Stormwater Disposal System

REVIEW & VISTA

雨水排放系統回顧及展望

香港水喉潔具業商會有限公司
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1. Introduction

Following the start of the summer time this year, heavy rainfall and repeated flooding were reported around the Territories. The frequency of flooding was found abnormally higher than the past years. It comes to the question that is the drainage system adopted for the past tens of years being unsuitable for current situation?

Stormwater drainage system is one of the essential elements to maintain the prosperity of a society. A good system could prevent the loss of money, property, life etc. However, since it looks fairly simple when compares with other engineering design, the stormwater drainage system had never been taken care in a serious way by most of the designer.

This article aims to explore the stromwater drainage system in the design, installation and maintenance aspect with an attempt to enlighten, if there is any, the practitioners including designer, contractor, facility management professionals on the improvement of the stormwater drainages system to achieve an effective and efficient disposal system.

2. Codes and Regulations

The design of the building stormwater drainage system of Hong Kong was governed by the Building (Standard of Sanitary Fitments, Plumbing, Drainage Works and Latrines) Regulations (the Regulations). However, the content of the stormwater drainage system in the Regulations is minimal perhaps due to the Regulations was drawn some sixty years ago after the World War II. The Regulations had only correlated the size of the rainwater pipes to the roof area being drained by a simple formula. There is neither guideline nor requirement such as rainfall intensity, catchment areas, hydraulic performance of the system etc. contained.

Unlike Hong Kong, various Codes (the Codes) such as that of the PRC, the EU, the USA and the Singapore, however, provide very detailed consideration in the stormwater drainage system in a scientific way.

Under these Codes, the stormwater drainage system is designed in a totally different approach. All of these Codes adopt the "Rational Method" in calculating the capacity of the stormwater drainage system. The drainage system is calculated by considering the return period of the storm, the rainfall intensity and the catchment area being drained. Return period of a storm and the rainfall intensity is chosen to suit the type of building to serve and this varies from a period of 1 year to 10 years from country to country , place to place.

6.2 Rate of run-off

Run-off from roofs and vertical surfaces should be calculated assuming that the surfaces are impermeable. The rate of run-off Q in litres per second is given by:

$$Q = \frac{A_e I}{3600}$$

where A_e is the effective catchment area in m^2 (see 6.1) and I is the design rainfall intensity in mm/hr (see Clause 5).

Rational Method

(Extract of Singapore Standard SS 525)

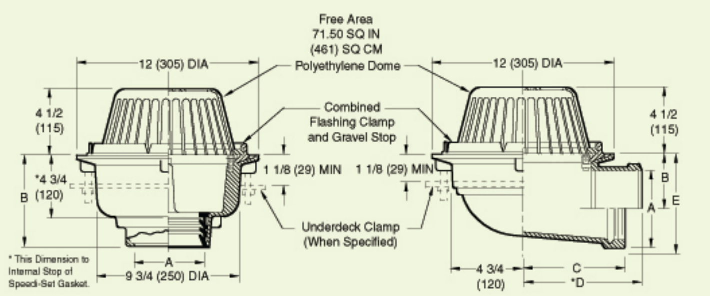
Other than the basic approach in designing the stormwater drainage system, there are some other noticeable features of these Codes which are different from the Regulations and are worth to take into consideration in the design namely:-

1. **Catchment Area** - In addition to the horizontal roof area, extra catchment area due to the projected area of the vertical walls of a roof is required to be added to the roof area as required

2. **Emergency Overflow Outlets** - Emergency overflow outlet is also required in all the above Codes. In addition, duplicate drain outlets for a single roof are recommended in the Code of the EU.

3. **Open Area of Strainer** - Open area of the drain outlet strainer plays an important role as this is the first place where stormwater enters the system. Insufficiency in the passage for stormwater would, not only decrease the efficiency of the drainage system, but could endanger the building by overloading the Roof structure or breakage of the water proofing system. In the Code of the USA, the free area of the strainer of a drain outlet shall be at least 1.5 times to 2 times of the area of the drain pipe connecting to the drain outlet. In the EU code and the Singapore code, the flow rate of a grated drain outlet shall be calculated via formulas or determined by experiments.

