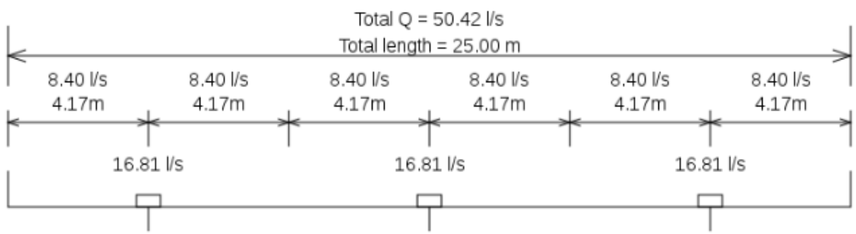
Gradient of horizontal pipe = **1 TO 100**
(0.573 degrees)
Gradient is less than 10 degrees; capacity calculated based on Table 9 (Colebrook-White formula):
Capacity of horizontal discharge pipe = 29.57 l/s.
This section is sufficient to drain necessary flow rate.

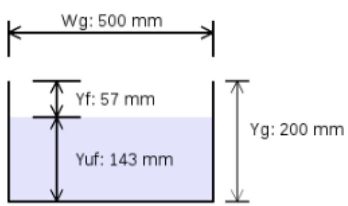
Rainwater Drainage Calculator for Valley, Parapet and Boundary Wall Gutters (Free Discharge)

The roof drainage outlets, gutter and rainwater downpipes are calculated based on the design principles for gravity drainage systems established in ***SS525:2006 Code of Practice for Drainage of Roofs.***

This calculation is meant for straight gutters without any change in direction, where roof outlets are evenly distributed along the gutter.
If change and direction is present, an outlet is to be placed very near to each angle/change of direction along the gutter.
All gutters should be designed with minimum slope of 1 to 150 fall (Cl.7.3.3).
All gutters should be designed to withstand the load of water when the gutter is fully filled up to spill over level and human load during maintenance without deformation in order to avoid ponding (Cl.7.3.3).

Gutter





Length of gutter 25 m

Number of roof outlets 3

Overall width of gutter (W_g) 500 mm

Minimum width for valley gutter: 500mm
Minimum width for parapet wall gutter: 300mm

Overall depth of gutter (Y_g) 200 mm

Is angle of more than 10^o included in length of gutter? No

FASTFLOW

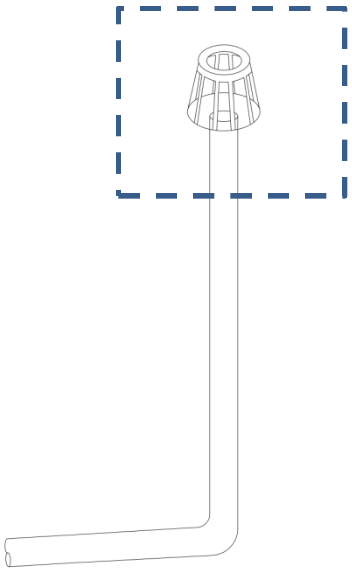
Software for the Design of Roof Drainage using Gravity System for Flat Roof

www.flowpedia.com

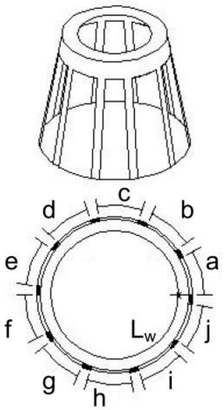
Main Concerns with Gravity Systems

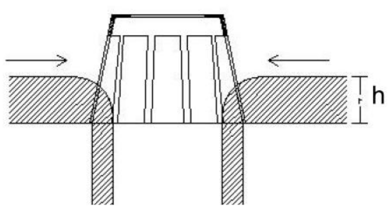
- Designers/Specifiers are not fully aware of the risks they undertake when designing Gravity systems.
- This results in major UNDER-DESIGN.
- This leads to major RISKS!
- So WHAT are the RISKS?
- How can they be MITIGATED?

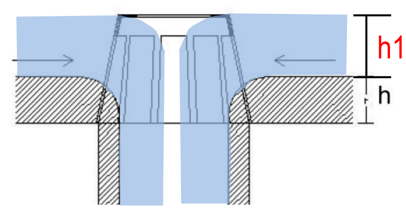
Risk of Under Design of RO



Flooding / Ponding on the Roof





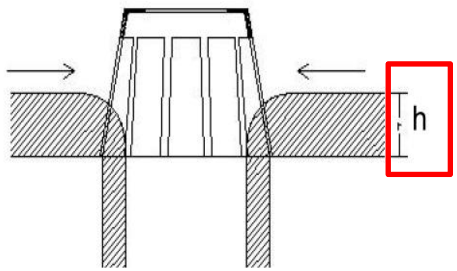


Design water depth around outlet based on code

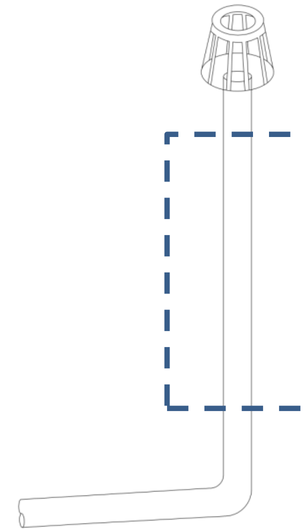
Surcharge of rainwater on roof resulting from number of rainwater downpipes being **UNDER-DESIGNED**

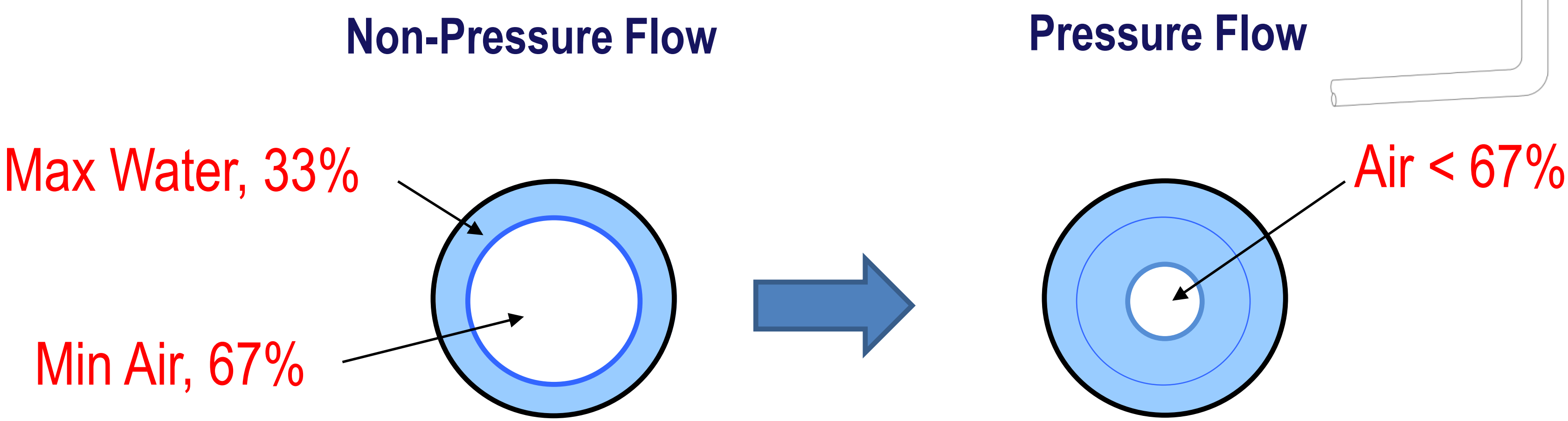
Mitigation

- Check that the assumed Water Level on the Roof is compatible with design of the
  - Rainwater Outlet opening area
  - Proper distribution of Catchment Area
  - Waterproofing Concept and Details
  - Roof Access thresholds
  - M&E services plinth
  - Roof loading capacity



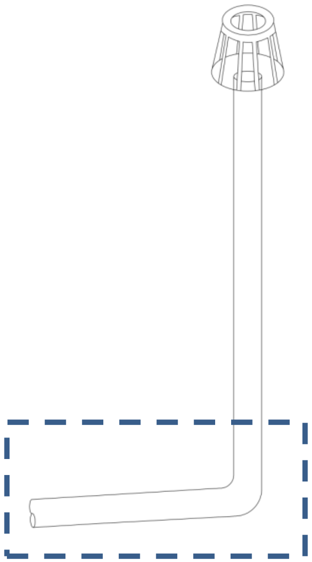
Risk of Under Design of vertical RWDP

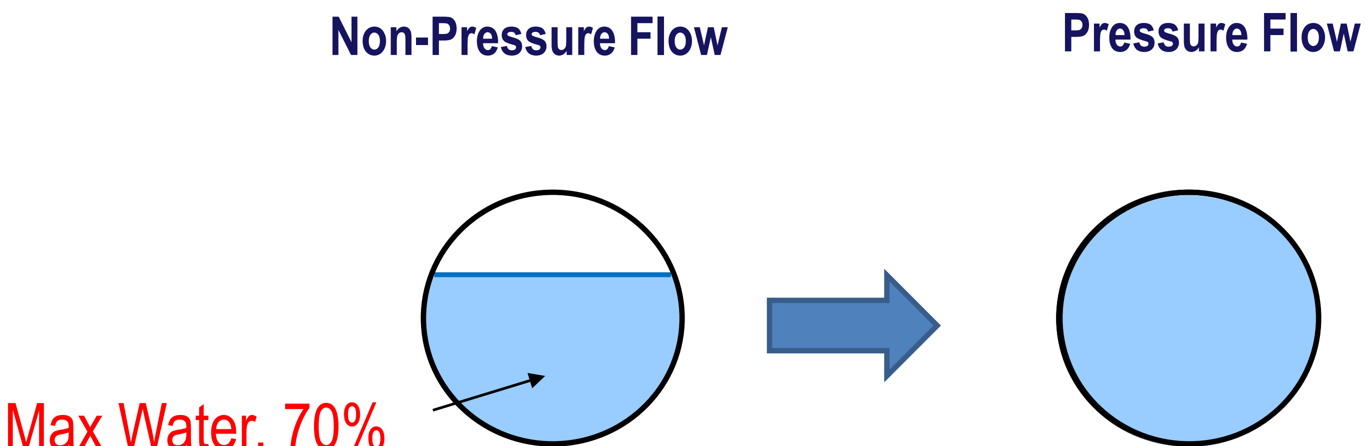




DANGER of OVERLOADING Gravity System potential pipe failures

Risk of Under Design of horizontal RWDP



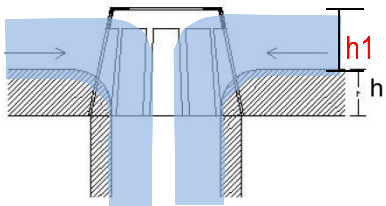


DANGER of OVERLOADING Gravity System potential pipe failures

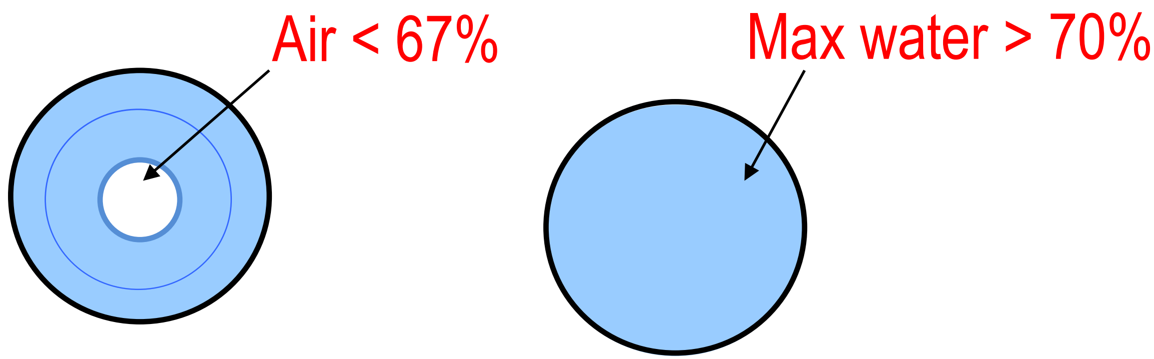
FASTFLOW

Summary – Proper design of Gravity Systems

- If the system is UNDER-DESIGNED then two things may happen.



UNDER-DESIGN

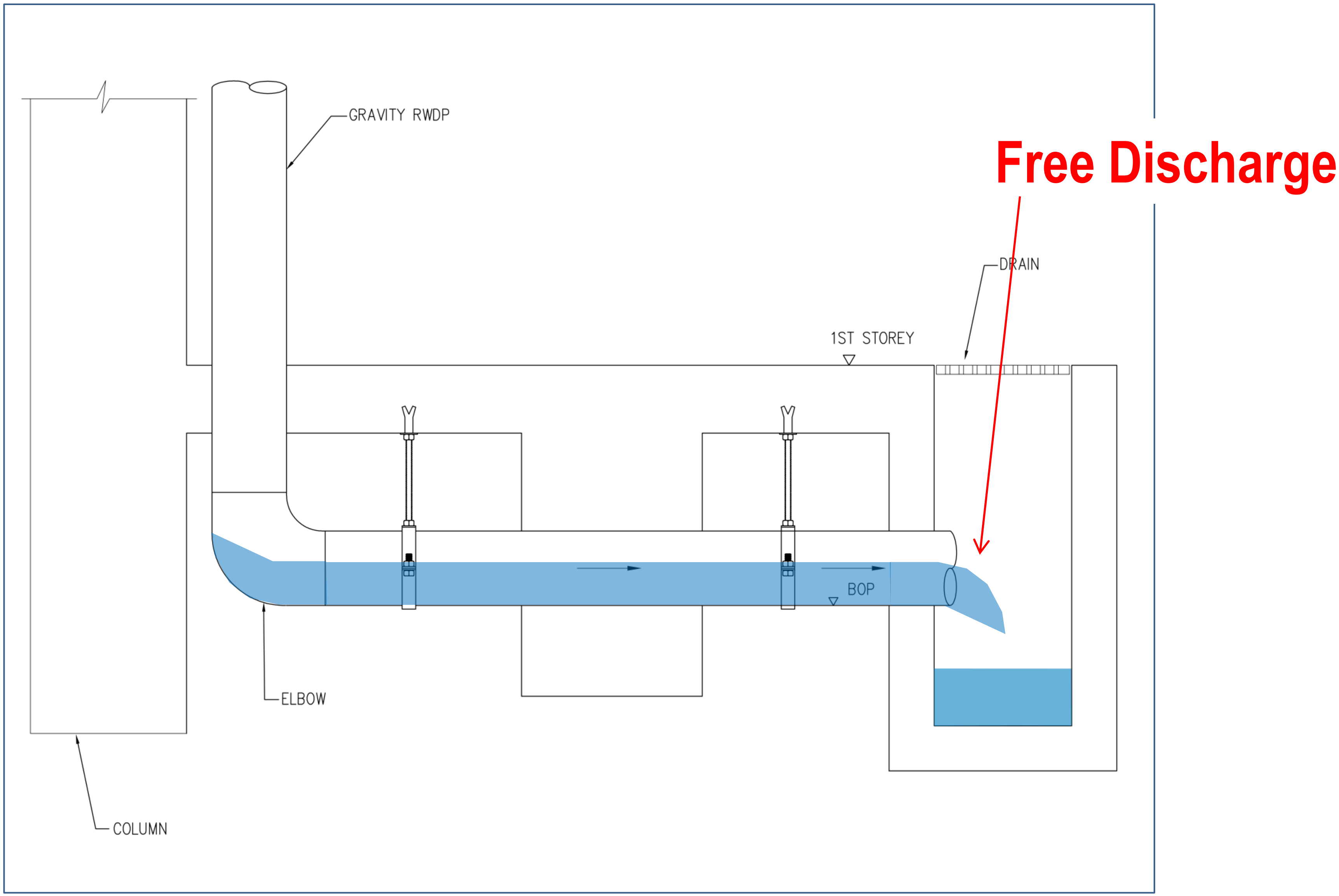


1. WATER LEVELS RISE >> **OVERFLOW AND FLOODING**

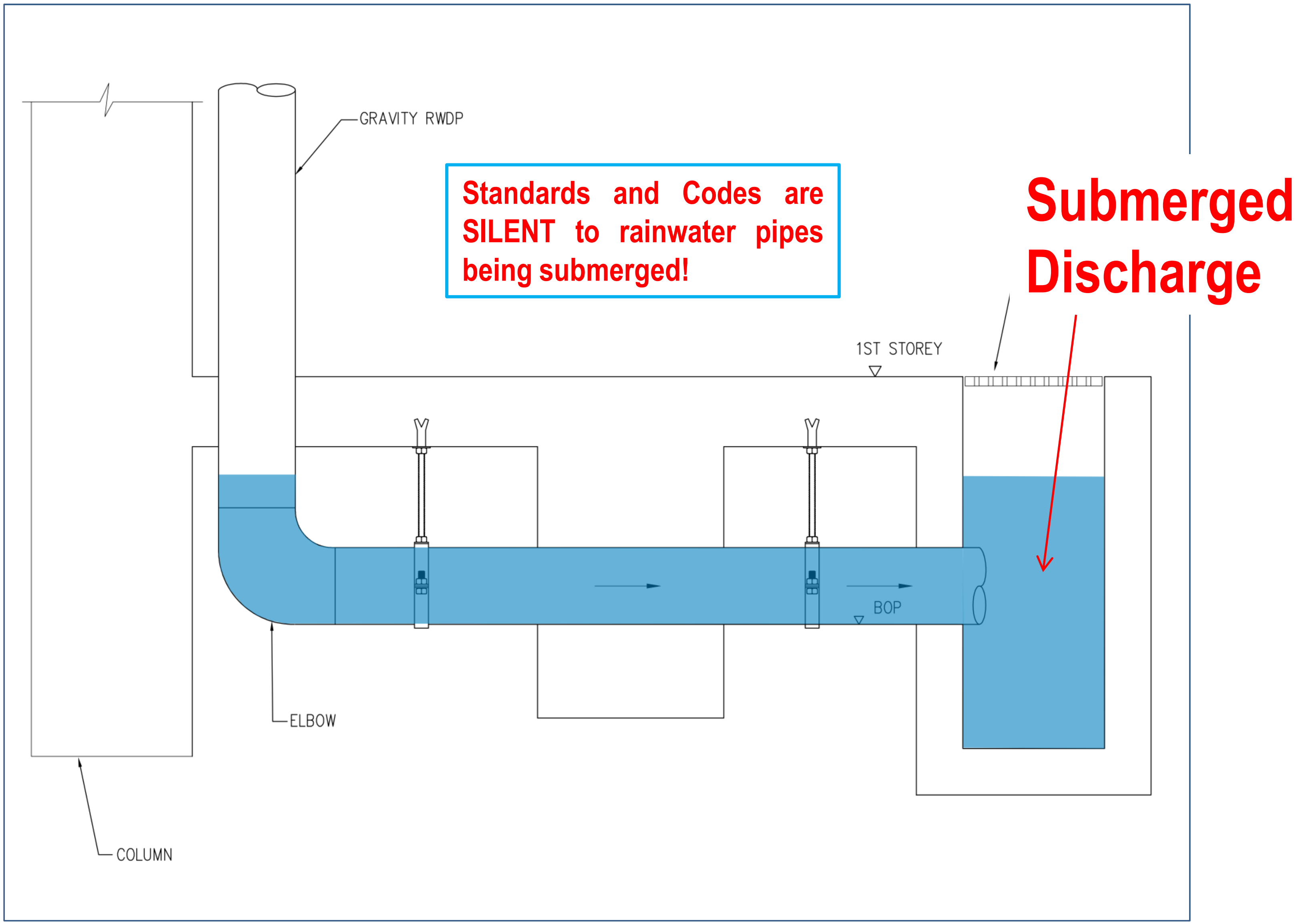
2. PIPE SYSTEM BECOMES PRESSURED >> **PIPE FAILURE**

- **Check Flow Rates of all 3 components of the Gravity System to ensure the overall drainage capacity is met in accordance to SS525.**

Risk Mitigation - Discharge of Gravity System



Risk Mitigation - Discharge of Gravity System



Other Important Consideration of Gravity Systems Design

- Check Rainwater Discharge Point.

