Technical paper

High-rise design practice and codes for drainage and ventilation systems

In line with research or not?

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Abstract

Engineers around the world, all have the same issues when it comes to designing high-rise and drainage ventilation systems, what codes to follow and do they work for the building? At present the standards they have to follow contradict current research, in regards to the correct venting required to ensure that the water traps seals are protected from transient pressure.

Context of this paper

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Introduction

The most common standards used to design high-rise drainage systems around the world are:

- EN 12056-2: The design guide for Europe, also commonly used in the Middle East and Asia.
- AS/NZS 3500-2003: Used in Australia, New Zealand, also in the Middle East and Asia.
- BS 5572: Can still be found in being used in Asia and the Middle East, despite its withdrawal as a British Standard in 2000 when it was replaced in the building regulations by the EN 12056-2.
- International Plumbing Code: A private code for the USA adopted by 30 states.
- Unified Plumbing Code: A private code for USA adopted by 12 states in the USA and also recently adopted by the Indian Plumbing Association as the IUPC. The UPC is also followed in Vietnam and the Philippines.

There are a number of other plumbing standards but from experience in the market place these listed seem to be the main standards that are adopted. Each of these standards recommends passive venting solutions (vent pipes) with smaller vent diameters or reduced loadings with increased vent lengths for taller buildings. The data for the guidance is based on research carried out form the 1930-1970, when the world was building smaller buildings than we are today.

EN 12056-2 drainage venting requirements

It can be seen by the recommendations of the standard show in the below Tables 1 to 3 that engineers have been given the vent requirements for the size of pipes that they use in their system.

Q_{max} l/s	System I DN	System II DN	System III DN	System IV DN
	Branch/Vent	Branch/Vent	Branch/Vent	Branch/Vent
0,60	*	30/30	see Table 6	30/30
0,75	50/40	40/30		40/30
1,50	60/40	50/30		50/30
2,25	70/50	60/30		60/30
3,00	80/50**	70/40**		70/40**
3,40	90/60***	80/40****		80/40****
3,75	100/60	90/50		90/50

* Not permitted.
** No WC's.
*** Not more than two WC's and a total change in directions of not more than 90°.
**** Not more than one WC.

Table 1.
Branch loadings with required branch and vent sizing

Stack and stack vent	Secondary vent	System I, II, III, IV Q_{max} (l/s)	
DN	DN	Square entries	Swept entries
60	50	0,7	0,9
70	50	2,0	2,6
80*	50	2,6	3,4
90	50	3,5	4,6
100**	50	5,6	7,3
125	70	7,6	10,0
150	80	12.4	18,3
200	100	21,0	27,3

* Minimum size where WC's are connected in system II.
** Minimum size where WC's are connected in system I, III, IV.

Table 2.
Secondary stack and vent requirements commonly used in high-rise designs

Limitations	System I	System II	System III	System IV
Maximum length (L) of pipe	10,0 m	No Limit	see Table 9	10,0 m
Maximum number of 90° bends*	No Limit	No Limit		No Limit
Maximum drop (H) (45° or more inclination)	3,0 m	3,0 m		3,0 m
Minimum gradient	0,5 %	1,5 %		0,5 %

* Connection bend not included.

Table 3.
Limitations

The EN 12056 was developed for buildings up to 20 floors, and was based from existing European codes, from the research carried out by CEN in the 1950-1960, although there is no maximum height specified in the standard. Buildings in the UK and across Europe are commonly being built well above twenty floors, especially in main city areas.

It can be seen in Table 3, that if a 200 DN stack is being used, the secondary vent should be sized at 100 DN; 50% smaller than the waste carrying stack. It can also be seen that a 150 DN pipe (which is the most commonly used pipe used in high-rise buildings) requires a secondary vent of 80 DN; 47% smaller than the waste carrying pipe.

AU/NZS 3500-2003 drainage vents requirements

The AU/NZS 3500 is a standard that must be followed; any design outside the scope of the standard must gain alternative solution approval from the city or state where the project is based.

Table 4 gives the maximum branch vent sizing required and for 50 mm to 100 mm traps the largest branch vent required by the code is 40 mm DN.

Table 5 gives the sizing requirement for the relief/ stack vents for the size of stacks that they are installed upon. It indicates for the size the stack the maximum FU as well as the required vent size and the maximum height allowed for the size of the vents.