It is, of no doubt that the methodology used in other countries presents a more comprehensive and logical approach in dealing with the stormwater drainage system. Whilst there is still, under the context of the Regulations, no sign that the local Authority is willing to adopt the design approach of other countries, it is still worth for the designer to compare his design using the Regulations and various Codes to appreciate the deviances in details.



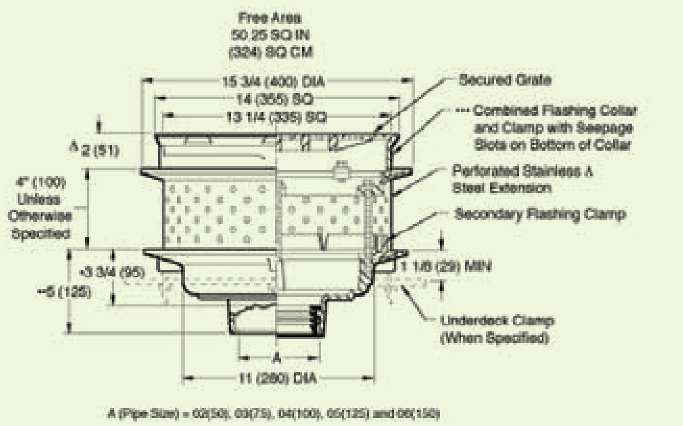
A SIZE	02 (50)	03 (75)	04 (100)	05 (125)	06 (150)
B	6 (150) for Caulk, NO-HUB and Speedi-Set 4 3/4 (120) for Threaded				

recommended deck opening

with suffix -R	13 (330) DIA
less Suffix -R	11 (280) DIA

A SIZE	02 (50)	03 (75)	04 (100)
B	4 1/2 (115)	4 (100)	3 1/2 (89)
C	6 (150)	6 (150)	6 (150)
*D	7 1/4 (185)	7 1/2 (190)	7 3/4 (195)
E	6 1/2 (165)	6 5/8 (168)	6 5/8 (168)

*For NO-HUB outlets this dimension is 9(230)



Drain Outlets
(Extract of Jay R. Smith MFG. Co.)

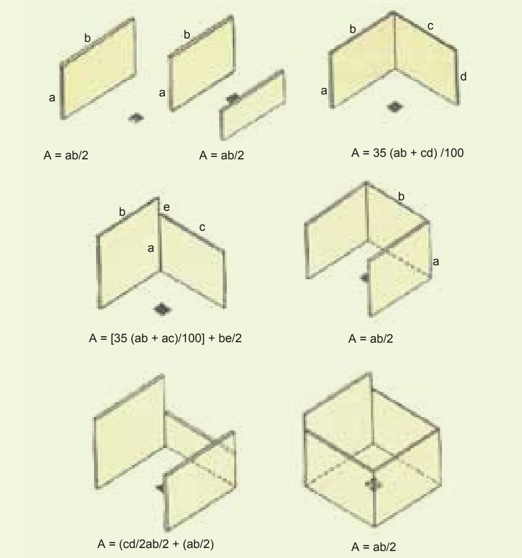


Figure 2-3 Computation of wall areas (A)

Computation of Effective Catchment Area
(Extract of ASPE handbook)

3. Design Practice and Documentation

3.1 Collection of Stormwater and Disposition of Drain Outlets on Roof

It is difficult to lay down simple rules for the design of the stormwater drainage system as this depends on various factors such as collection methods on Roof, i.e. surface channels or point drains, the expected loading of the screedings of the roof, the layout of the upper most floor, etc.

There is always a debate on the use of point drain against that of surface channels on Roof. The former is simple in construction but could be difficult to perform satisfactorily especially for roofs which are in irregular shape. The latter is better in a performance base and could provide a better finishing appearance of the roof and is recommended. Designers are to note that both of these methods of collection require proper co-ordination with the architect and the builders.