- *"The system should be able to withstand the maximum **hydraulic head**, which could occur should a blockage take place at the lowest point"* (from Clause 4 of SS525). Ensure the pipe system is correctly specified and capable of withstanding this pressure.

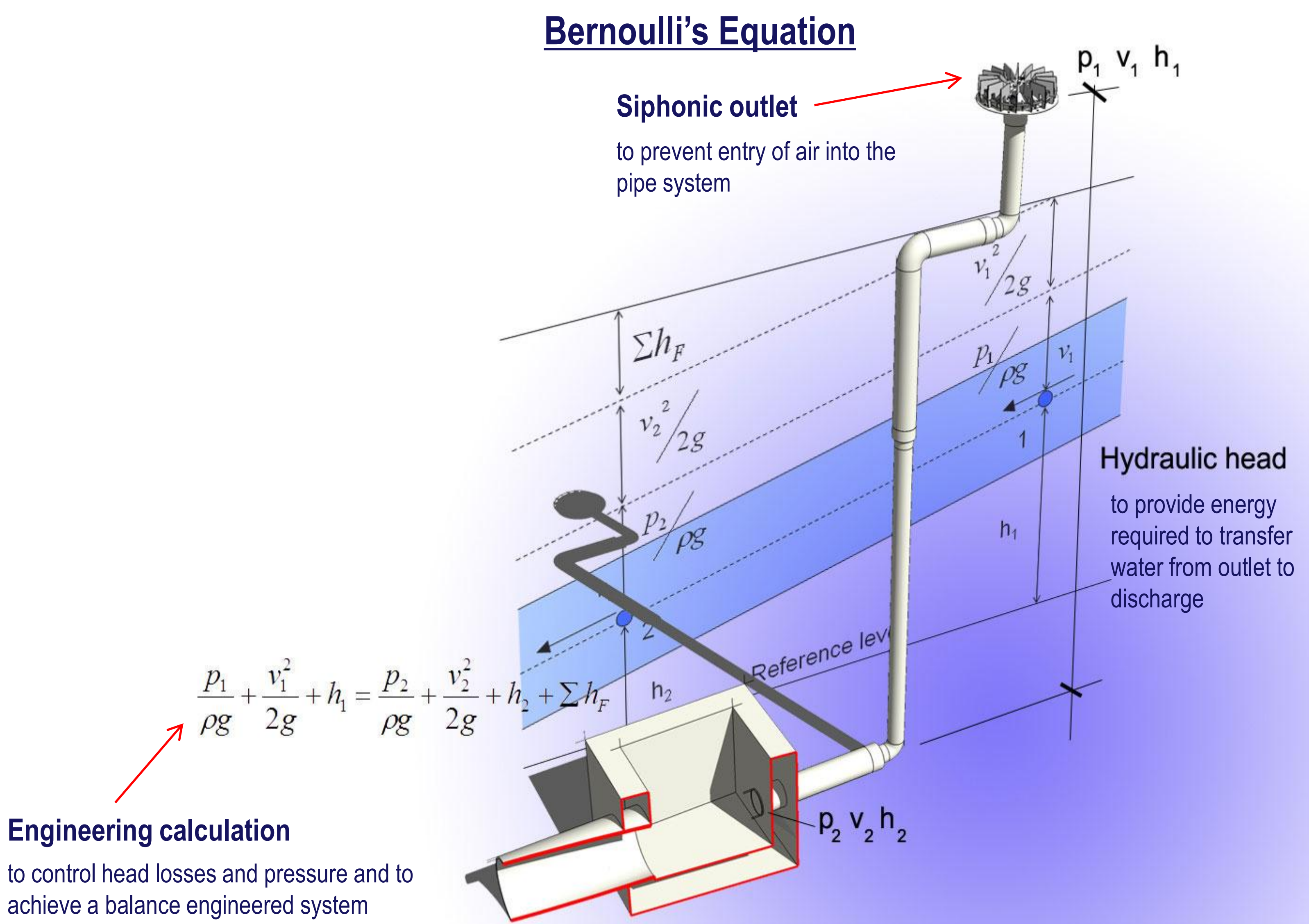
FASTFLOW

What is a Siphonic System?

A closed-flow roof drainage system operating under gravity-induced sub-atmospheric pressures (negative pressure) based on the vertical differential fluid head principle.

ASPE / ANSI 45-2013 : Siphonic Rood Drainage

Principles of Siphonic System

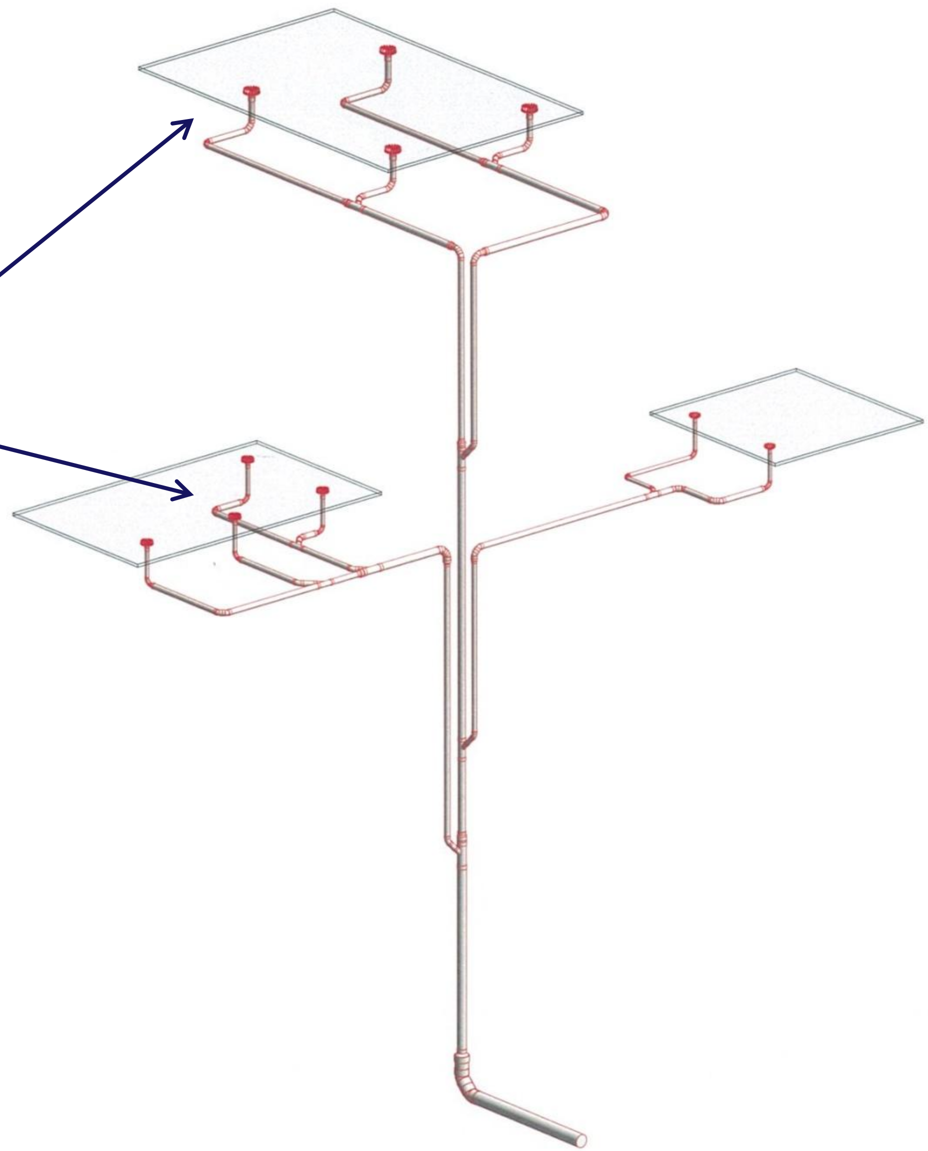


$$\frac{p_1}{\rho g} + \frac{v_1^2}{2g} + h_1 = \frac{p_2}{\rho g} + \frac{v_2^2}{2g} + h_2 + \sum h_F$$

FASTFLOW

An Engineered Solution

Multiple siphonic outlets from different roofs can be linked with zero gradient horizontal pipes coming down with a common stack



An Engineered Solution

- SS525 : 2006 Recommends that a Specialist should carry out the design of the Siphonic System.
- Architect/Designer/Specifier should establish the PERFORMANCE REQUIREMENTS.
  - Rainfall Intensity
  - Catchment Area to be drained
  - Outlet location distribution
  - Preferred Pipe Routing
  - Discharge Point

An Engineered Solution

- The Specialist should produce solutions that meet the Performance Requirements.
- Siphonic Specialist must have:
  - Relevant experience and knowledge
  - Approved Analytical Software
  - Approved Siphonic System comprising of Siphonic Outlets, Pipe System and Bracket/Bracing System

FASTFLOW

Key points in Open To Sky Drainage
- Responsibilities

- SS525 covers both the design of Gravity and Siphonic.
- The Performance Requirements of the Roof Drainage are established by the **QP/Architect.**
- Gravity Systems are generally designed by the **QP/Architect using** prescriptive solutions based on SS525.
- Siphonic System are designed by a Siphonic Specialist and endorsed by specialist **QP/PE.**

FASTFLOW

Recommendations for Design of Open To Sky Drainage

- Develop a Roof Drainage RISK ASSESSMENT PLAN which acts as a Checklist for Risk Mitigation.
- Consider the merits and demerits of a Gravity System and a Siphonic system on a project by project basis.
    - Tangible Benefits
    - Intangible Benefits
    - Cost Benefits