Size of fixture Trap DN	Size of Trap-Vent DN
40	32
≥50 ≥100	40

Table 4.
Branch vent sizing

Size of stack DN	Maximum fixture units connected	Maximum developed length of vents, m Required vent size, DN: 32	40	50	65	80	100	125	150
40	16	6	15						
50	20	8	15	46					
50	36	6	10	30					
65	20		12	40	110				
65	56		7	24	80	170			
80	20		8	27	70	110			
80	80			12	20				
100	150			9	25	70	280		
100	300			8	22	60	216		
100	500			6	19	50	197		
125	300				9	22	95	280	
125	750				7	19	72	230	
125	1 100				6	14	62	190	
150	700				4	9	37	155	300
150	1 300					7	30	130	250
150	2 400					6	24	100	200
225	1 700							16	62
225	4 000							14	43
225	7 000							6	31

Table 5.
Size of relief vents and stack vents

An example project of a 254 meter building (86 floors) was designed using table 5 with 225 DN stacks. The FU rating is between 1700 FU (Qww 15.8l/s) to 7000 FU (Qww 32.2l/s) so the maximum developed vent length allowed in meters would be 62 meters with 150DN vent the largest vent size in the standard.

15 FU = 1.5 l/sec of flow rate.

$$Q_{water} = \sqrt{\sum FU / 6.75}$$

This project of 254 meters, high-rise, would falls outside the scope of the standard according to table 5 if the 225 stack was used.

To meet the requirement of the standard the design would have to use smaller stack diameters for example:

125DN stack with a FU 300 (Qww 6.6l/s) with a 125DN vent.

Or

150DN stack with a FU 1300 (Qww 13.8l/s) with a 150 DN vent.

Both of the solutions would require more stacks to be installed into the project, taking up more space.

Even if the load is reduced, and the correct vent stack is used, the requirement in table 4 for the branch vent to be a maximum size of 40 DN would add resistance of this small pipe diameter and can lead to restriction of communication for pressure relief of the branches in high-rise buildings and thus lead to the possibility that the traps seals could be depleted due to induced siphonage.

Main USA codes

The IPC is the most commonly adopted code within the USA followed by the UPC and is more of a rule book than a code or guide which is enforced by local inspectors. This raises separate issues as they generally have good interpretation and understanding of the code book, but have not undergone degree-level engineering required to design drainage systems in high-rise buildings. This leads to two issues: Firstly, the inspector becomes the dominant factor in the design of the system and if the building system is not to the code it will not be accepted (red flagged); and secondly, the design engineer becomes accustomed to designing to the code and can therefore forget the principles of engineering and understanding of the requirements of the system.

If the code is wrong then the design is wrong. The question that needs to be addressed is whether the code is suitable for high-rise buildings.

Section 91.16 of the code relating to vent pipe sizing states: "Size of stack vents and vent stacks. The minimum required diameter of stack vents and vent stacks shall be determined from the developed length and the total drainage fixture units connected thereto in accordance with [Table 6], but in no case shall the diameter be less than one-half the diameter of the drain served for less than 1 ¼ inches (32 mm)."

DIAMETER OF SOIL OR WASTE STACK (inches)	TOTAL FIXTURE UNITS BEING VENTED (dfu)	MAXIMUM DEVELOPED LENGTH OF VENT (feet)[a] DIAMETER OF VENT (inches)										
		1¼	1½	2	2½	3	4	5	6	8	10	12
1¼	2	30										
1½	8	50	150	—	—	—	—	—	—	—	—	—
1½	10	30	100									
2	12	30	75	200								
2	20	26	50	150		—	—	—	—	—	—	—
2½	42		30	100	300							
3	10		42	150	360	1,040						
3	21	—	32	110	270	810	—	—	—			
3	53		27	94	230	680						
3	102		25	86	210	620						
4	43	—		35	85	250	980	—	—	—	—	—
4	140			27	65	200	750					
4	320			23	55	170	640					
4	540	—	—	21	50	150	580		—	—	—	—
5	190				28	82	320	990				
5	490				21	63	250	760				
5	940	—	—	—	18	53	210	670	—	—	—	—
5	1,400				16	49	190	590				
6	500					33	130	400	1,000			
6	1,100	—	—	—	—	26	100	310	780	—	—	—
6	2,000					22	84	260	660			
6	2,900					20	77	240	600			
8	1,800	—	—	—	—		31	95	240	940	—	—
8	3,400						24	73	190	720		

Table 6.
Size guide for IPC code

Table 7 illustrates the sizing of vents within the Uniform Plumbing Code.