All drain outlets on roof should preferably be positioned away from the internal part of the building so that flooding to the building could be minimized in case of blockage occurs at the drain outlets. The drain outlets should also carefully be sited to avoid all prominent areas such as dining rooms, living rooms, electrical rooms etc.

In the event that the ingress of drain pipes to sensitive areas is inevitable, measures shall be provided to prevent water leakage. The drain pipes should be properly treated with acoustic enclosures, fire rated enclosures or drip trays be incorporated etc. For locations where the ingress of water borne pipes is strictly prohibited such as electrical rooms, computer rooms and the likes, the provision of water leakage detection system is recommended.

3.2 Sizing of Stormwater Drain Pipes

Having determined the flow rate of the stormwater system from the Rational Method, the sizing of the stormwater downpipes become the next issue to resolve for the designer. Unfortunately, there is neither requirement nor guideline stated under the Regulations on sizing the stormwater downpipes against the flow to be handled. However, the allowable capacity of stormwater downpipes is laid down in all the Codes.

The sizing of the vertical downpipes in the various Codes follows the usual hydraulic principle. As it is common recognized that pipe filling degree exceeding 1/3 of the downpipe in the sewage system would create adverse pressure fluctuation to the system leading to breakage of water seal of trap of sanitary fitment and backflow at the lower part of the drainage system. Hence, the maximum filling degree of vertical stacks of the sewage system allowed in various Codes is taken as 1/3 of the pipe diameter

The Codes had followed the same principle adopted in the sewage system and recommend a maximum filling degree of 1/3 of the diameter of the downpipe. This leaves 2/3 of the pipe diameter for venting of the system as well as balance of pressure fluctuation at the lowest part of the vertical stacks. The sizing of downpipe in the Codes abides to the hydraulic principle and provides sufficient venting space for the system. Hence, cross reference to these Codes is recommended.

There is also no specific requirement laid down for the sizing of the horizontal in the Regulations. No consideration was made to the depth of flow, velocity of flow etc. Designers would normally add up all the catchment areas and size the horizontal drain pipe by the formula provided in the Regulations.

The Codes, however, specify that the depth of flow of the horizontal drainage pipe shall be in the range of 0.7 (EU, Singapore and the USA) to 0.8 maximum (PRC) and also a minimum cleansing velocity.

This criterion is recommended since:-
1. stormwater contains less debris which is less prone to blockage in the pipe runs.
2. The concern of loss of water seal of trap due to excessive pressure drop in the system is not required.
3. A minimum velocity would reduce the chance of blockage.

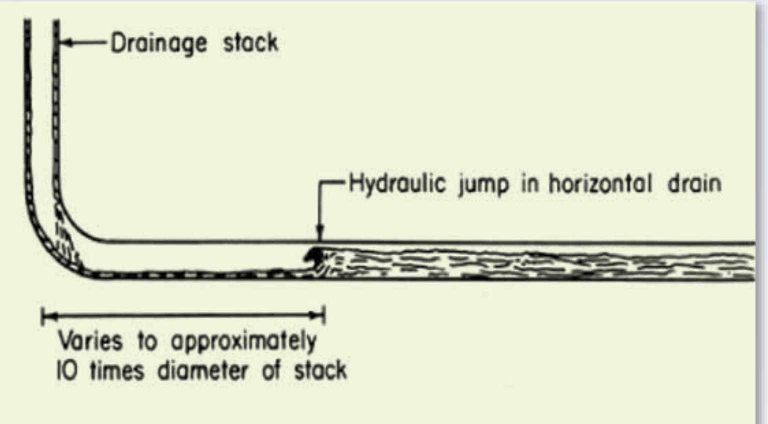
3.3 Stormwater Drainage System in High Rise Buildings

Nowadays, high rise buildings are extraordinarily common all over the world. There is always a mishap that the lowest part of the drainage system would need to withstand a high hydraulic pressure due to the gravitational force acting on it. Starting from this, there are various opinions such as zoning of vertical downpipes, provision of retarding chambers etc. being considered in the design of the stormwater system for high rise buildings.