Q
A

FASTFLOW

...the art of drainage

Case Study: Open to Sky

Open to Sky Drainage

Marina Bay Sands Sky Park, Singapore

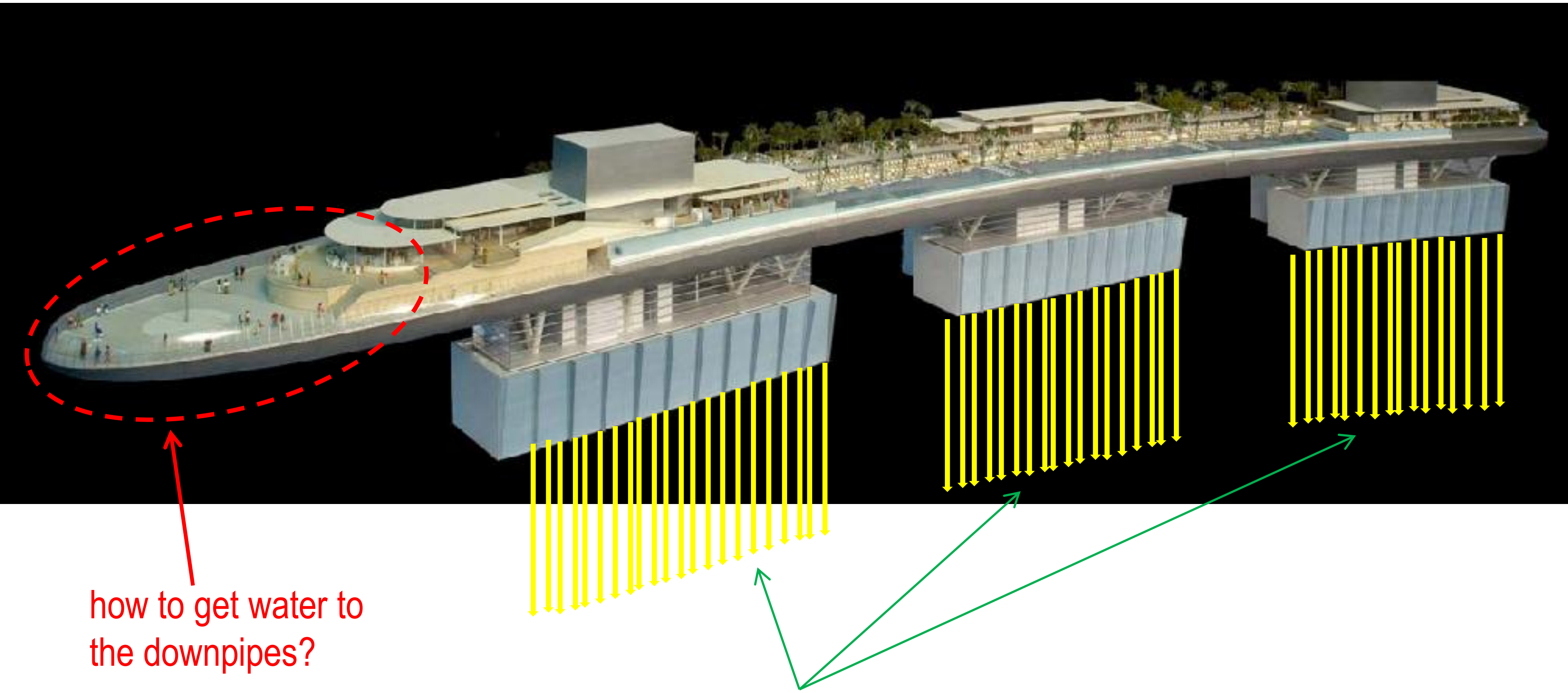
Catchment area of 12,500 sqm

Flow rate of 1,145 l/s at design rainfall intensity of 330mm/hr

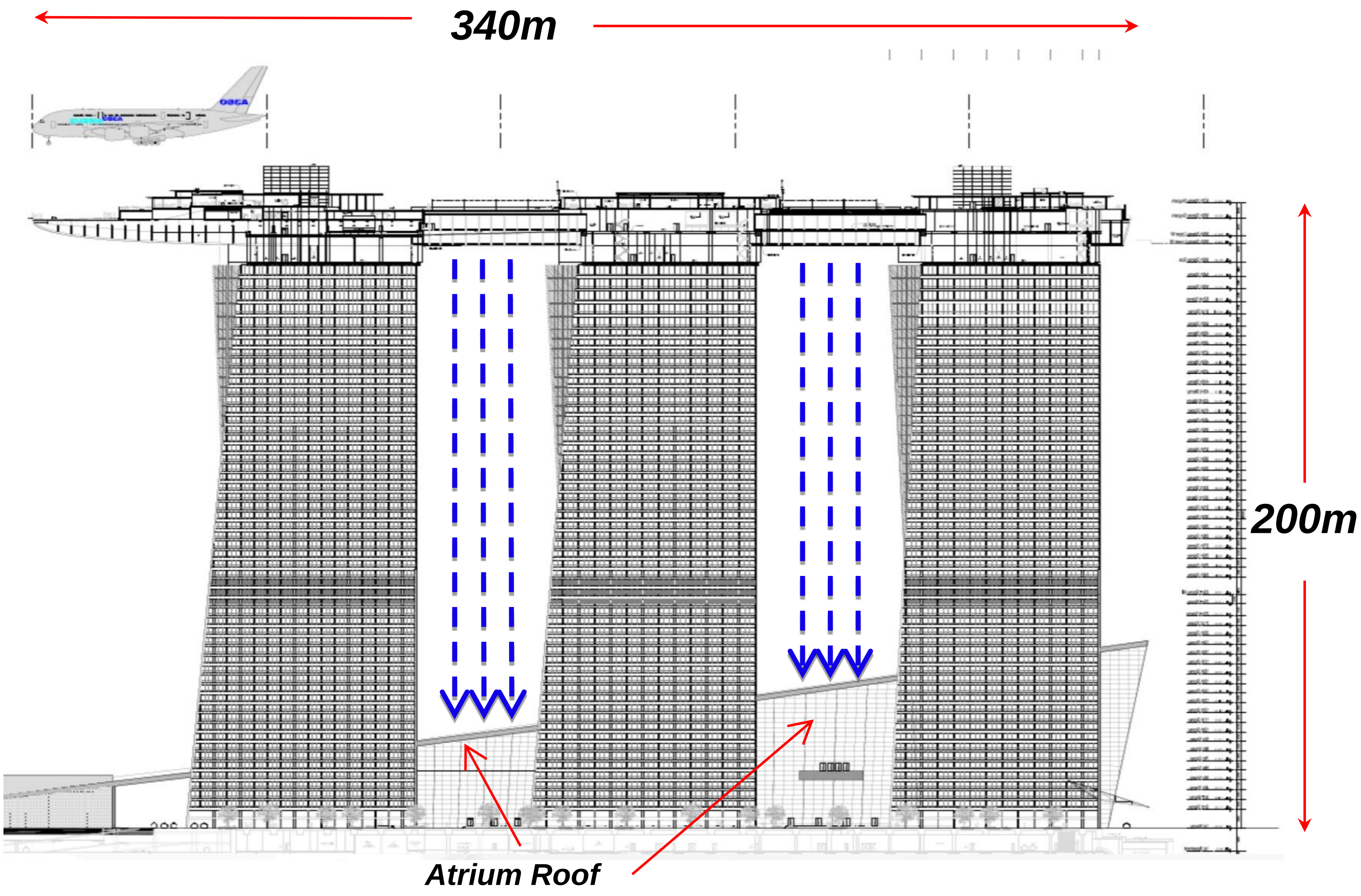
200m above street level

Approx. 40m wide by 340m long

Gravity System



100 no. 150mm dia. gravity pipe
57 no. 200mm dia. gravity pipe

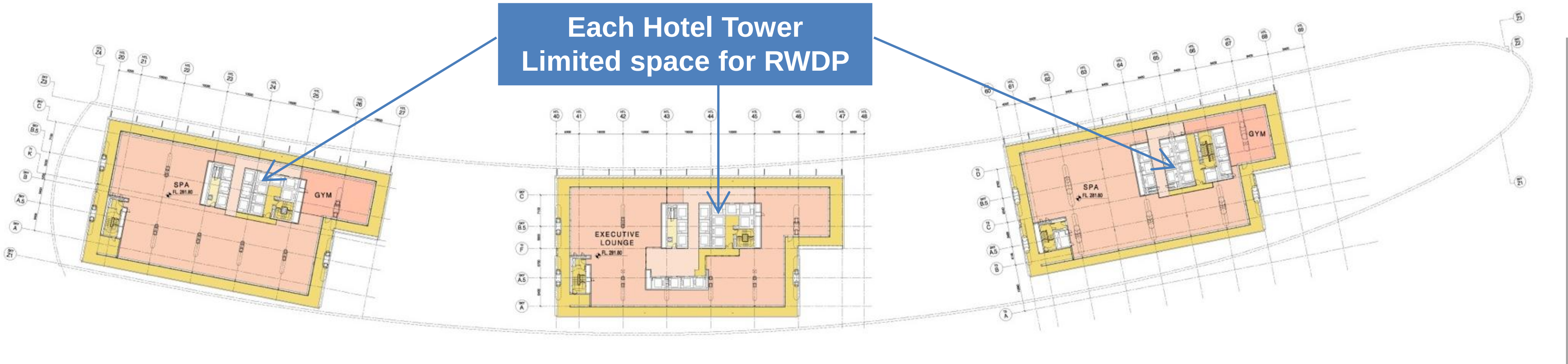


340m
200m
Atrium Roof

SITE CONDITION

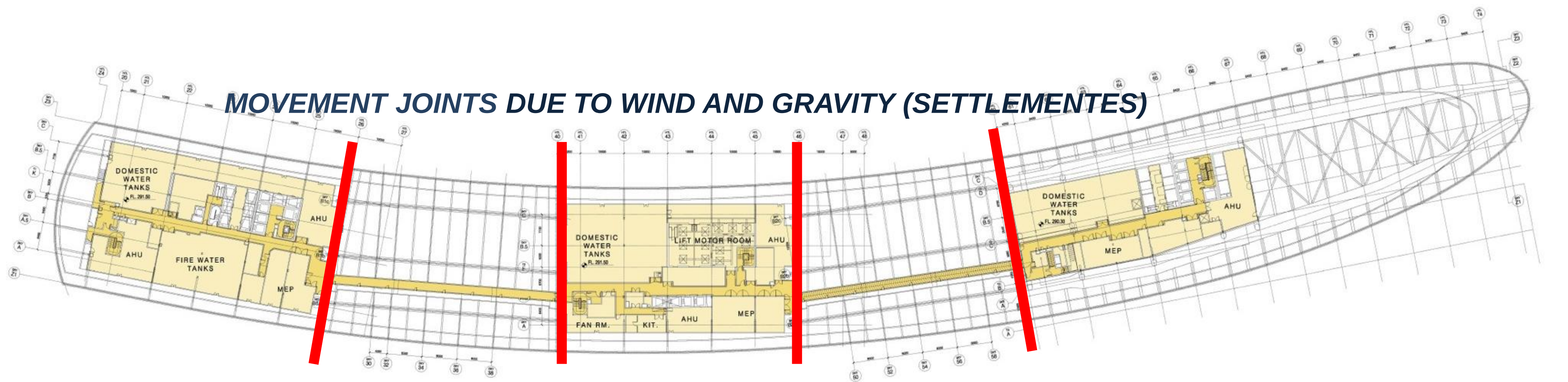
Structure for 3 Hotel Blocks 80-90% completed in July 2009

FASTFLOW



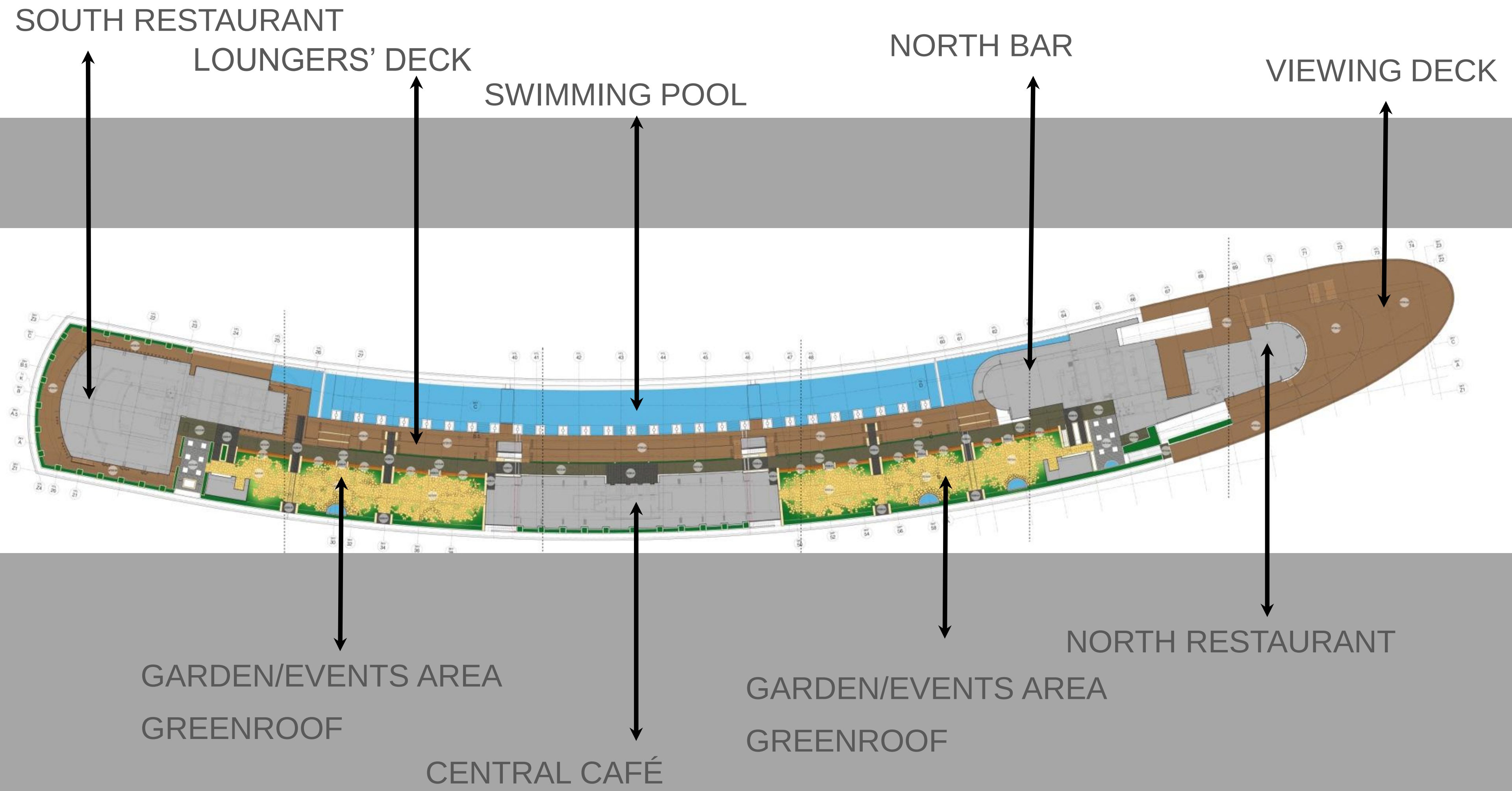
L55: 281.8m

BUILDING STRUCTURE CONSTRAINT



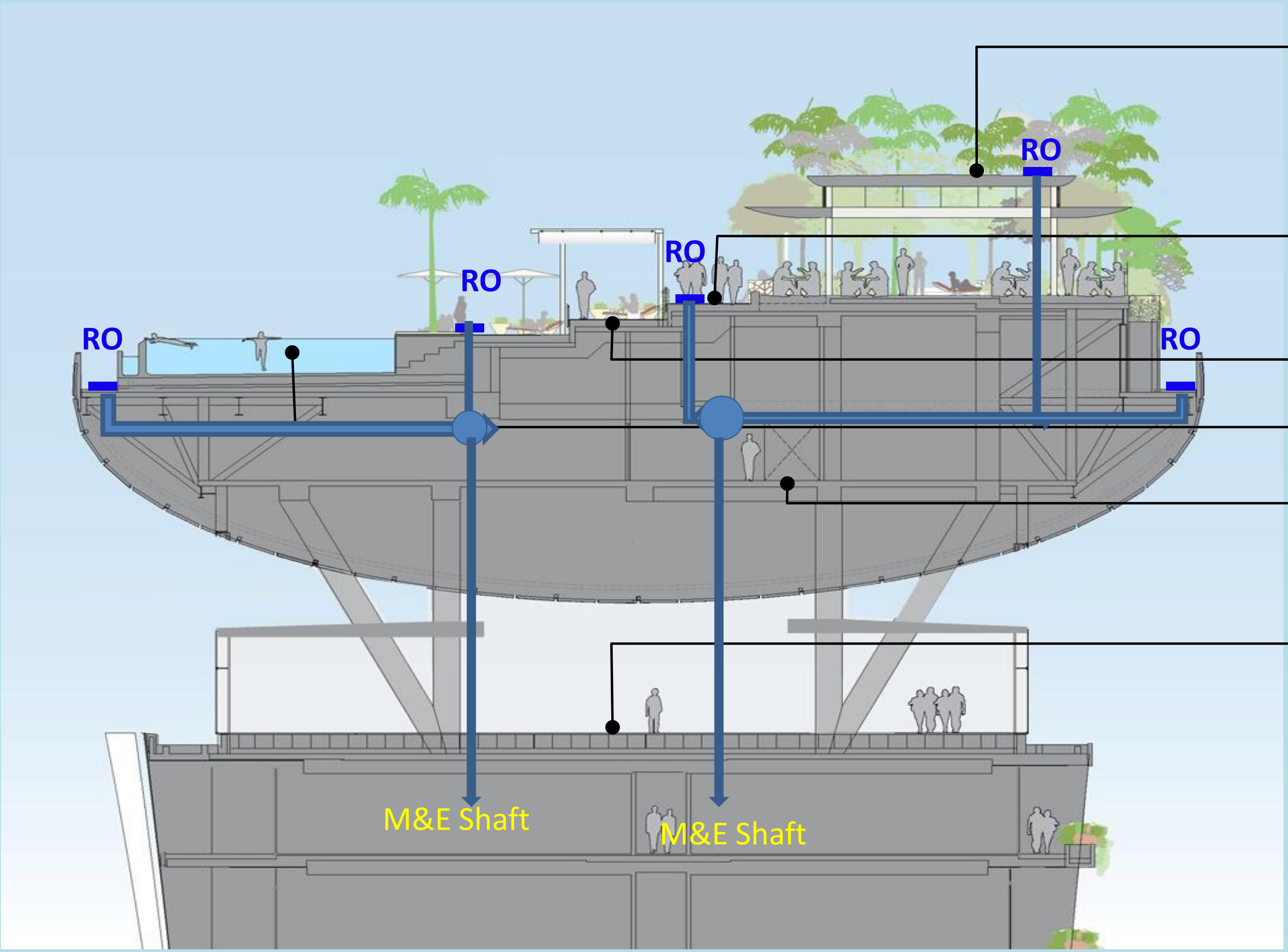
L55: 291.5m

MOVEMENT JOINTS BETWEEN TOWERS



INTERFACING GREEN ROOF DRAINAGE WITH SIPHONIC DRAINAGE

Siphonic System



F&B PAVILLION

(GARDENS/EVENTS' AREAS IN BETWEEN)