Maximum Unit Loading and Maximum Length of Drainage and Vent Piping

Size of Pipe, inches (mm)	1-1/4 (32)	1-1/2 (40)	2 (50)	2-1/2 (65)	3 (80)	4 (100)	5 (125)	6 (150)	8 (200)	10 (250)	12 (300)
Maximum Units											
Drainage Piping[1]											
Vertical	1	2[2]	16[3]	32[3]	48[4]	256	600	1380	3600	5600	8400
Horizontal	1	1	8[3]	14[3]	35[4]	216[5]	428[5]	720[5]	2640[5]	4680[5]	8200[5]
Maximum Length											
Drainage Piping											
Vertical, feet	45	65	85	148	212	300	390	510	750		
(m)	(14)	(20)	(26)	(45)	(65)	(91)	(119)	(155)	(228)		
Horizontal (Unlimited)											
Vent Piping (See note)											
Horizontal and Vertical											
Maximum Units	1	8[3]	24	48	84	256	600	1380	3600		
Maximum Lengths, feet	45	60	120	180	212	300	390	510	750		
(m)	(14)	(18)	(37)	(55)	(65)	(91)	(119)	(155)	(228)		

[1] Excluding trap arm.
[2] Except sinks, urinals and dishwashers.
[3] Except six-unit traps or water closets.
[4] Only four (4) water closets or six-unit traps allowed on any vertical pipe or stack; and not to exceed three (3) water closets or six-unit traps on any horizontal branch or drain.
[5] Based on one-fourth (1/4) inch per foot (20.9 mm/m) slope. For one-eighth (1/8) inch per foot (10.4 mm/m) slope, multiply horizontal fixture units by a factor of 0.8.

Table 7.
Sizing of vents from the UPC

If a standard high-rise design was used, 150 DN stack with 100 DN vent pipes, then the standard would be suitable for a 40 floor building. If the building has to be taller, they would have to increase the size of the stack as well as the size of the vents, even though the DFU loading was not increased. This can lead to oversized systems that may not be required and will take up more space within the building.

International code discussion

Tables 2, 3, 5 and 7 provide the main guidance available to engineers for their system designs. The guidelines or rules in these standards allow for taller buildings but only by reducing the loading or oversizing the system.

The research carried out at Heriot-Watt University, as well as other leading technical institutions and manufacturers with high-rise testing facilities, can and should assist code and standards originations in providing technical solutions for the design engineers to design systems that are safe and practical for the needs of high-rise buildings.

Introducing a new concept that are not part of the guide tables within the standards, that challenges the guide sizing and system designs that are available can only be achieved by having the latest research that meets the requirements of high-rise drainage systems.

Conclusion

Over the last decade there has been an unprecedented increase in high-rise buildings around the world requiring engineering disciplines to meet the requirements in structural and system operation to these types of buildings. In regards to drainage, has this been met? This paper highlighted and asked the question if the standards and codes meet these demands for high-rise building designs. The leading research carried by Heriot-Watt University has demonstrated that the current standard and code requirements may not be sufficient in their recommendations to provide effective guidance to the engineering community to design workable safe systems. There are many cases where the recommendations in the standards have been modified by the engineers as they have experienced problems in prerious designs and wish to engineer out problems in future buildings. Sometimes this has been restricted by the regulators within different states due to their insistence that the code is followed as it is written, and therefore engineers are unwilling to deviate from this even if it means that the system may become susceptible to failure. Drainage is a relatively easy system to understand for any type of building design: Hydraulic loading for the sizing of pipes; and a venting system that keeps the pressures below +- 400Pa throughout the system. If the pressures are kept well below this, in the region of +- 200Pa, there is less stress placed on the trap seals within the system. With a passive system there is a single limitation, that being the only way to relieve the transient pressures through a network of ventilation pipes that terminate at the top of the building. Using systems such as active drainage ventilation or stack-aerators manage the air pressures within the drainage system, so the limitations on the vent pipe lengths is removed for tall buildings.

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