Researches in the hydraulic performance of vertical stacks revealed that the above concern does not exist. For a properly sized downpipe (at a filling degree of 1/3 or less of the diameter of the downpipe), it was observed that the flow velocity of the fluid inside the downpipe would reach its maximum value after descending for some three to six meters, i.e. one or two storeys of a building . At this point and further downstream, the fluid would be descending in a constant velocity in the range of 3 m/s to 6m/s. Therefore, extra thrust, pressure at the bottom of the vertical stacks due to gravity would unlikely occur.

Despite there is no direct relationship between the gravitational force and the surge pressure at the bottom of the downpipes, backflow is frequently reported at the lower part of downpipe. This pheonomanence has further strength the mind of the designer that extra provision should be made to resolve the situation.

It is true that backflow occur frequently at the bottom part of the downpipe but this is actually due to the hydraulic jump at the lower part of the system. Since the terminal velocity of a downpipe could be as high as 6m/s, this fluid of high speed when discharge into the horizontal part of the system would decelerate due to a reduction in the velocity of flow. The depth of flow in the horizontal part downstream would then increase gradually until the flow passage was blocked. At this point, the core of air running down together with the fluid would strike on the fluid wall leading to a pressure surge in the pipework. Should the condition continues, the back pressure thus build up could lead to backflow at the lower portion of the system.



Hydraulic Jump at Base of Vertical Stack

To alleviate the backflow at the lower part of the downpipe, the following measures are suggested:

- To increase the size of the downpipe (one commercial size larger), preferable before the last bend of the downpipe and the associated horizontal pipe.
- To adopt large radius bend at the bottom of the downpipe.
- To increase the slope of the horizontal collection pipe.
- To provide separate connection for the lowest drain outlets to the vertical stack.
- To provide extra vent pipe for the downpipe.
- Zoning of vertical stacks, provision of off-sets, provision of velocity reducing chamber would have no apparent merits to the backflow of downpipes.
- Separate collection system is recommended for stormwater of Roof and Podium

3.4 Underground Stormwater Drainage System

The sizing of underground stormwater pipework should adopt the similar approach to that of the horizontal stormwater pipe since these should perform in a similar manner from hydraulic point of view.

The Regulations requires that all drain inlets connecting to a drain or sewer shall be provided with an efficient gully trap. The gully trap would act as a guard at the frontline to prevent the escape of foul air from the underground system to the atmosphere. There is no such requirement in other Codes and is a unique requirement of Hong Kong.
The gully trap would be constructed at underground and can either be an open one with grating cover or a sealed one with solid cover depending on the location of it. For a sealed gully trap, a ventilation pipe is required.

The provision of such gully trap would, on one hand, safe guard the nuisance caused by the escape of foul air from the underground system to the atmosphere. However, this could, on the other hand restrict the flow of stormwater, obstruct the ventilation of the stormwater system and increase the chance of blockage and require routine maintenance.

Gully trap as a statutory requirement is unavoidable. Hence, the design of such requires special attention as it is very common that overflow of gully trap is found during heavy rainfall for the reason as stated above.

Since the flow velocity in the vertical downpipe is larger than that in a horizontal drain pipe having the same size and laid with regular fall, it is inevitable that overflow of stormwater water would occur in the trap gully. In addition, the core of air running down together with the fluid would further worsen the situation when it reaches the gully trap. In order to improve the situation, the following measures are suggested:-

- The size of the downstream pipe of the trap gully shall be calculated assuming a fill condition of 0.7 to 0.8.
- The size of gully trap shall be sized to match with the downstream drain pipe.
- Sufficient water head shall be provided above the gully trap to create the flow.
- Sufficient open grating area or properly sized vent pipe shall be provided for open gully trap and sealed trap gully respectively. Sizing of open grating and vent pipe shall be based on the air flow rate from the downpipe and the minimum size of the vent pipe shall be 100mm dia. or a grating of an equivalent free area.
- The routing of the vent pipe shall be as short as possible to ensure a quick release of air.