CENTRAL WALKWAY

POOL DECK

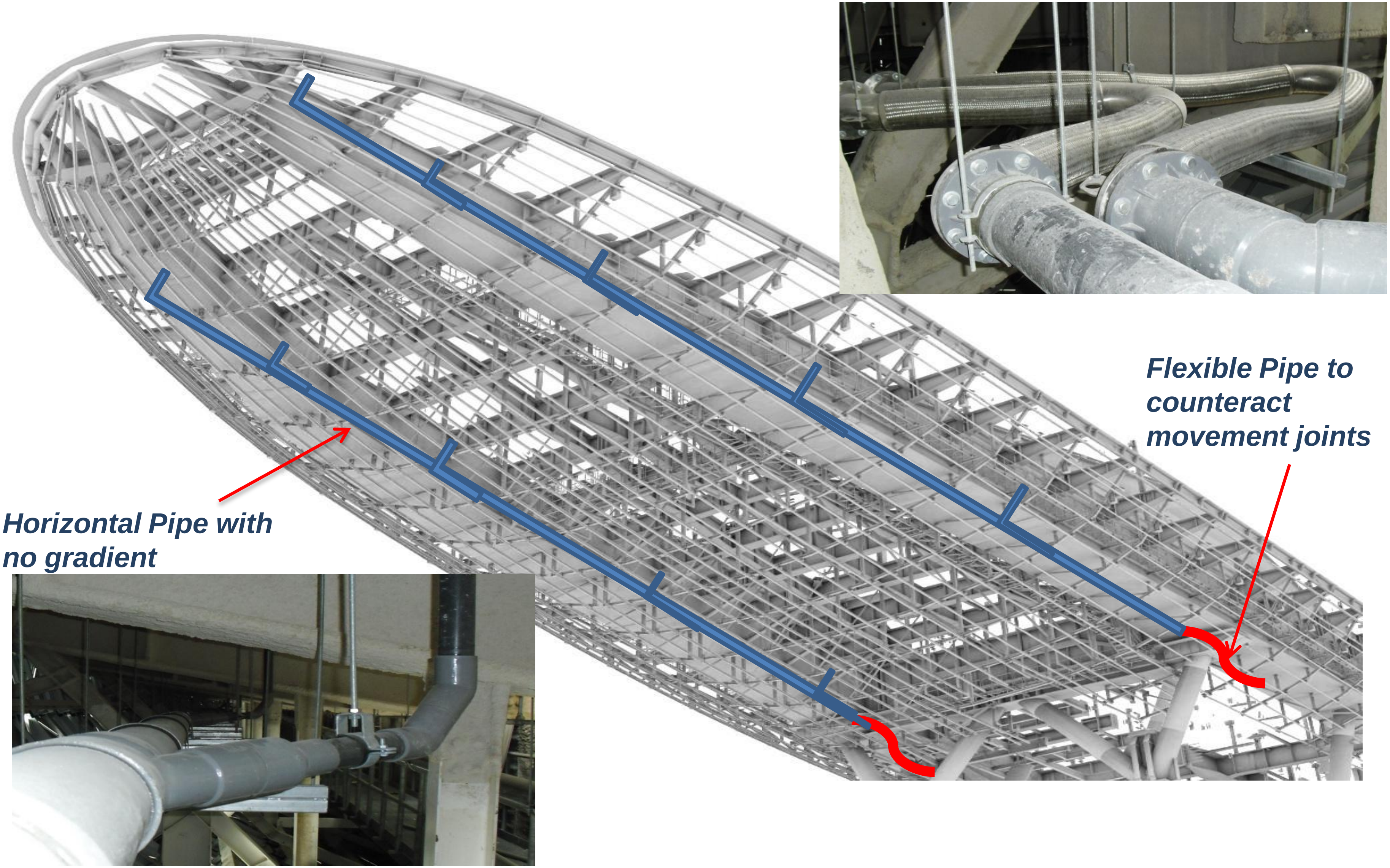
SWIMMING POOL

MEP FLOOR

GYM & SPA

FASTFLOW

Siphonic System

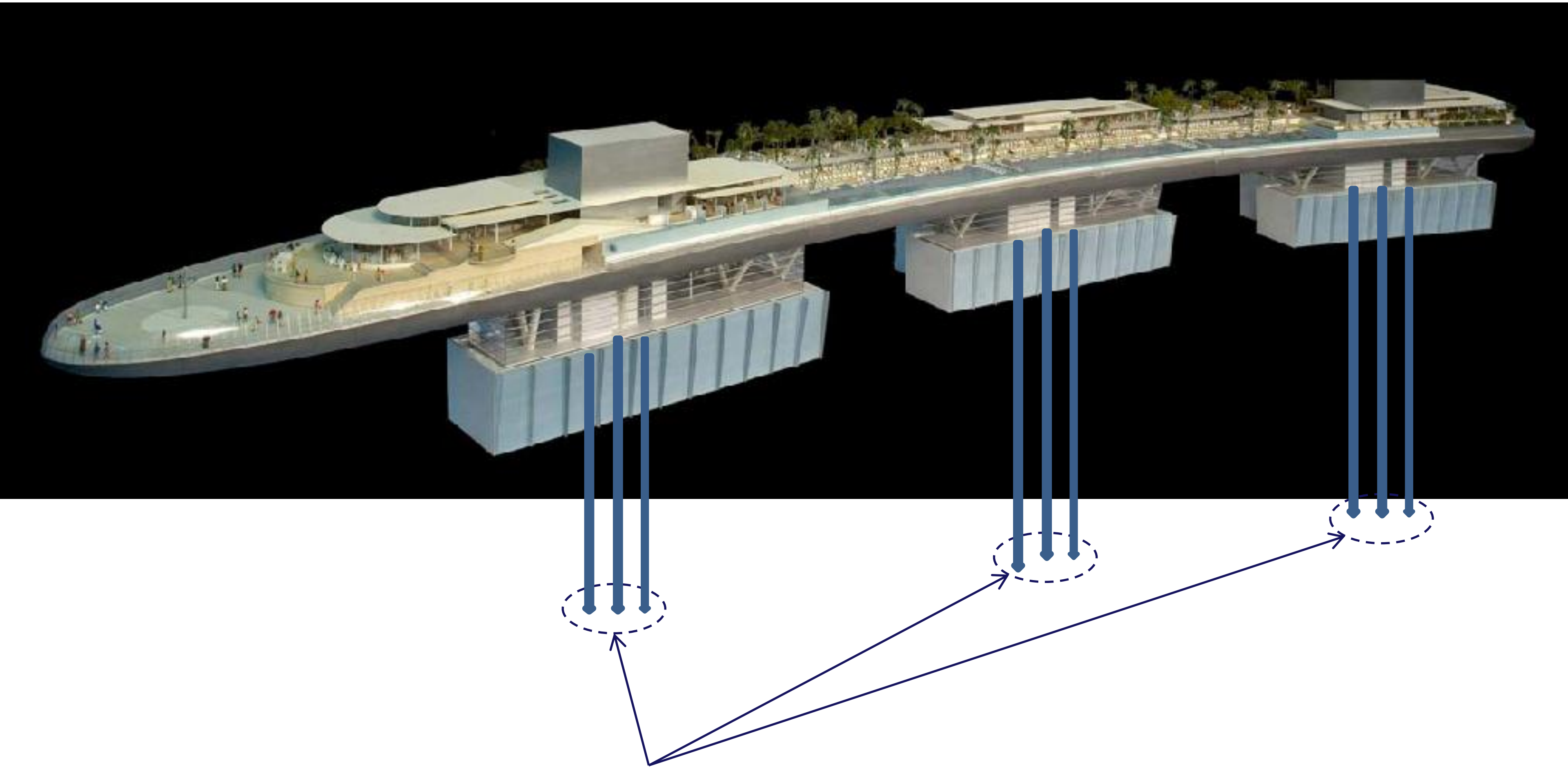


Flexible Pipe to counteract movement joints

Horizontal Pipe with no gradient

FASTFLOW

Siphonic System Solution

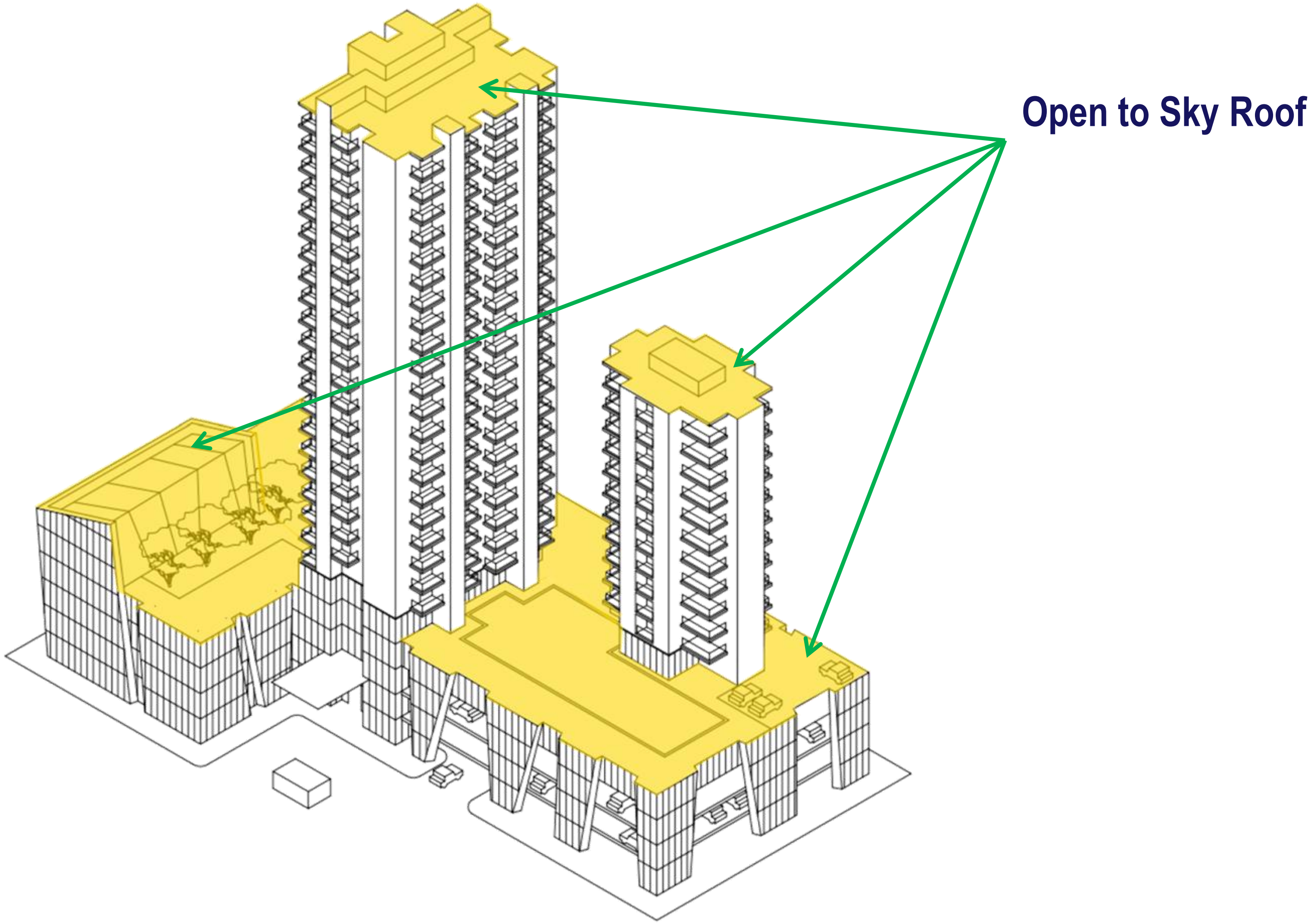


9 no. 150mm dia. Siphonic Stack

What are ‘Wind-Driven Rain Spaces’?

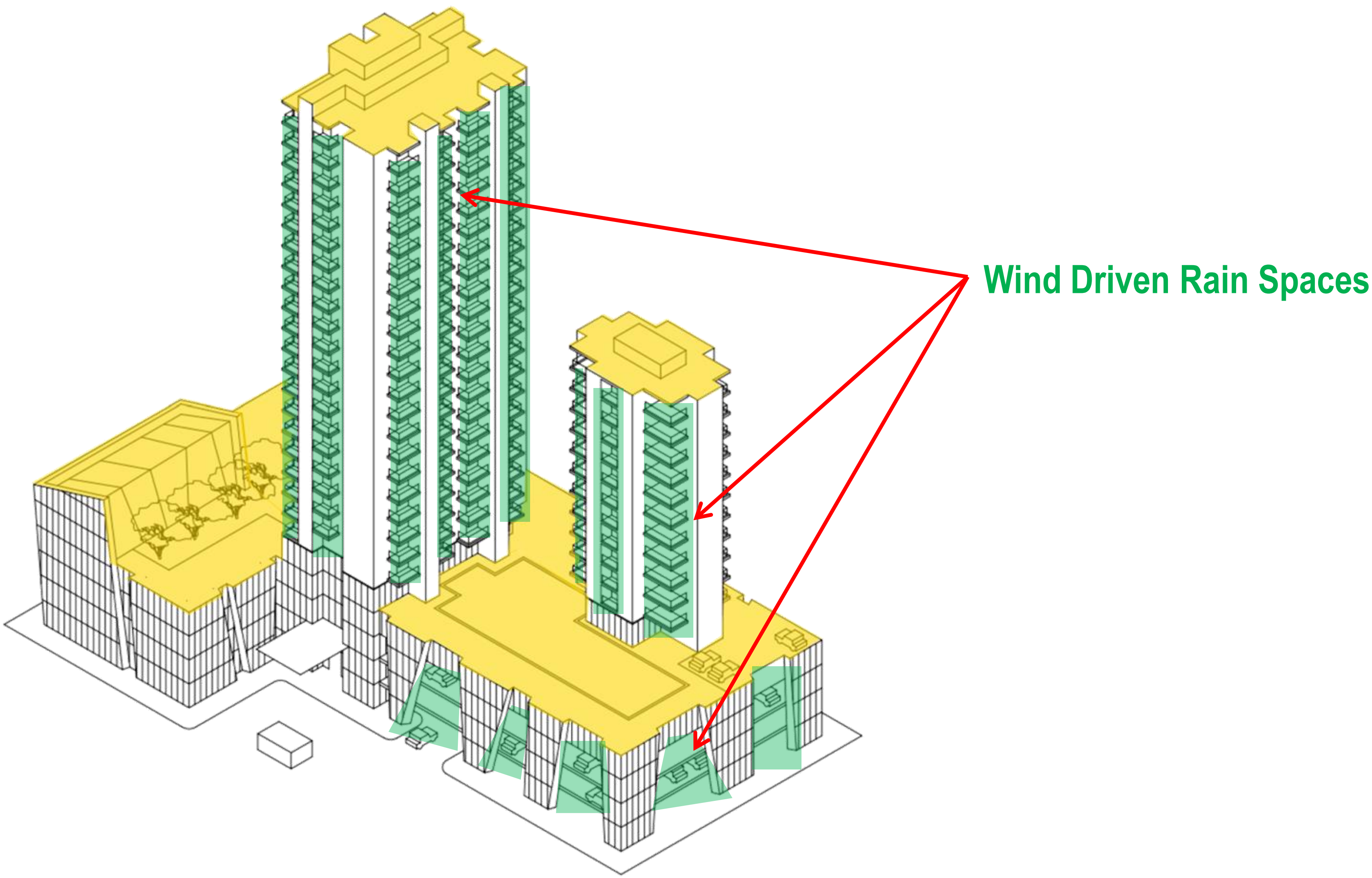
FASTFLOW

Open to Sky Roof



FASTFLOW

Wind Driven Rain Spaces



What are Wind-Driven Rain Spaces?

- Balconies
- Sky bridges
- Recreation areas
- Multi-storey car parks
- Lobbies
- Corridors
- Canopies
- Mechanical Rooms

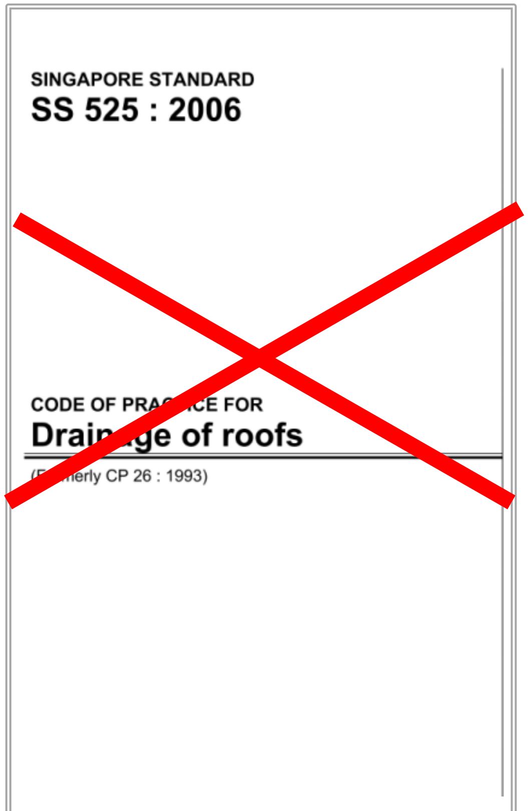
What are Wind-Driven Rain Spaces?

Wind-Driven Rain Spaces

Definition:

'Spaces which have at least one external façade which is unprotected from wind-driven rain making them susceptible to an ingress of water into that space.'

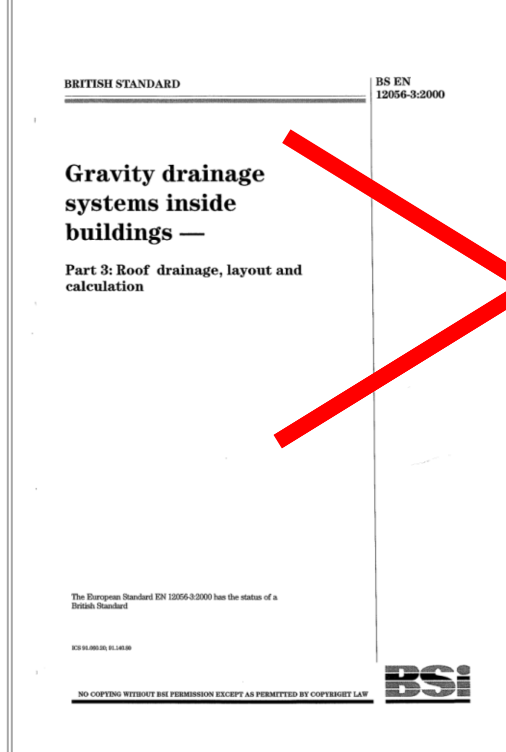
What are the Standards and Codes that regulates the Rainwater Drainage of Wind-Driven Rain Spaces?



SINGAPORE STANDARD
SS 525 : 2006

CODE OF PRACTICE FOR
Drainage of roofs
(Formerly CP 26 : 1993)

BS EN12056-3:2000



BRITISH STANDARD

BS EN 12056-3:2000

Gravity drainage systems inside buildings —

Part 3: Roof drainage, layout and calculation

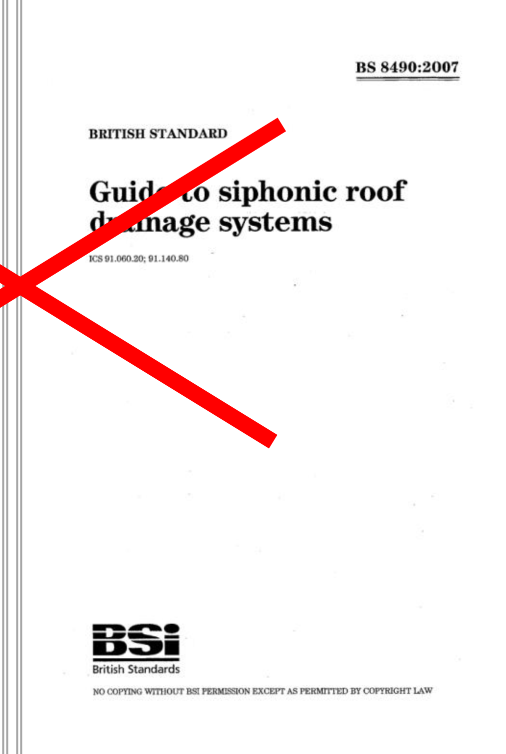
The European Standard EN 12056-3:2000 has the status of a British Standard

ICS 91.060.20; 91.140.80

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

BSI

BS 8490:2007



BS 8490:2007

BRITISH STANDARD

Guide to siphonic roof drainage systems

ICS 91.060.20; 91.140.80

BSI
British Standards

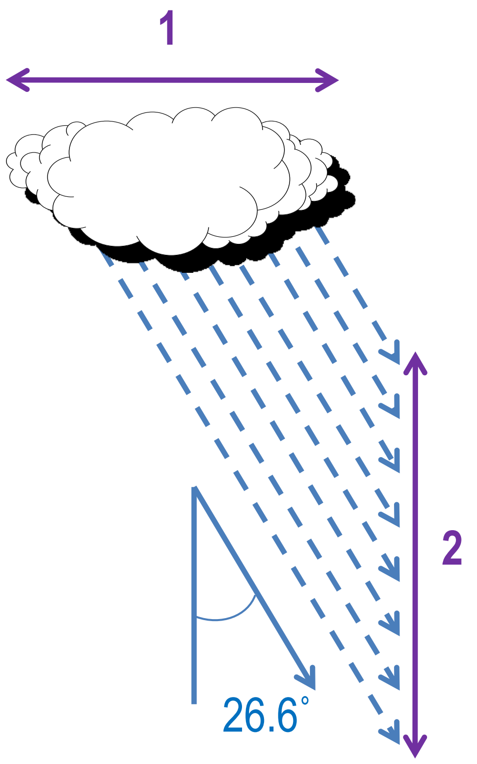
NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

NO CODES – NO STANDARDS

What is Wind-Driven Rain?

- *Wind driven rain (or driving rain) is one of the most important sources of moisture affecting building facades.*

- *Many modern buildings are now designed with spaces which whilst effectively covered are subject to wind-driven rain.*



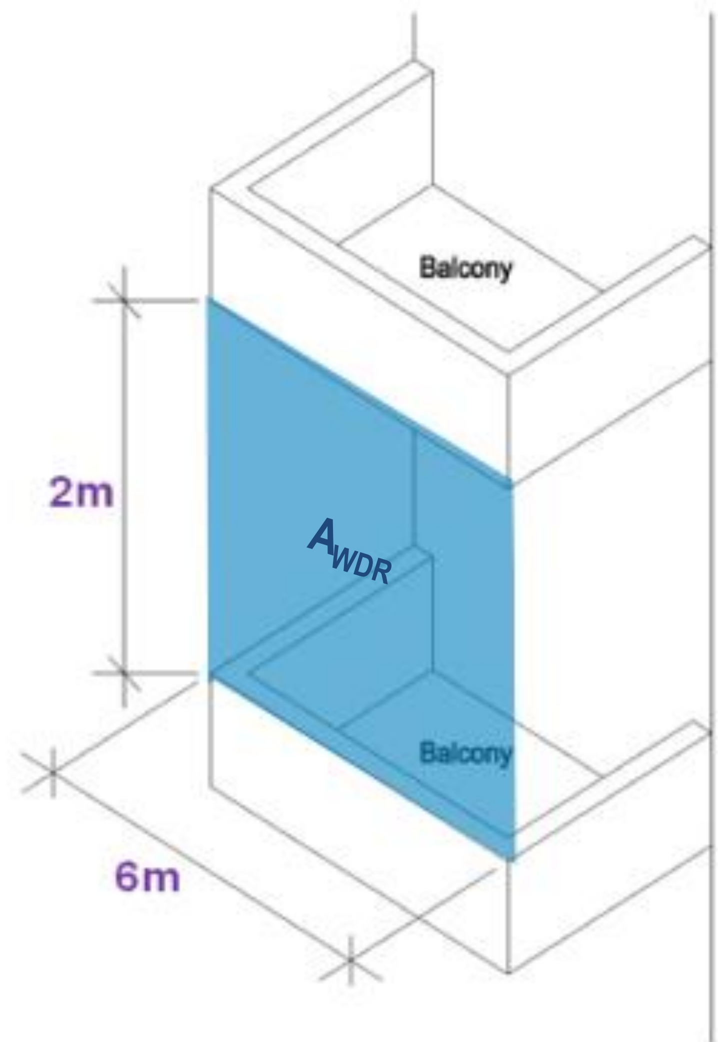
See Clause 6.1.4 of SS525

How Much Wind-Driven Rain Are We Talking about?

FASTFLOW

Catchment Area

- The diagram on the right shows the most commonly accepted definition of the vertical catchment area.
- Fast Flow has been using and promoting this concept over the last 12 years.
- It is accepted in Singapore, Malaysia, Thailand, Australia, Indonesia, India and Turkey.



A_{WDR} : vertical catchment area

(The max vertical opening area in any one plane of any Wind-Driven Rain Space which has an ingress of rainwater to that space)

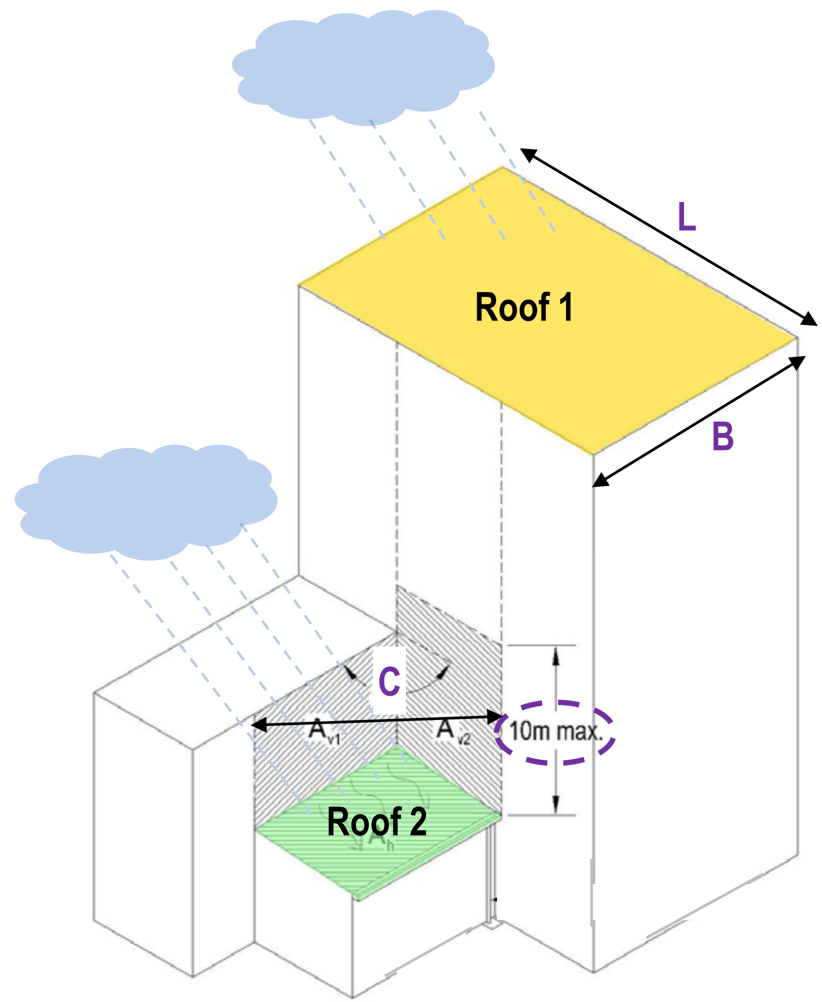
FASTFLOW

Rainfall Intensity

The rainfall intensity to be adopted in Wind-Driven Rain calculation should be assessed on the basic principles of SS525.

NOTE:

Balconies are sensitive areas. If water enters residential property the consequences can be significant. Adopting the same Rainfall Intensity as the roof has its logic but **RISK** must be assessed.



FASTFLOW

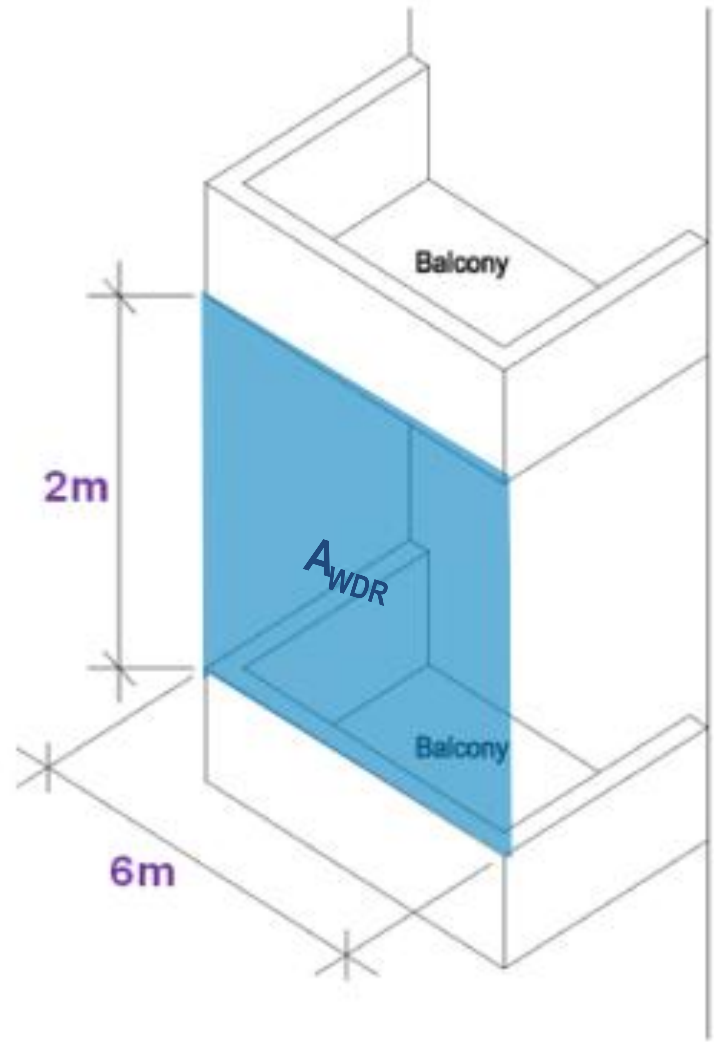
Rate of Run-Off

$$Q_{WDR} = \frac{F_R \times A_{WDR} \times I}{3600}$$

where

Q_{WDR}: rate of run-off

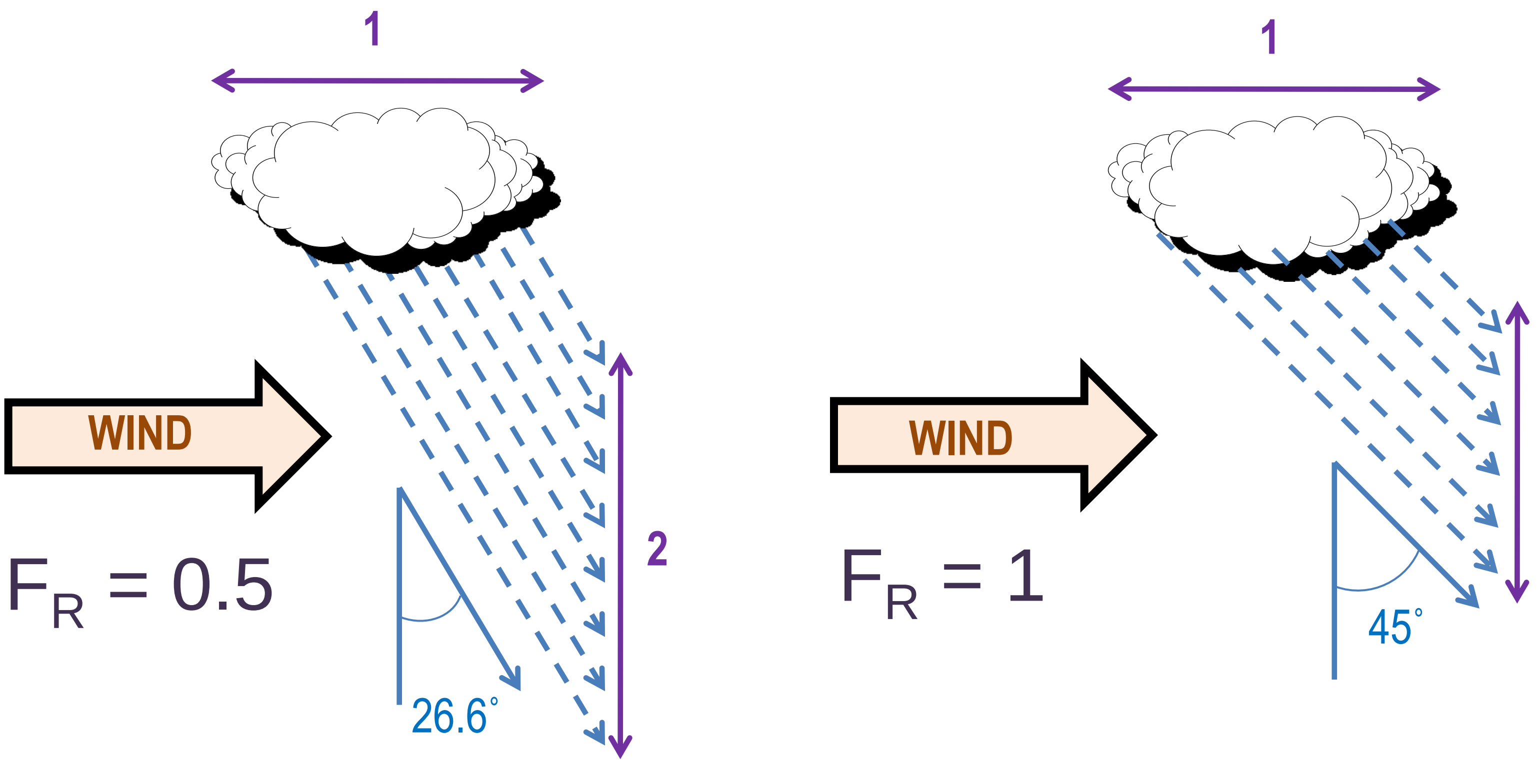
(The amount of water that will required to be drained from each and every Wind-Driven Rain Space)



What is the Factor of Risk (F_R)

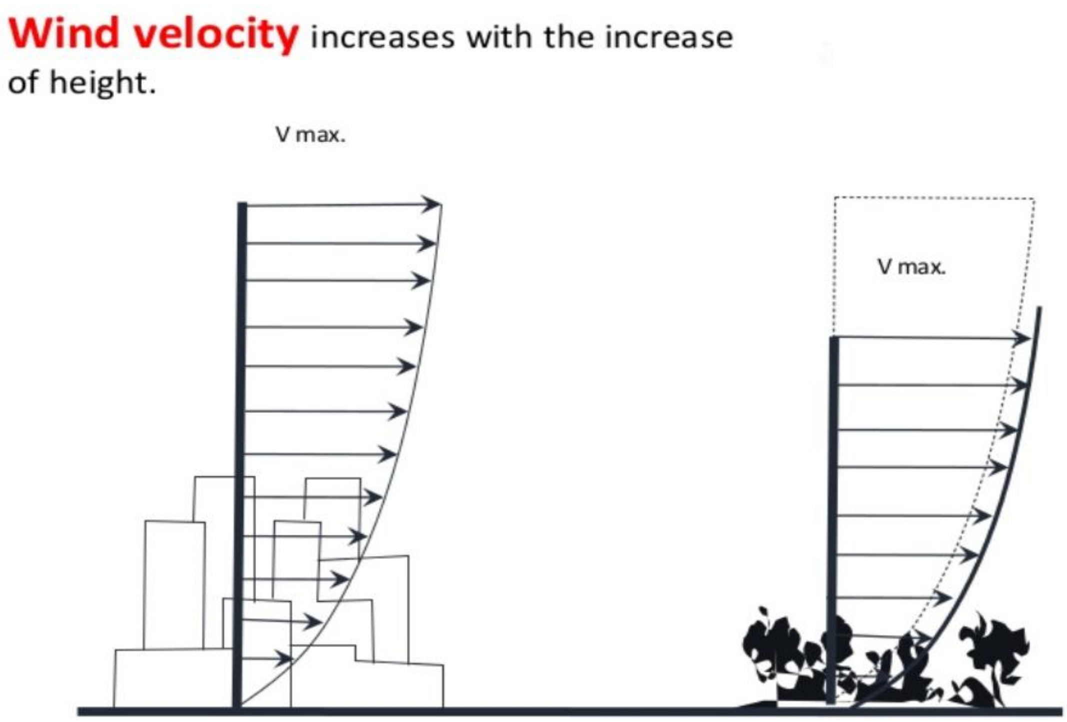
The Factor of Risk (F_R) is based on the concept of what angle the rain will fall at. In SS525 a factor of 0.5 is applied to elevation drainage which is deemed to fall onto adjacent roof areas. This factor is derived from the rain falling at 26.6˚.

However, rain falling at only 45˚ raises the F_R to 1.



Factor of Risk – What F_R should we use?

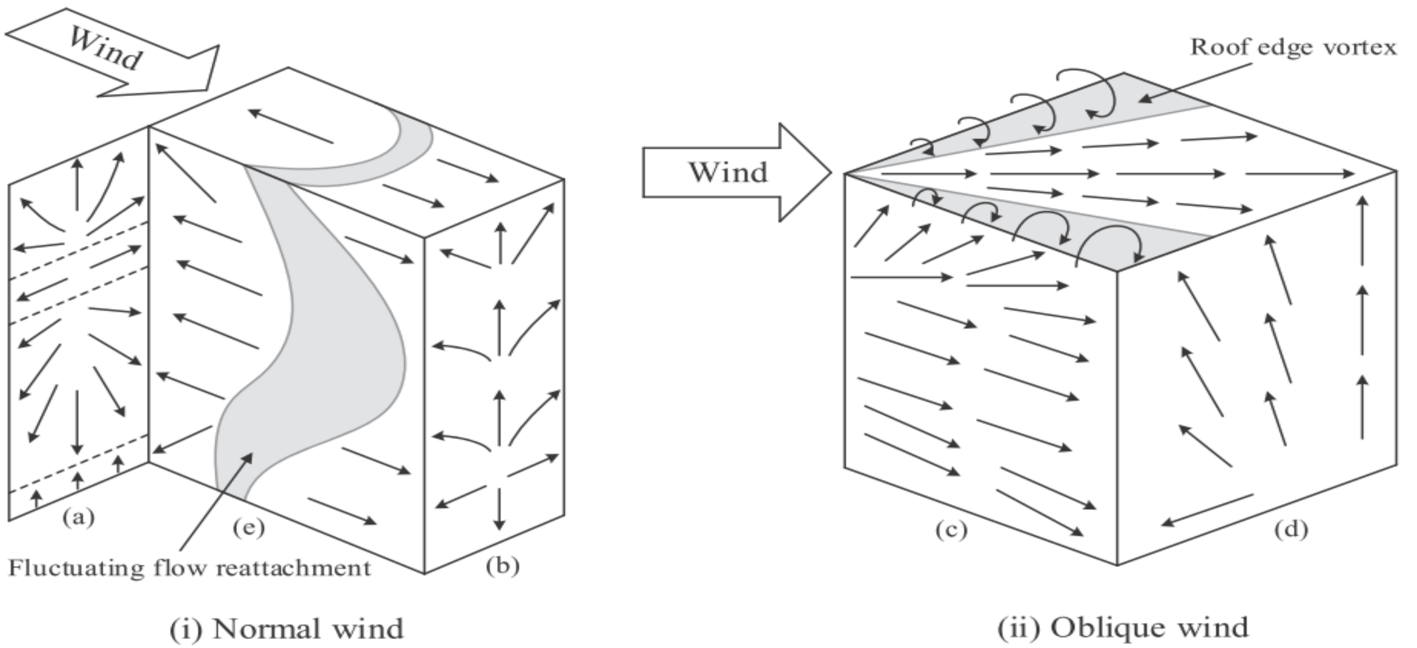
- F_R varies with height of building



Variation of wind velocity with height

Factor of Risk – What F_R should we use?