3.5 Pressurized Stormwater Drainage system

Stormwater drainage system is normally design as a gravity flow system, i.e. non-pressurized system and open channel type of flow is utilized.

However, pressurized systems, if conditions require, would also be adopted. Pressurized systems are classified as follows:

- Siphonic Drainage System
- Pumped System

3.5.1 Siphonic Stormwater Drainage System

Siphonic stormwater system has became more and more common in the last few years following the extensive development of casinos, cargo centers, mega shopping malls etc.

This system is designed on basis of the Bernoulli Equation and is a pressurized system working under the static head between the rainwater outlets and the discharge points. The entire system shall be an air tight system so that siphonic action continues from the rainwater outlets up to the discharge points.

The flow of water is created by the potential head of the system and the horizontal pipe can be laid without fall. In addition, the flow velocity of the siphonic system can be increased significantly (over 6m/s) so that the collection pipes can be reduced in size for the same roof drained by gravity system.

The characteristic of this system makes it most suitable for development with an extensive horizontal roof but does not allow an extensive fall of pipe.

This system is designed with software provided the manufacturer, any change in the configuration of the system such as location of outlets, pipe runs etc. would require re-design of the entire system. In addition, there is also some other restriction such as:-

- The minimum level different of the outlets and the discharge points is 3m.
- Special attention on the support of the pipework is required especially at location of change of flow.
- The maximum potential head that the system can withstand is 10 bars.
- A decompression zone with proper support is required to convert the siphonic system back to a gravity system.
- The receiving chamber after decompression zone requires proper sizing especially on venting of the chamber.
- Pipework used for this system shall have a good quality in terms of air tightness especially under negative pressure and strength to withstand hydraulic thrust.
- Special made drain outlet to prevent ingress of air from the atmosphere is required.


Drainage Pump used in Dry Pit (Extract of EIM Electric Co., Ltd.)

3.5.2 Pumped System

- At locations where gravity drainage system is not technically feasible, pumping of stormwater is inevitable.
- The design of the stormwater pumping system shall take into account of the followings for consideration:
- Inflow of stormwater to the pumping system - this is determined by the rainfall intensity and the catchment to be drained.
- Siting of the pump pit - this is preferred to locate at the most remote or less prominent locations where the effect of flooding can be kept to a minimum.
- Capacity of pump pit - the size of the drain pits shall be optimized to balance out the start / stop cycle of the pumps installed and the cost of civil works. In general, a minimum running time of 2 minutes for pump with motor of size 3.7kw and above and 1.5 minutes for pump having a motor less than 3.7kw is to be allowed.
- Type of pump - suitable type of drainage pumps (dry pit or wet pit) shall be chosen to suit the operation as well as facilitate easy and convenient maintenance in future. Dry pit pumps are preferred as this can be easily maintained but require larger space for installation against that of the wet pit pump.
- Quantity of drainage pumps - the total outflow of all duty pumps shall not be less than that of the inflow to the system. In addition, flexibility shall be allowed to prevent frequent start / stop of the drainage pumps in occasions where only small rain occurs.
- Standby facilities shall be provided - stand by pumps, emergency power supply, independent control supply must be provided.