- F_R varies with shape of building and wind orientation

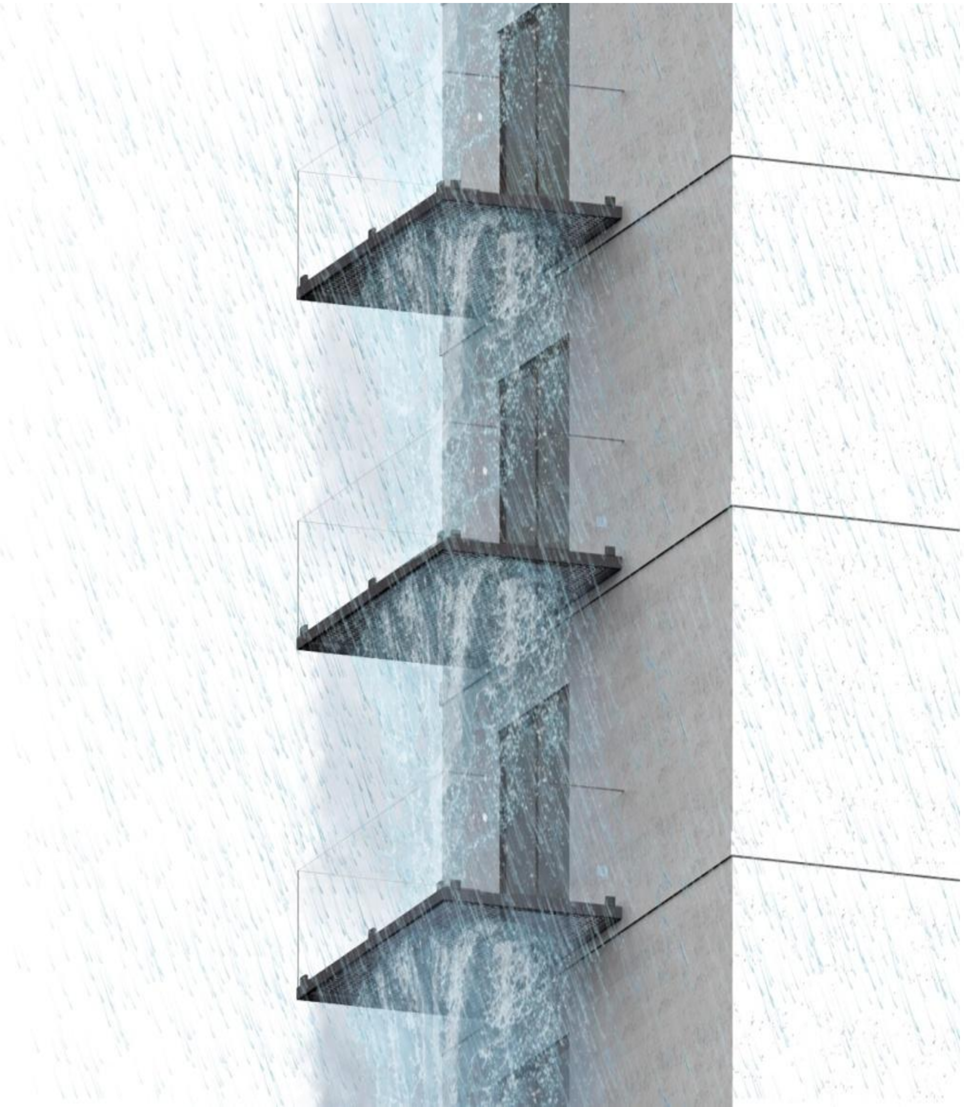


Mao, Jiachen & Gao, Naiping. (2015). The airborne transmission of infection between flats in high-rise residential buildings: A review. Building and Environment. 94. 10.1016/j.buildenv.2015.09.026.

FASTFLOW

How is Rainwater Drained from these Spaces?

Solution 1:
Perforated Balcony Floor



Solution 2:
Scupper

Solution 3:
Break Vent

It has been adopted in some low to medium rise buildings.

But it has many concerns and limitations.

1. Concealment v. Aesthetics
2. Maintenance v. Concealment
3. Capacity

Some of the Break Vent systems currently being used in the Market Place

Malaysia and Singapore

Singapore HDB

Neither of these SYSTEM carry any test data
nor have been VALIDATED

Solution 4:
Linked Vertical Stack

It is the most used for high-rise. There is however a major misconception of how this solution works. It has evolved from historical practice, maybe 'rule of thumb' or 'best guess' approach.

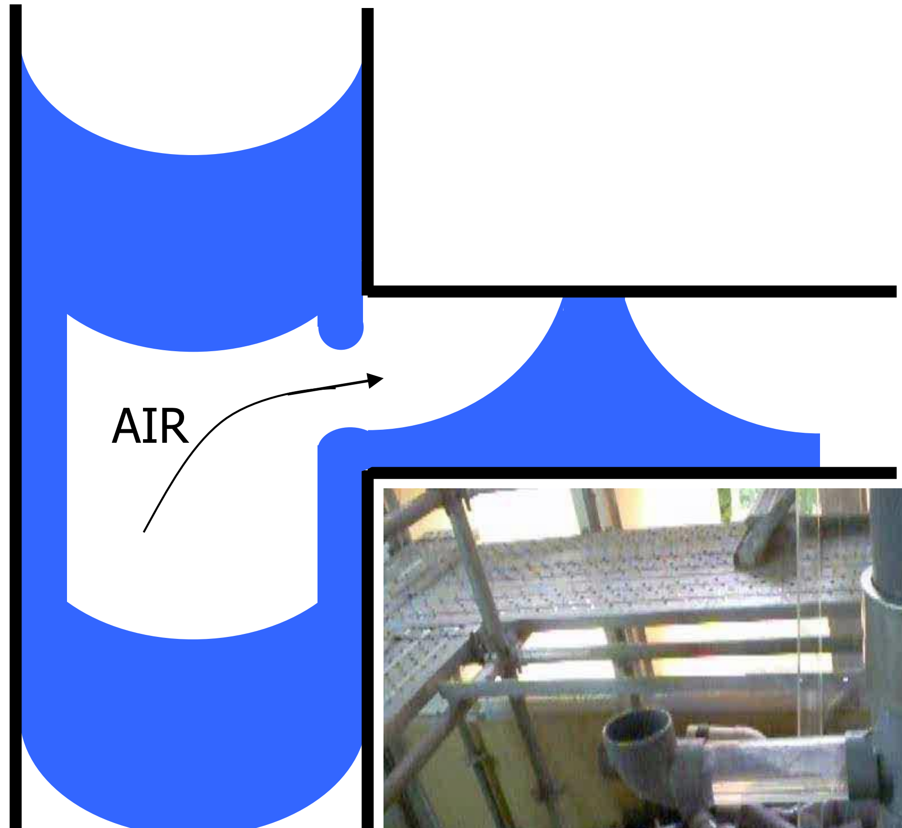
But it has
'No Basis in Engineering'.

FASTFLOW

FASTFLOW

Why does this happen?

- Water Plug Forms
- Air escapes through easiest path the branches
- It brings along water with it



Results in BACKFLOW!

FASTFLOW

Test Report Reference. 54S070713/EPK
dated 12 FEB 2007

TEST RESULTS:

1. Pipe Junction: 75 x 50mm Standard Tee

Q (l/s)	Observations
0.0 - 2.2	No spouting of water from backflow pipe observed.
2.3	Minor spouting of water from backflow pipe observed.
3.4	Regular spouting of water from backflow pipe observed.
> 3.6	Major spouting of water from backflow pipe observed. (see Photo 1)

Photo 1: Spouting of water from backflow pipe

Test Report Reference. 54S070713/EPK
dated 12 FEB 2007

TEST RESULTS (CONTINUED):

2. Pipe Junction: 100 x 50mm Standard Tee

Q (l/s)	Observations
0.0 - 1.9	No spouting of water from backflow pipe observed.
2.0	Minor spouting of water from backflow pipe observed.
3.0	Regular spouting of water from backflow pipe observed.
> 4.0	Major spouting of water from backflow pipe observed. Water often fills up to the rim of backflow pipe. (see Photo 2)

Photo 2: Spouting of water from backflow pipe

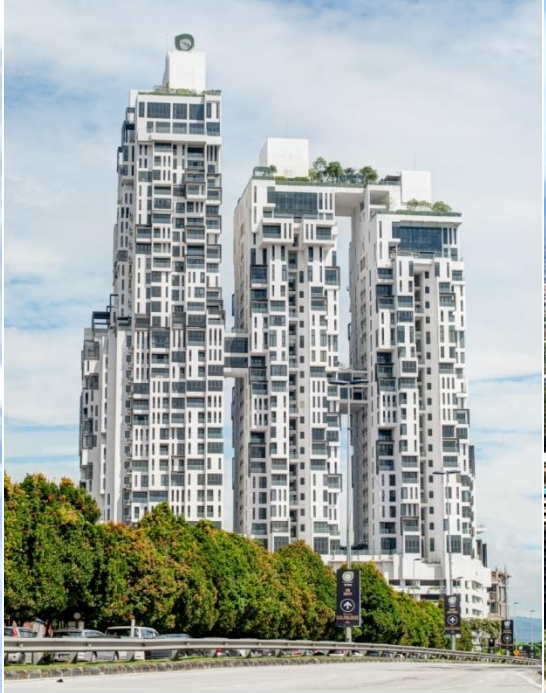
The capacity of a 75mm vertical stack (with 50mm branch) is 2.2 l/sec.

The capacity of a 100mm vertical stack (with 50mm branch) is 2 l/sec.

Siphonic is an Engineered solution for draining Roof Areas.

Can Wind-Driven Rain Spaces have an Engineered solution too?

Sky Habitat,
Singapore



ICON Residence,
Malaysia

Jewel Gold Coast,
Australia

The Interlace,
Singapore

Magnolias Ratchadamri Boulevard,
Thailand

ION Orchard,
Singapore

FASTFLOW

An Engineered Solution

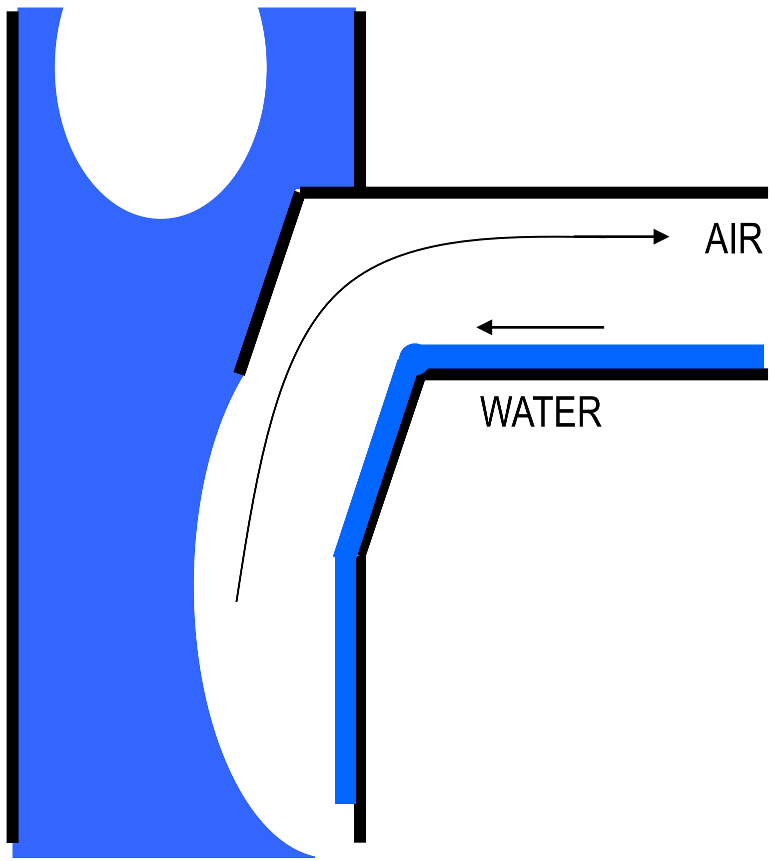
- All of the Projects shown on the previous slides have used the **PRESSURISED SYSTEM.**
- The Pressurised System has been draining Wind-Driven Rain Spaces since 2007.
- The Pressurised System was the result of intensive Research and Development with final testing and **VALIDATION by TUV** in 2007.
- Technology Patent was applied for in 2007 and the first Patent was granted in 2009 in Singapore.
- It is the only **ENGINEERED** system in the world for wind driven rain spaces.

FASTFLOW

HOW IT WORKS?

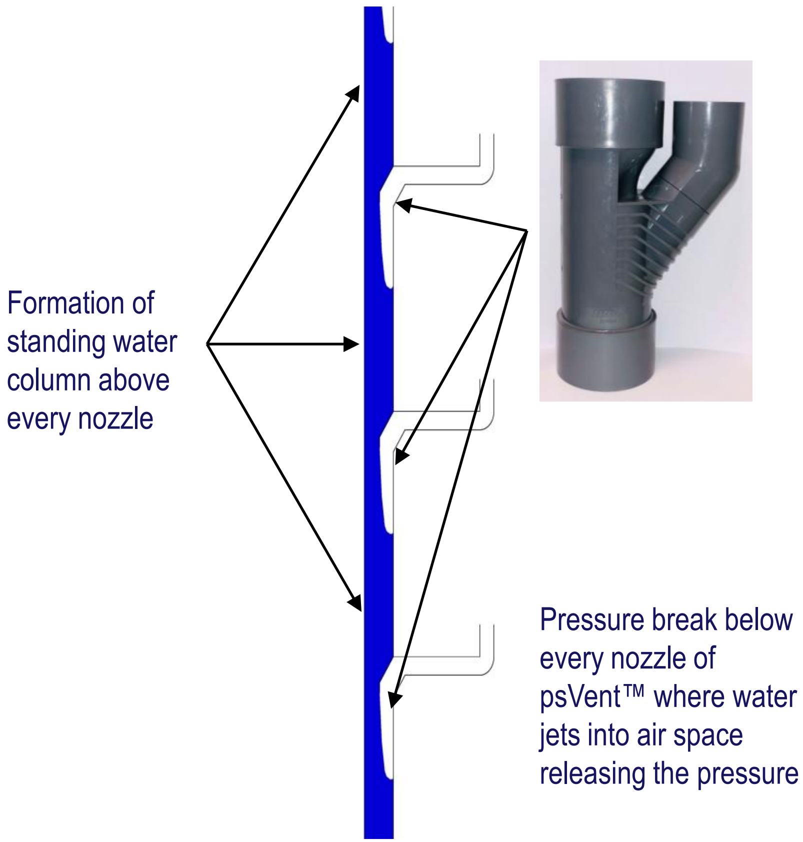
- Water Plug is intentionally formed
- Water is forced through the nozzle
- Water is discharged at high velocity
- Allows clear passage for air to escape
  - ➡ No backflow through branch pipe
- Allows water to enter through the branch

psVent™



Prevent pressure fluctuation

- Pressure in under-designed gravity stack is unstable and not predictable.
- psVent™ ensures that a controlled 2-phase flow (air & water) stack is stable.
- With this the stack capacity and pressure can be predicted and controlled.




psVent anti-backflow junction
Fast Flow Systems Pte Ltd

FASTFLOW

High Flow Capacity

- Controlled water column above every fitting
- Can achieve stack capacity of 20 l/s

Test Report Reference. 54S070713/EPK
dated 12 FEB 2007

TEST RESULTS (CONTINUED):

3. Pipe Junction: Ø75 Anti Backflow Junction

Setup: The Ø75 anti backflow junction consists of 3 backflow exit holes, with 2 of these exit holes sealed and the remaining exit hole connected to the backflow pipe.

Q (l/s)	Observations
0.0 - 20.0	No spouting of water from backflow pipe observed. No presence of water inside backflow pipe. Suction of air into the backflow pipe observed. (see Photo 4)

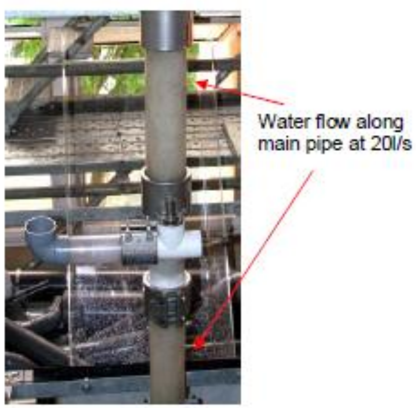


Photo 3: Water flow at 20l/s

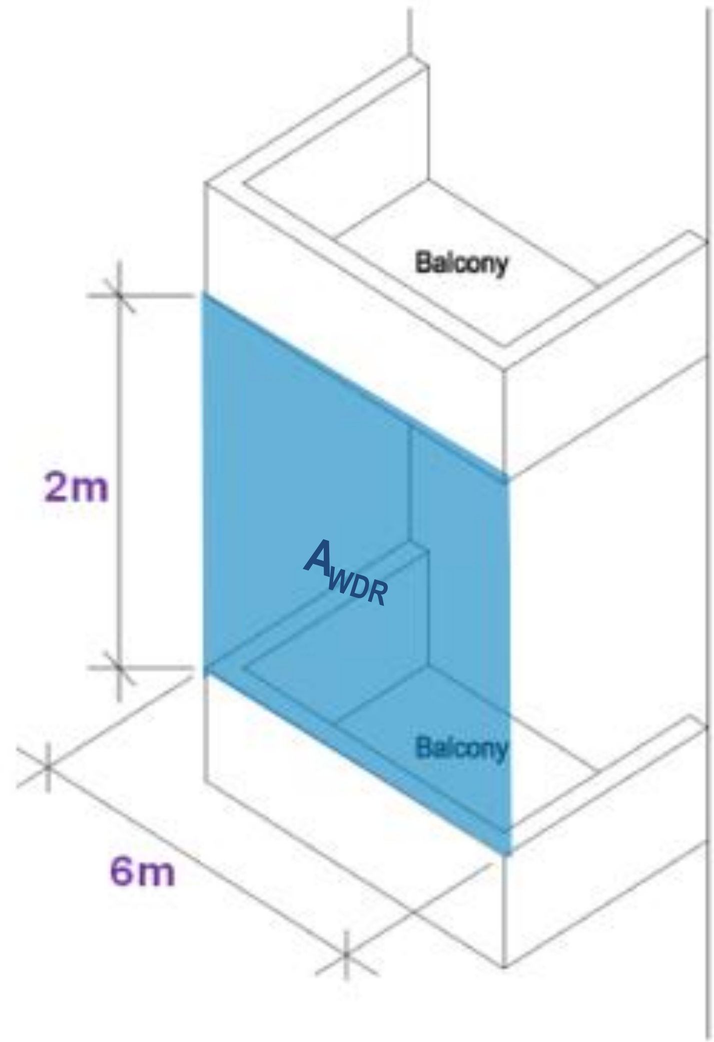
Photo 4: No presence of spouting of water at backflow pipe at 20l/s

Rate of Run-Off

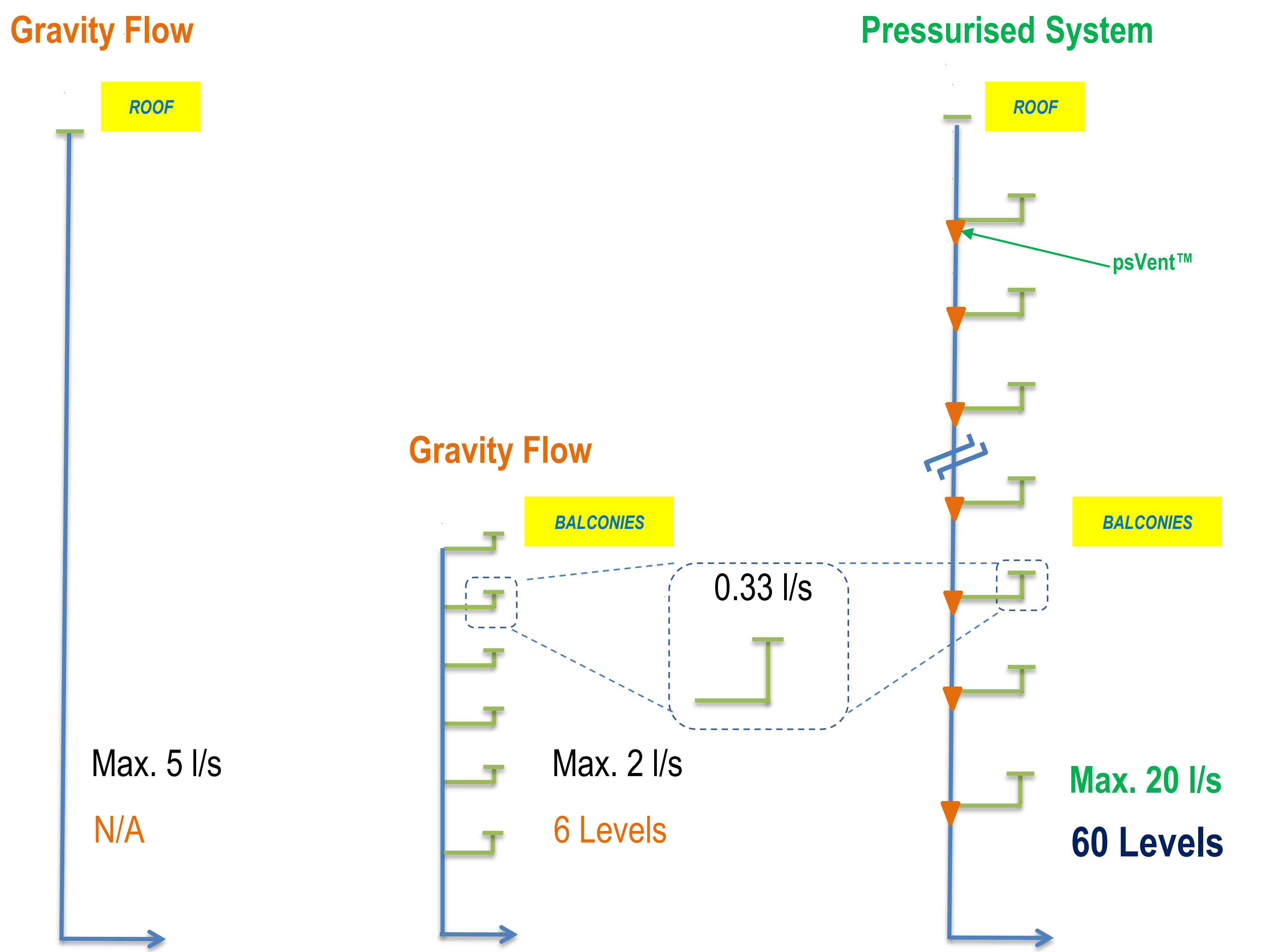
$$Q_{WDR} = \frac{F_R \times A_{WDR} \times I}{3600}$$

Illustration:

- $A_{WDR} = 2m \times 6m = 12m^2$
- If $I = 200mm/hr$ & $F_R=0.5$
- $Q_{WDR} = 0.33\ l/s$



Capacity of Dia. 75mm Vertical Pipe



FASTFLOW

Recommendations for Design of Wind-Driven Rain Spaces

- Architect/Designer/Specifier should develop a Specification based on Performance Requirements.
- Specification should invite proposals from Rainwater Specialists who can propose solutions which meet the Performance Requirements.
- Each solution must be based on Engineering Principles, must have been Tested and must carry a Certificate of VALIDATION.

FASTFLOW

Recommendations for Design of Wind-Driven Rain Spaces

- Develop a Wind Driven Rain RISK ASSESSMENT PLAN which acts as a Checklist for Risk Mitigation.
- Consider the merits and demerits of the various system available in the market
  - Tangible Benefits
  - Intangible Benefits
  - Cost Benefits


Q
A

FASTFLOW

...the art of drainage

Case Study: Wind-Driven Rain Spaces

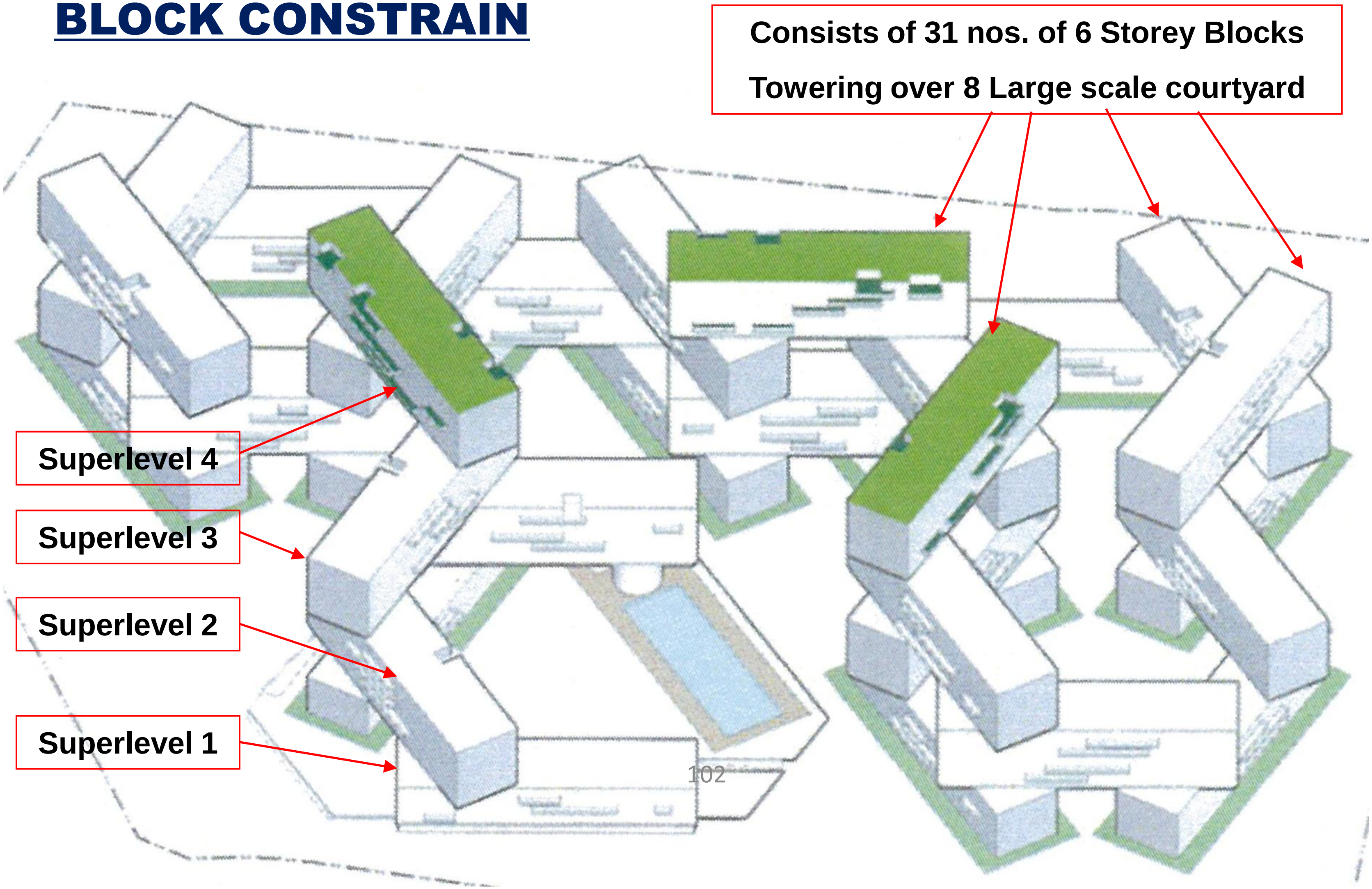
CASE STUDY

The Interlace

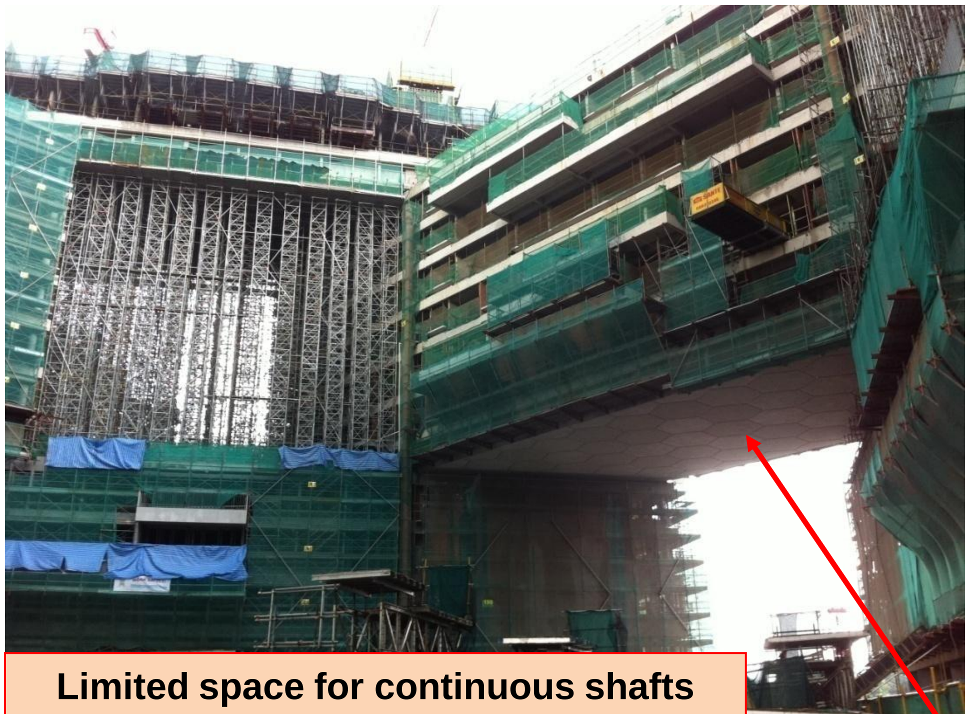
CASE STUDY on WDR

- Complex building profile with limited common shafts and space constraint.
- Staggering and inconsistent balconies profile.
- Show-case the WDR drainage system