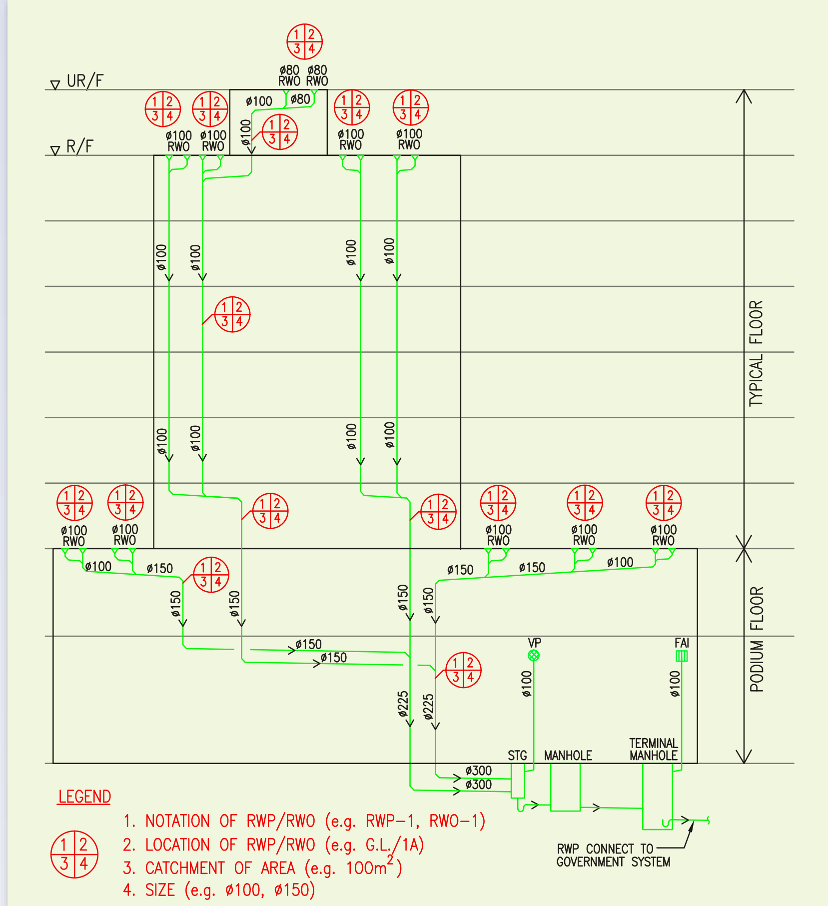
3.6 Documentation

Design information shall be properly documented in the form of drawings and specification for inclusion in the Contract so that the design can be implemented properly based on the designer's intent.

Drawings shall contain the necessary information to facilitate easy checking by other parties as well as the designer. The following information shall be included:

- Demarcation of the catchment area.
- Catchment area served by each drain outlet.
- Aggregate catchment areas for stormwater pipes .
- Notation of downpipes.

Besides the layout drawings, a schematic diagram for the stormwater drainage system detailing the above information for a moderately complex project is also suggested for obvious reasons.



TYPICAL STORMWATER DRAINAGE SCHEMATIC DIAGRAM

4 Materials and Installation

4.1 Pipework

Various types of pipe are available for use in the stormwater drainage system, namely, UPVC, epoxy coated hubless cast iron(ECCIP), ductile iron and concrete.

It is difficult to define the exact type of pipework to be used as each type of pipework would have its own merit over the others. The following table list down the pros and cons of each type of pipework normally encountered in normal stormwater system :-

Pipework	Pros	Cons
UPVC	• Less expensive • Lighter • Suitable for aboveground and • underground use	• Fragile • Limited size (up to 150mm / 160mm) • Prone to be attacked by UV light • Combustible
ECCIP	• Durable • Corrosion resistant	• Heavier than UPVC • More expensive • Not suitable for underground usage (except with external epoxy coating)
Ductile Iron/Cast Iron	• Durable • Corrosion Resistant • Suitable for aboveground and underground use	• More heavy • Most expensive
Concrete	• Durable • Less expensive	• Subject to corrosion • Most heavy • For use in underground only

4.2 Joints

Jointing method of various type of pipework is listed in the following table:

Type of Pipework	Jointing Method
UPVC (Aboveground)	Cement Solvent
UPVC (Underground)	Push fit gasket
ECCIP	Coupling joint with gasket
Ductile Iron / Cast Iron	• Push fit joint with gasket (for gravity system) • Flange joint / self restraint push fit joint (for pumped system)
Concrete	• Push fit joint with gasket (for small size of pipe) • Cement joint (for large diameter pipe)

4.3 Installation

It is essential that stormwater drainage system shall be properly installed in order to achieve a durable and efficient system. Besides, the installation shall follow some basic principles such as:-

- All pipe run shall be kept as short as possible.
- No bend or other obstruction to flow shall be used unless absolutely necessary.
- Long radius bend, Y-tee instead of elbow, straight tee shall be used as far as possible.
- Eccentric instead concentric fittings shall be used.

Sufficient pipe brackets, supports shall be provided in accordance with the various manufacturers' recommendation.

The following table summarizes special measures other than the normal brackets and supports for various type of pipework:

Pipework	Special measures
UPVC	• Expansion joint shall be provided in accordance with the manufacturer's recommendation for installation at outdoor areas
ECCIP (Gravity System)	• Support shall be provided near each joint. • Additional anchor point shall be provided at bottom of stack and change of direction of flow. • Grip collar or the likes shall be provided at the two consecutive bends downstream of the stacks and other locations as recommended by the manufacturer for high rise installation. • Stack support shall be provided as per recommendation of the manufacturer.
ECCIP (Siphonic System)	• Support shall be provided at each joint. • Additional anchor point shall be provided at bottom of stack. • Grip collars or the likes shall generally be provided at the bends, tees, decompression zones, at top of the stacks. • Anchor point shall be provided at regular intervals. • Stack support shall be provided as per recommendation of the manufacturer. • Acoustic treatment to brackets shall be provided due to high velocity of flow.
Ductile Iron / Cast Iron (Gravity System)	• Additional anchor point shall be provided at bends and bottom of stacks
Ductile Iron (Pressurized System)	• Additional anchor point shall be provided at bends and bottom of stacks.

5 Testing and Maintenance

5.1 Testing

After the installation of the stormwater drainage system is completed, this must be tested to ensure the system is air tight as well as water tight. Various tests as recommended are listed as follow.

5.1.1 Air test

Both the EU, the Singapore and the USA Code require air test be conducted.

A pressure of 38mm (w.g.) and a testing period of 3 minutes is recommended in the EU and the Singapore Code.

For USA, a pressure of 5 psi for a period of 15 minutes is required.

No requirement in the PRC code for air test is noted.

5.1.2 Water Test

Water test is specified in the PRC and the USA code.

A static pressure of 3m (minimum) and a test period of 15 minutes is required in the USA code.

The PRC code requires that all downpipes be filled up with water up to the outlets and a testing period of 1 hour.

No requirement of water test is specified in the EU nor the Singapore code but both codes requires that all internal stormwater pipes shall be capable to withstand a head of water likely occur during blockage.

5.1.3 Flushing Test

This is a test by running water through the system and carry out inspection to check out any leakage at joints. There is no code covering this type of test.

Amongst all the tests, air test is the most widely adopted by various Codes and is therefore recommended. Depending on the complexity of the project, the system may need to be sub-divided into different sections for the test in actual practice.

After air test is conducted, the system shall be functionally test by the flushing test to check if leakage occurs. Colour dye could be used for ease of identification of defective joints.

5.2 Maintenance

All engineering systems require regular and routine maintenance to ensure that they are functioning properly as well as effectively.

Although stormwater drainage system is almost a maintenance free system and does not contain much complicated machinery, proper attendance is also required.

A maintenance schedule shall be drawn up for implementation. As a minimum, the following shall be included:-

- The stromwater drainage system shall be inspected prior to the rainy season. Inspection shall include all channels, outlets, pipework, pipe supports, manholes, sump pits, drainage pumps etc.
- All obstacles such as debris, leaves etc. at the surface channels, drain outlets shall be removed.
- All manholes, sump pits, gully traps and the likes shall be cleaned.
- Regular maintenance to drainage pumps shall be carried out in accordance with the manufacturer's recommendation.
- All drainage pumps including the control shall be tested prior to the rainy season.
- Proper logs and records shall be kept for future reference.

Besides the maintenance schedule, a contingency plan shall also be prepared to cater for emergency conditions which may occur due to unforeseeable events. This plan shall include the reporting mechanism of the frontline personnel and the management and all sort of emergency measures to protect the premises from flooding during the chaotic conditions.

Acknowledgement :
E.I.M. Electric Co., Ltd. | Jay R. Smith MFG. Co | ASPE Handbook | Singapore Standard SS525