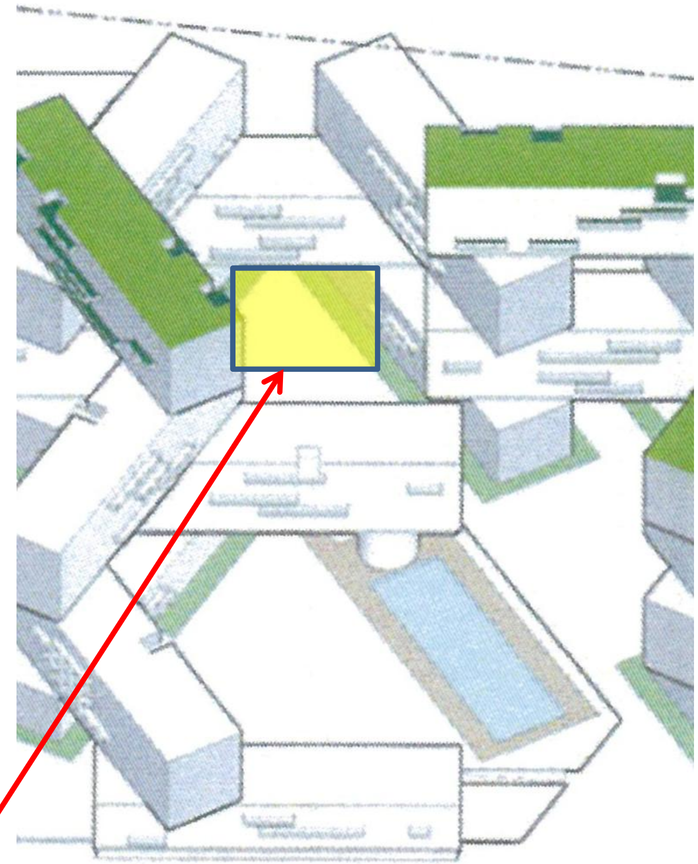
INTER-LOCKING BLOCK CONSTRAIN



INTER-LOCKING BLOCK CONSTRAIN



Limited space for continuous shafts



7 storey high void over courtyard

FASTFLOW

INTER-LOCKING BLOCK CONSTRAIN

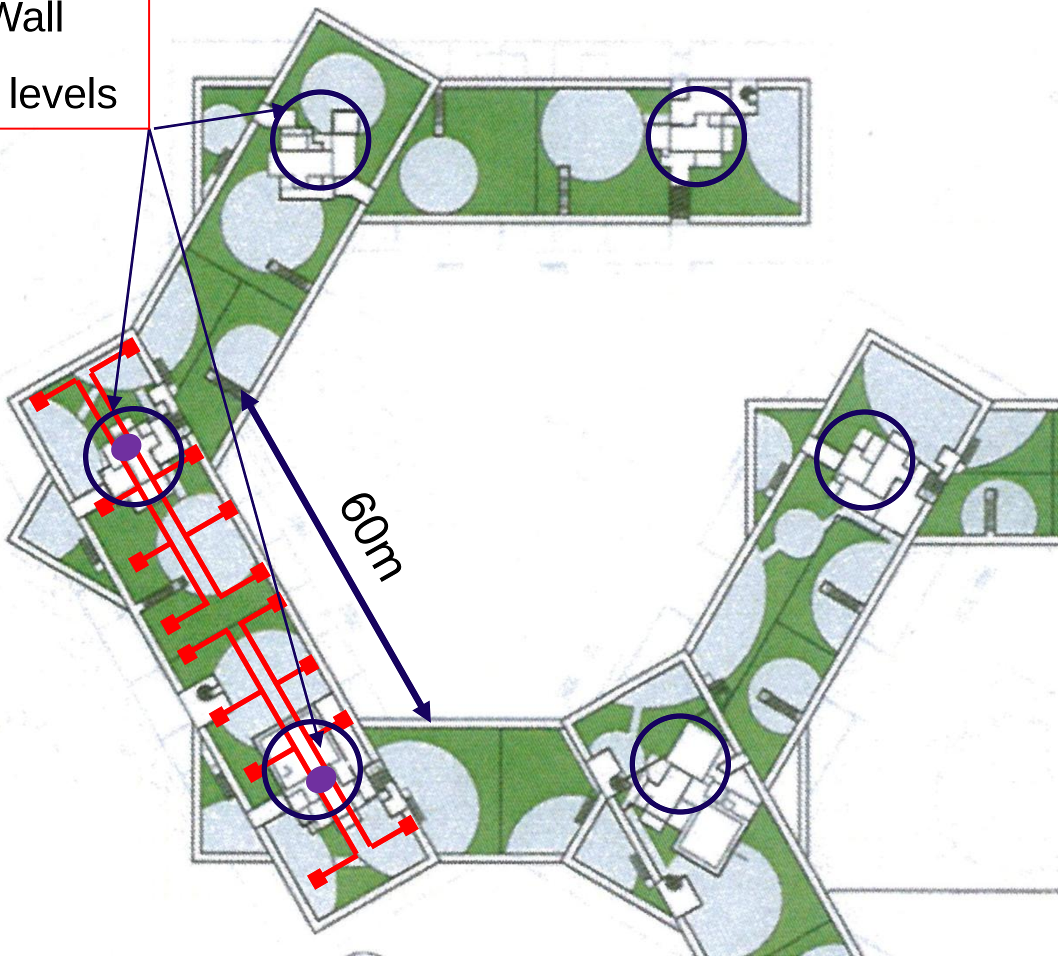
Supported by 23 nos Common Core Wall

Continuous structure piercing 4 super levels

INTER-LOCKING BLOCK CONSTRAIN

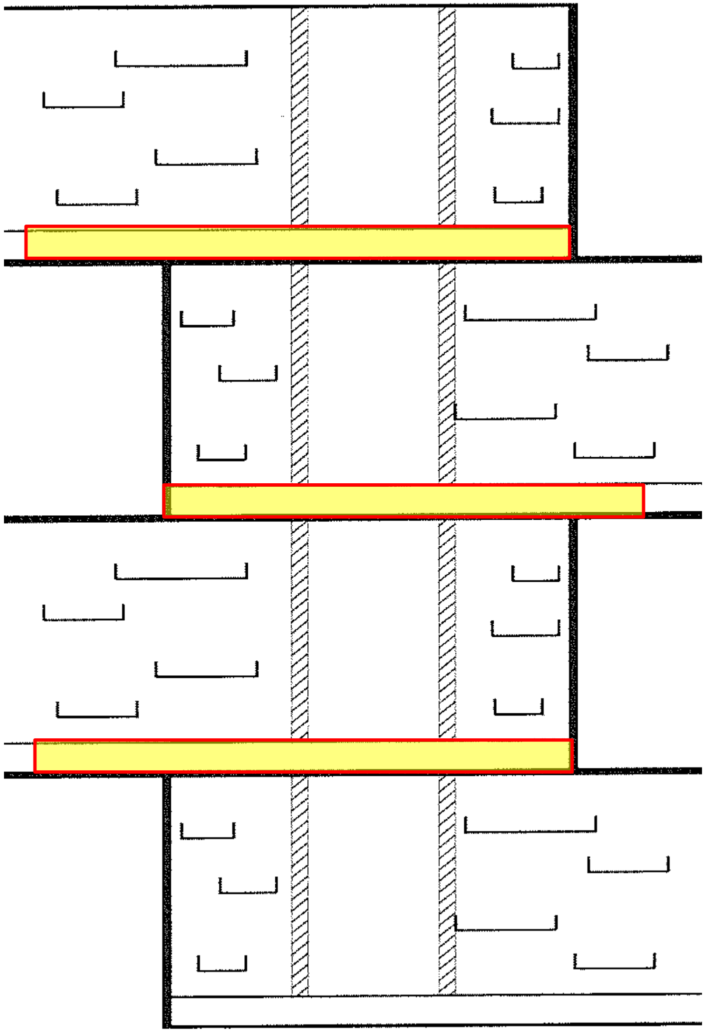
Supported by 23 nos Common Core Wall

Continuous structure piercing 4 super levels

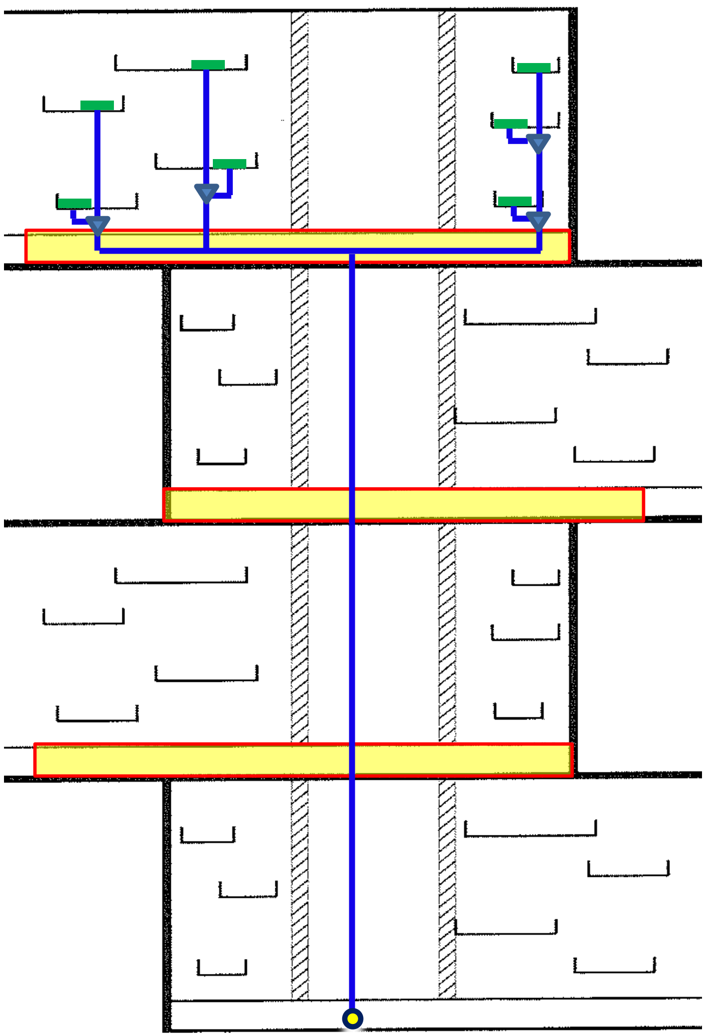


FASTFLOW

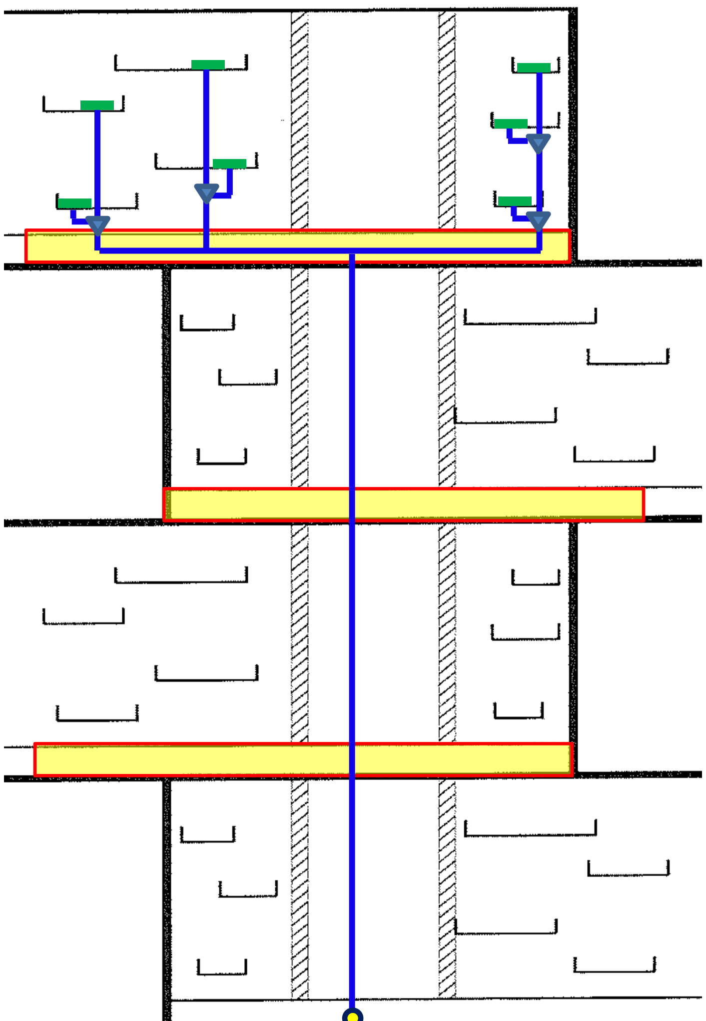
M&E Transfer Zone

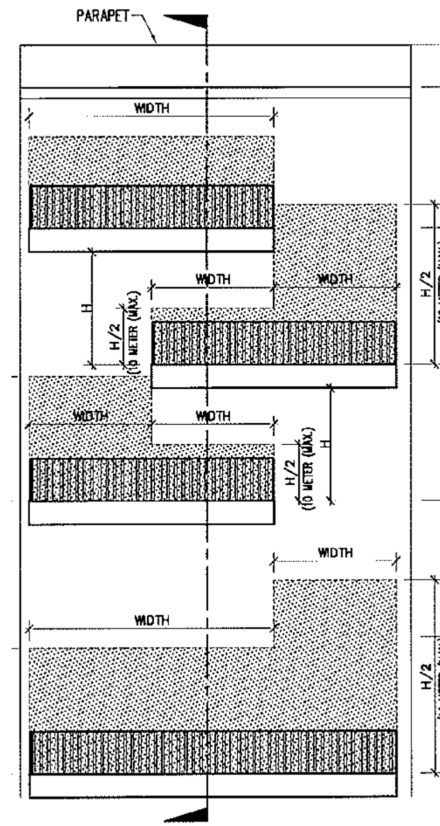


PIPES IN M&E DECK

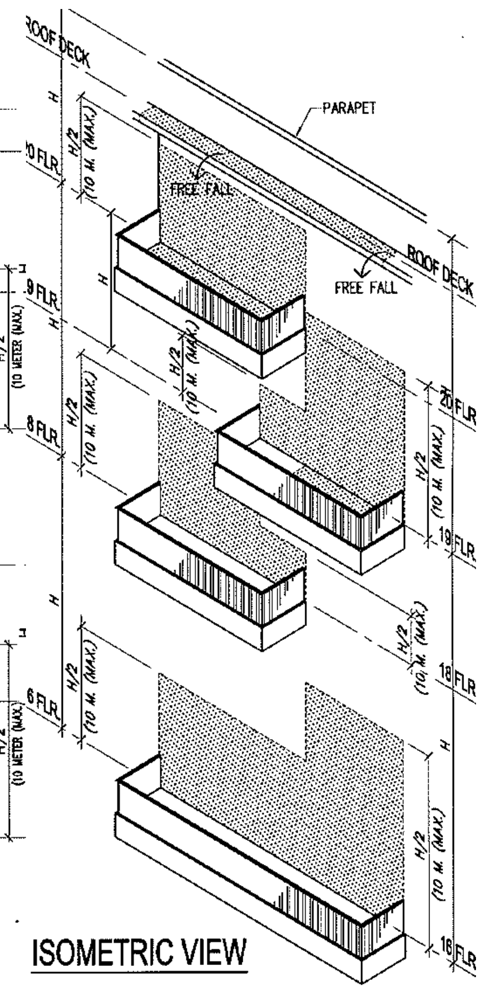


STAGGERED BALCONY PROFILE



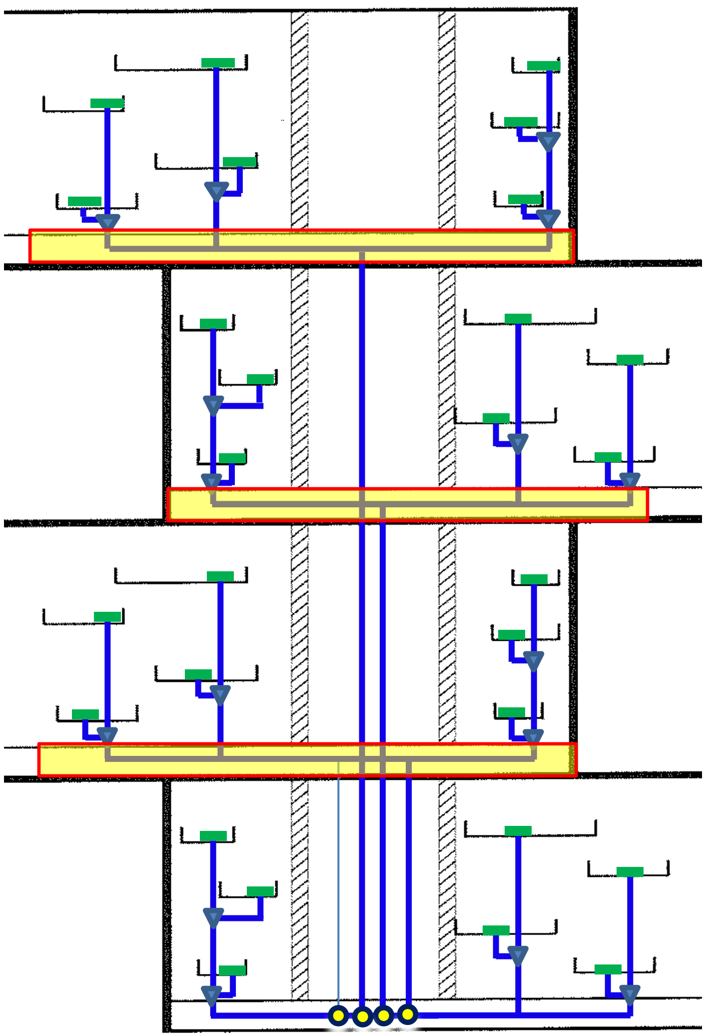


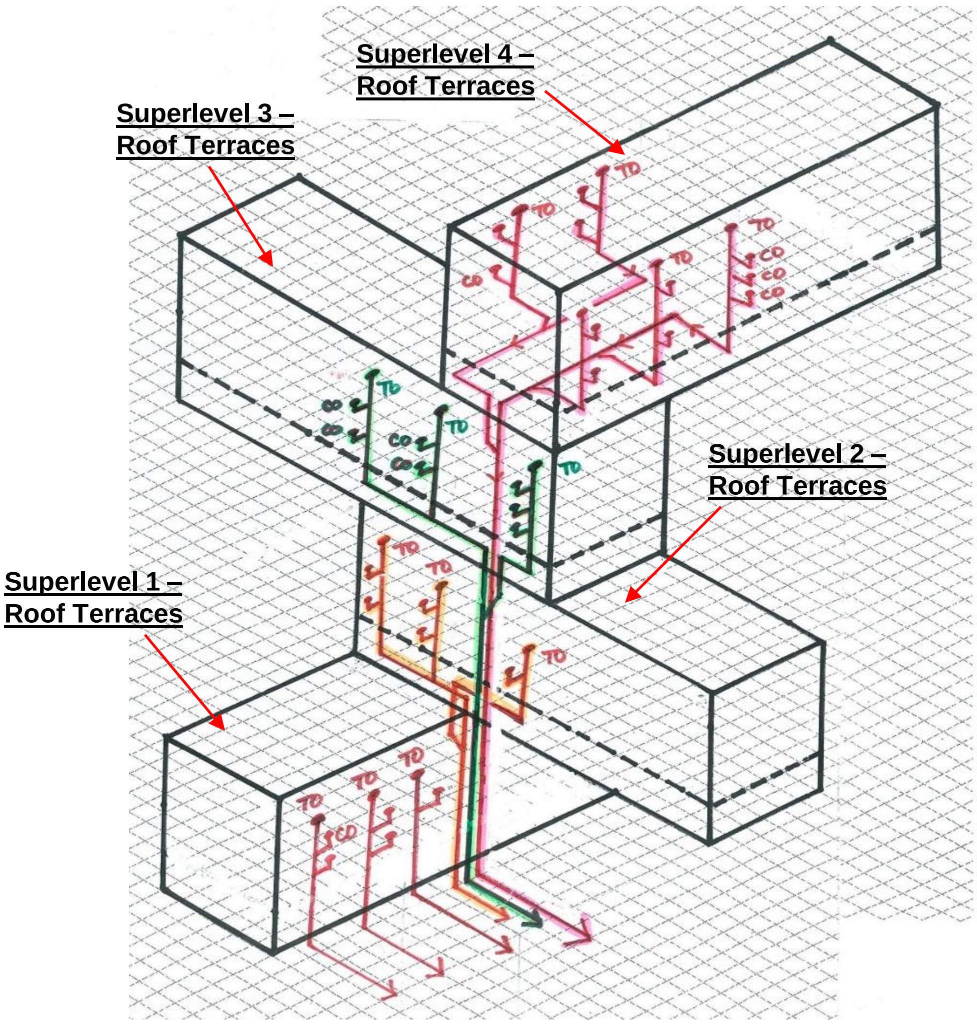
ELEVATION



ISOMETRIC VIEW

Flexibility of System





SUMMARY

- Fully Engineered WDR System.
- Combine multiple stack to a common collector system
- Horizontal run without gradient
- Breakthrough in drainage system.......
  Smaller RDWPs with no back flow problem.

FASTFLOW

...the art of drainage

What should we take away from this presentation?

FASTFLOW

Urbanisation > Built Environment > Sustainability > Challenges in the design for Rainwater Systems.

Are current codes and standards keeping pace with the needs and demands from Architects or are they becoming irrelevant?

- Global Urbanisation, Social Change, Changing Lifestyle, Growing Wealth are all placing demands for buildings which offer so much more than before. You only have to think about the JEWEL @ CHANGI. Buildings are more complex, more demanding in their need for engineering solutions.

- How is this relevant to the subject we have presented today?

FASTFLOW

Urbanisation > Built Environment > Sustainability > Challenges in the design for Rainwater Systems.

Are current codes and standards keeping pace with the needs and demands from Architects or are they becoming irrelevant?

- The advent of Siphonic System drainage and its increasing versatility provides professionals such as yourselves with a system that allows you to achieve solutions to draining rainwater SAFELY and SMARTLY and which was never possible with Gravity.

Fast Flow Siphonic System

- Gravity Systems are still being used. Unfortunately, the use of Gravity Systems is made on the presumption that they are more cost effective.
- But in most cases this presumption is ill-founded because 'most of the time' Gravity Systems are UNDER-DESIGNED and the other tangible and intangible benefits of Siphonic are not accounted for.

Urbanisation > Built Environment > Sustainability > Challenges in the design for Rainwater Systems.

Are current codes and standards keeping pace with the needs and demands from Architects or are they becoming irrelevant?

- Now whilst Siphonic and Gravity Systems exist for Roof Drainage and are both dealt with in Building Codes, the drainage of Wind-Driven Rain Spaces is NOT dealt with in Building Standards or Codes.
- As with Roof Drainage the demands for solutions to draining vertical catchment areas is rising exponentially because of lifestyle needs e.g. Balcony Drainage.
- Industry is providing solutions and eventually, Standards and Codes will verify this.
- In the interim you as the Architect/Designer/Specifier MUST ensure you fully understand the risks you undertake in designing for such drainage requirements.

Urbanisation > Built Environment > Sustainability > Challenges in the design for Rainwater Systems.

Are current codes and standards keeping pace with the needs and demands from Architects or are they becoming irrelevant?

- We would like to leave you this fact!
- An ‘Engineered Solution’ for rainwater drainage of ‘WIND-DRIVEN RAIN SPACES’ does exist.
- In the future it is likely alternative systems will be available and will be VALIDATED but until that happens you do have available to you the

Fast Flow Pressurised System

Urbanisation > Built Environment > Sustainability > Challenges in the design for Rainwater Systems.

Are current codes and standards keeping pace with the needs and demands from Architects or are they becoming irrelevant?

Fast Flow is a Total Rainwater Management Specialist

Thank You

FASTFLOW

...the art of drainage